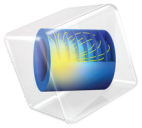

COMSOL Multiphysics

Programming Reference Manual

5.4

COMSOL

COMSOL Multiphysics® Programming Reference Manual

Version: COMSOL 5.4

Contact Information

Visit the Contact COMSOL page at www.comsol.com/contact to submit general inquiries, contact Technical Support, or search for an address and phone number. You can also visit the Worldwide Sales Offices page at www.comsol.com/contact/offices for address and contact information.

If you need to contact Support, an online request form is located at the COMSOL Access page at www.comsol.com/support/case. Other useful links include:

- Support Center: www.comsol.com/support
- Product Download: www.comsol.com/product-download
- Product Updates: www.comsol.com/support/updates
- COMSOL Blog: www.comsol.com/blogs
- Discussion Forum: www.comsol.com/community
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Part number: CM020007

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1

Introduction

This *COMSOL® Multiphysics Programming Reference Manual* details features and techniques that help you control COMSOL Multiphysics® using the application programming interface (API) for use with the Java® programming language. The COMSOL API can be used in the Application Builder, from a standalone Java application, and from the LiveLink™ *for* MATLAB® interface. If you are using the COMSOL API from the Application Builder, see also the *Application Programming Guide* for useful information when creating methods for applications.

In this chapter:

About the COMSOL API

You can use the COMSOL API to develop custom applications based on COMSOL. The easiest way to create such applications is by using the Application Builder available with the COMSOL software.

You can run Java class files with COMSOL API-based applications in different ways:

- In the Application Builder as part of methods that you add using the Method Editor in the Application Builder's development environment (see also the *Application Programming Guide*)
- From the COMSOL Desktop®. A model created using a class file appears automatically in the Desktop.
- From a batch sequence in a study.
- Using the `comsol batch` command.

The LiveLink™ *for* MATLAB® operates using the COMSOL API and additional utility M-file functions. See the *LiveLink™ for MATLAB ® User's Guide* for additional information.

Code examples for the individual API functions in this guide show what the code looks like when using Java® and when using the LiveLink™ *for* MATLAB®.

Where Do I Find More Information?

A number of internet resources have more information about COMSOL, including licensing and technical information. The electronic documentation, topic-based (or context-based) help, and the application libraries are all accessed through the COMSOL Desktop.

If you are reading the documentation as a PDF file on your computer, the blue links do not work to open an application or content referenced in a different guide. However, if you are using the Help system in COMSOL Multiphysics, these links work to open other modules, application examples, and documentation sets.

CONTACTING COMSOL BY EMAIL

For general product information, contact COMSOL at info@comsol.com.

COMSOL ACCESS AND TECHNICAL SUPPORT

To receive technical support from COMSOL for the COMSOL products, please contact your local COMSOL representative or send your questions to support@comsol.com. An automatic notification and a case number are sent to you by email. You can also access technical support, software updates, license information, and other resources by registering for a COMSOL Access account.

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Events	www.comsol.com/events
COMSOL Video Gallery	www.comsol.com/video
Support Knowledge Base	www.comsol.com/support/knowledgebase

Getting Started

In this section:

The Model Object

In the COMSOL API you access models through the *model object*, which contains all algorithms and data structures for a COMSOL model. The COMSOL Desktop also uses the model object to represent your model. This means that the model object and the COMSOL Desktop behavior are virtually identical.

You use *methods* to create, modify, and access your model. The model object provides a large number of methods, including methods for setting up and running *sequences of operations* to create geometry, meshes, and for solving your model. The methods are structured in a tree-like way, much similar to the nodes in the model tree in the *Model Builder* window on the COMSOL Desktop. The top-level methods just return references that support further methods. At a certain level the methods perform actions, such as adding data to the model object, performing computations, or returning data.

You must have a basic understanding of the Java® programming language in order to fully appreciate how to work with the model object. However, the Application Builder includes tools like code recording, auto-completion, and predefined code templates that make it easier to create methods.

Compiling a Model File for Java®

The Application Builder also contains a compiler for code using the COMSOL API and Java.

First make sure that COMSOL Multiphysics is installed. See the *COMSOL Multiphysics Installation Guide* for more information if required.

To test compiling a model files for Java, load `feeder_clamp.mph` from the COMSOL Multiphysics Applications Libraries into the COMSOL Desktop.

You can learn most of the syntax for creating a model using the COMSOL API by first creating a model using the COMSOL Desktop and then saving the model as an application file for Java.

Win

To open the **Application Libraries** window:

- From the **Home** toolbar, **Windows** menu, select **Application Libraries** ( ). When a toolbar is compressed, you sometimes select it from the **Windows>** menu.
- You can also customize the Quick Access Toolbar and then click the **Application Libraries** ( ) button on the toolbar.
- Select **Application Libraries** from the **File** menu.

Mac

Linux

To open the **Application Libraries** window:

- On the Main Toolbar, click the **Application Libraries** ( ) button.
- Select **Windows>Application Libraries**.

In the Application Libraries tree, expand **COMSOL Multiphysics** and then **Structural Mechanics**. Select the **feeder_clamp** model, then click the **Open** button to open it. To get a Java file to compile, choose **Save As** from the **File** menu and choose **Model file for Java (*.java)** as the file type. It is suggested that you save the file as `feeder_clamp.java` in your home directory.

To compile `feeder_clamp.java`, enter

```
<COMSOL path>\bin\win64\comsolcompile feeder_clamp.java
```

on Windows and

```
<COMSOL path>/bin/comsol compile feeder_clamp.java
```

on Linux and Mac, where *<COMSOL path>* is the COMSOL installation directory.

The Model File for Java

The model file for Java has the following structure:

```
import com.comsol.model.*;
import com.comsol.model.util.*;

public class feeder_clamp {

  public static void main(String[] args) {
    run();
  }

  public static Model run() {
    Model model = ModelUtil.create("Model");
    ...
    return model;
  }
}
```

Any model that you create in the COMSOL Desktop can be saved as a model file for Java.

When you compile a model file for Java into a class file and run it, COMSOL runs exactly those instructions that are included in the model file for Java. When opening an MPH-file and saving it as a Java file only those sequences that have been explicitly run are run in the Java file. But saving it as a model file for Java, the file does not contain a `runAll` command for the solver sequence. To run a solver sequence, add a line similar to `model.sol("sol1").runAll();` (where `sol1` is the tag for the solver to run) at the bottom of the Java file, above the line that contains `return model;`.

Running a Compiled Model File for Java from the Desktop

Select **Open** on the **File** menu. In the **Open** dialog box, under **File** name, select **Compiled Model File for Java (*.class)**. Click **Open**. The file is run and appears as the model in the COMSOL Desktop.

Running a Compiled Model File as a Batch Job from the Desktop

Right-click **Job Sequences** in a study and add a study. In the added study, right-click and add **External Class** under **Other**. Then right-click the batch sequence and select **Compute**.

Runs the main function of a compiled class with the system property `cs.currentmodel` set to the tag of the model calling the class. Thus you can retrieve the current model using the steps:

```
import java.io.*;

tag = System.getProperty("cs.currentmodel");
model = ModelUtil.model(tag);
```

Running a Compiled Model File with the COMSOL Batch Command

To run the file, enter

```
<COMSOL path>\bin\win64\comsolbatch -inputfile feeder_clamp.class
```

on Windows, or enter

```
<COMSOL path>/bin/comsol batch -inputfile feeder_clamp.class
```

on Linux and Mac, where *<COMSOL path>* is the COMSOL Multiphysics installation directory.

Getting the COMSOL Installation Path from the Windows Registry

If you want to have your application find your COMSOL Multiphysics installation automatically, you can have your application examine the registry key

```
HKEY_LOCAL_MACHINE\SOFTWARE\COMSOL\COMSOL54\
```

The value name `COMSOLROOT` contains the installation path.

Setting up Eclipse for Compiling and Running a Java® File

Instead of using the COMSOL commands for compiling and running a Java® file that uses the COMSOL API one can use an Integrated Development Environment for doing these tasks. Using Eclipse makes it easier to write the Java code because Eclipse has built-in support for code completion and syntax highlighting. Furthermore, the debugger that comes as a part of Eclipse can be used to run the code line by line to verify the function of the code

and check for any programming errors. Eclipse is free and can be downloaded from www.eclipse.org. To set up Eclipse for running an exported Java file, perform the following actions in Eclipse:

1. Create a new Java Project and click **Next**.
2. Go to the **Libraries** tab and click **Add External JARs**. Add all JAR files placed in the `plugins` directory under the COMSOL installation directory (typically `C:\Program Files\COMSOL\COMSOL54\Multiphysics`). This allows Eclipse to find the definitions of the classes used by the COMSOL API and to run the code in client/server mode. Click **Finish**.
3. Drag and drop your exported Java file the `src` folder of your Eclipse project.
4. Add this line to the beginning of the main method

   ```
   ModelUtil.initStandalone(false);
   ```

   The argument should be false for programs that do not use graphics and true for applications that do.
5. To run your Java program, you can create a Run Configuration in Eclipse. You do this from **Run Configurations** on the **Run** menu in Eclipse. Select the **Environment** tab. Click the **New** button. Use the **Name** PATH (on Windows), `LD_LIBRARY_PATH` (on Linux), or `DYLD_LIBRARY_PATH` (on Mac) and enter the following text in **Value**: `<comsolinstalldir>/lib/<platformname>`, where `<comsolinstalladir>` is the directory where COMSOL Multiphysics is installed, and `<platformname>` is one of `win64/glnxa64/maci64` depending on your platform. Click **Apply**.
6. The Java program can now be started in either Run or Debug mode from Eclipse. The Java program is run as a single process where the COMSOL libraries are being loaded as requested. This is the preferred way of running normal, small model files.
7. For large simulation where the application itself has to hold many megabytes in memory in addition to the memory requirement of COMSOL, it can be beneficial to run in client-server mode. To do so, open the Java file in the editor and go to the main method. Now you have to remove the line added in step 4 and add two new lines that control the connection to the COMSOL server from your own program. The main method needs to look like this:

   ```
   public static void main(String[] args) {
       ModelUtil.connect("localhost", 2036);
       run();
       ModelUtil.disconnect();
   }
   ```

   When you have edited the main method you must save the file. Eclipse automatically compiles the file.
8. You also need to call `System.exit(0)` at the end of the Java program if `ModelUtil.initStandalone()` has been called.
9. To run the code you must first start the COMSOL server. When the server has started note the port number that is written in the console. If this number does not match the number written in the call to `ModelUtil.connect` you have to edit this call and save the file again.

The Java program can now be started in either Run or Debug mode from Eclipse. Notice that the COMSOL server window responds by writing that a connection has been set up when your application starts.

2

General Commands

This chapter contains reference information about general commands for creating and modifying the main parts of the model object and for creating general-purpose functionality in a model, such as functions, variables, units, coordinate systems, and component couplings. It also contains information about image generation and about errors and warnings. In this chapter:

About General Commands

Overview of General-Purpose Commands

The following table contains the available general-purpose commands and methods:

TABLE 2-1: GENERAL COMMANDS GROUPED BY FUNCTION

FUNCTION	PURPOSE
`get* and Selection Access Methods`	Access objects of the basic data types
`set()`	Assign objects of the basic data types
`setEntry()`	Set vector property value at specified entry
`setIndex()`	Assign objects at indices of the basic data types
`Selections`	Selections
`ModelUtil`	Model object utility methods
`model`	Model object
`model.attr()`	Model entity list methods
`model.attr(<tag>)`	Model entity methods
`model.batch()`	Batch jobs
`model.bem()`	Boundary elements (BEM)
`model.capeopen()`	CAPE-OPEN thermodynamics interface
`model.coeff()`	Coefficient form equations
`model.common()`	Common definition nodes in components
`model.component()`	Model component nodes
`model.constr()`	Constraints
`model.coordSystem()`	Coordinate systems, PMLs, infinite elements, and absorbing layers
`model.cpl()`	Component couplings
`model.elem()`	Elements
`model.elementSet()`	Mesh element sets
`model.extraDim()`	Extra dimensions
`model.field()`	Fields
`model.form()`	Settings forms
`model.frame()`	Frames
`model.func()`	Functions
`model.geom()`	Geometry sequences
`model.group()`	Load groups and constraint groups
`model.init()`	Initial values
`model.intRule()`	Integration orders
`model.massProp()`	Mass properties
`model.material()`	Materials
`model.mesh()`	Meshing sequences
`model.methodCall()`	Model methods
`model.modelNode()`	Model nodes (component nodes; see `model.component()`)

TABLE 2-1: GENERAL COMMANDS GROUPED BY FUNCTION

FUNCTION	PURPOSE
`model.multiphysics()`	Multiphysics features container
`model.nodeGroup()`	Group nodes in the model
`model.ode()`	Global equations
`model.opt()`	Optimization interface
`model.pair()`	Pairs
`model.param() and model.result().param()`	Parameters
`model.physics()`	Physics
`model.probe()`	Probes
`model.reduced()`	Reduced-order modeling
`model.result()`	Postprocessing interface
`model.savePoint()`	Manage selections and hide features used by result features
`model.selection()`	Named selections
`model.shape()`	Shape functions
`model.sol()`	Solver sequences
`model.solverEvent()`	Events
`model.study()`	Studies
`model.unitSystem()`	Unit systems
`model.variable()`	Variables
`model.view()`	Views
`model.weak()`	Weak form equations

ABOUT VALID TAGS

A *tag* is a string that you use to refer to a model feature. When specifying a tag, it must fulfill the following format requirements: Begin with a character a–z or A–Z followed by any number of _ (underscores), numerals 0–9, or characters a–z or A–Z.

ABOUT ASSIGNING VALUES TO PROPERTIES

Even if a property is numeric, it is also possible to use a string or string array. The strings can contain expressions defined in terms of parameters defined in Global Definitions>Parameters. See Table 2-2 under `set()` below for examples of syntaxes for assignment methods.

ABOUT FILE PATHS

In general, the file paths in methods for saving and opening files, for example, are client paths (on the client computer's file system). The exceptions are methods that explicitly performs an operation on the server, such as `ModelUtil.loadOnServer()`, which takes a server path as its argument.

The syntax that includes the component level, such as `model.component(<ctag>).geom(<tag>)...` is the default and is used throughout this chapter for parts of the model object that are stored inside a model component. To use the earlier `model.geom(<tag>)...` syntax, clear the **Use component syntax** check box on the **Methods** page in the **Preferences** dialog box. You can also run existing scripts without this syntax.

get and Selection Access Methods*

Use these methods to access properties of the different parts of the model object.

SYNTAX

The following syntax is used for all of these access methods (exemplified there with the getStringArray method for returning the value of the a string array with the name <*name*> for the *something* object.

```
something.getStringArray(<name>);
```

Note that throughout this manual, the access methods are collectively referred to as `get*(<name>)`, where `*` can be any of the basic data types used below. Use these methods to read property values. The names of the access methods indicate the data type for the data that they return.

```
something.getString(<name>)
```

returns the value as a string.

```
something.getStringArray(<name>)
```

returns the value as a string array.

```
something.getStringMatrix(<name>)
```

returns the value as a string matrix.

```
something.getInt(<name>)
```

returns the value as an integer.

```
something.getIntArray(<name>)
```

returns the value as an integer array.

```
something.getIntMatrix(<name>)
```

returns the value as an integer matrix.

```
something.getDouble(<name>)
```

returns the value as a double.

```
something.getDoubleArray(<name>)
```

returns the value as a double array.

```
something.getDoubleMatrix(<name>)
```

returns the value as a double matrix.

```
something.getBooleanArray(<name>)
```

returns the value as a Boolean array.

```
something.getBooleanMatrix(<name>)
```

returns the value as a Boolean matrix.

```
something.selection(<name>)
```

returns the value as a selection object, which can be edited. This is not simply an access function. It is used to obtain a selection object both for editing and for accessing data from.

In addition,

```
something.getEntryKeyIndex(<name>,<key>)
```

returns the index of a given key in a property, and

```
something.getEntryKeys(<name>)
```

returns the possible entry keys for a given property.

NOTES

All arrays that are returned contain copies of the data; writing to the array does not change the data in the model object. This observation applies to all access methods of the model object that return arrays of basic data types.

SEE ALSO

`set()`

set()

Use this method to assign values to objects of the basic data types.

SYNTAX

Use these methods to assign property values. All assignment methods return the object itself, which means that assignment methods can be appended to each other.

The basic method for assignments is

```
something.set(name,<value>);
```

The *name* argument is a string with the name of the property. The *<value>* argument can be of different types as indicated in Table 2-2, where the two different syntaxes for assignment in the COMSOL API and the LiveLink™ *for* MATLAB® are listed.

TABLE 2-2: SYNTAXES FOR ASSIGNMENT METHODS.

TYPE	JAVA® SYNTAX	MATLAB® SYNTAX
string	`set("name","value")`	`set('name','value')`
string array	`set("name", new String[]{"val1","val2"})`	`set('name',{'val1','val2'})`
double string array	`set("name",new String[][]{{"1","2"}, {"3","4"}})`	`set('name',{'1','2';'3','4'})`
integer	`set("name",17)`	`set('name',17)`
integer array	`set("name",new int[]{1,2})`	`set('name',[1 2])`
integer matrix	`set("name",new int[][]{{1,2}, {3,4}})`	`set('name',[1 2; 3 4])`
double	`set("name",1.3)`	`set('name',1.3)`
double array	`set("name",new double[]{1.3,2.3})`	`set('name',[1.3 2.3])`
double matrix	`set("name",new double[][]{{1.3,2.3}, {3.3,4.3}})`	`set('name',[1.3 2.3; 3.3 4.3])`
boolean	`set("name",true)`	`set('name',true)`
boolean array	`set("name",new boolean[]{true,false})`	`set('name',[true,false])`
boolean matrix	`set("name",new boolean[][] {{true, false},{false, false}})`	`set('name', [true,false;false,false])`

For matrix-type properties, `set(name,<string>)` splits the string at spaces and commas.

The following example shows how two set methods can be appended:

```
model.result("pg1").set("edgecolor", "black").set("edges", "on");
```

This is equivalent to:

```
model.result("pg1").set("edgecolor", "black");
model.result("pg1").set("edges", "on");
```

That is, in this case, the set method returns the plot group `"pg1"`.

The following methods using `set` are deprecated in version 5.1 (use `setIndex()` instead):

```
set(name,pos,<value>)
set(name,pos1,pos2,<value>)
```

The following methods using `set` are deprecated in version 5.0:

```
com.comsol.model.ParameterEntity.set(String, int, double)
com.comsol.model.ParameterEntity.set(String, int, double[])
com.comsol.model.ParameterEntity.set(String, int, int)
com.comsol.model.ParameterEntity.set(String, int, int[])
com.comsol.model.ParameterEntity.set(String, int, int, double)
com.comsol.model.ParameterEntity.set(String, int, int, int)
com.comsol.model.ParameterEntity.set(String, int, int, String)
com.comsol.model.ParameterEntity.set(String, int, String)
com.comsol.model.ParameterEntity.set(String, int, String[])
```

SEE ALSO

`get* and Selection Access Methods`, `setIndex()`

setEntry()

Use the `setEntry` method to set property values at specified entries using a key instead of an index to locate the row to change

SYNTAX

Use this method to assign property values of different types at specified entries:

```
setEntry(name, key, value);
```

where all input arguments are strings:

- *name*, representing the property name.
- *key*, representing the index key.
- *value*, representing the property value.

The *value* can also be a double, an integer, or (with limited applicability; primarily for part links) a Boolean.

For example, if `pi1` is a part instance feature with input parameters `a` and `b` in a geometry, the following lines

```
GeomFeature f = model.component("comp1").geom("geom1").feature("pi1");
f.setEntry("inputexpr", "a", "2");
f.setEntry("inputexpr", "b", "3");
```

set the value of the input expression for parameter `a` to the string `2` and for parameter `b` to the string `3`. You can also set the values of the input expressions to numerical values (doubles):

```
f.setEntry("inputexpr", "a", 4);
f.setEntry("inputexpr", "b", 5.0);
```

`setEntry` lets you use a key to access rows in the table, defined by the content in one of the columns (in this case, the column that contains parameter names.

setIndex()

Use this method to assign values at indices in array properties of the different parts of the model object. When there are no indices, you can use `set()` instead.

SYNTAX

To use the `setIndex` method, use one of these syntaxes:

```
something.setIndex(name,<value>,<index>);
```

for array properties, or

```
something.setIndex(name,<value>,<firstIndex>,<secondIndex>);
```

for matrix properties.

Use these methods to assign values to an element in array or matrix properties, defined by specific indices (0-based). All assignment methods return the parameter object, which means that assignment methods can be appended to each other.

If *<index>* points beyond the current size of the array, then the array is extended as needed before element *<index>* is set. The values of any newly created intermediate elements are undefined.

The *name* argument is a string with the name of the property. *<value>* is a string representation of the value to set. A double array element, for example, can still be set from a string representation of the double, typically used when the property value depends on a model parameter. The values can also be a Boolean or a Boolean array. For example:

```
something.setIndex(name,<value>,2)
```

This code assigns the value for the element with the third index in the array (because the indices are 0-based) of an array property *name* to be the value *value*. If the parameter later changes, this property changes accordingly. You can also use an additional input argument for a second index value, for a 2-dimensional array (matrix), for example,

```
something.setIndex(name,<value>,1,4)
```

This code assigns the value *<value>* to the (1, 4) element in a matrix.

For double arrays the modifying method is also of use when assigning the value in MATLAB®, if not all arrays have the same length. When using a cell matrix, all rows must have the same length. The method

```
something.setIndex(name,<value>,<index>)
```

can be used to get around that limitation. It inserts an array in the indexed position in the double array. The MATLAB code

```
something.setIndex('name',{'1','2','3'},0)
something.setIndex('name',{'4','5'},1)
```

is equivalent to the Java® code

```
something.set("name",new String[][]{{"1","2","3"},{"4","5"}})
```

SEE ALSO

set()

Methods Associated to Set, SetIndex, and the Various Get Methods

The following methods are available where the `set`, `setIndex`, and `get<Type>` methods are available:

```
String[] properties();
```

which returns the names of all available properties.

```
boolean hasProperty(String name);
```

which returns true if the feature has the named property.

```
String[] getAllowedPropertyValues(String name);
```

which returns the allowed values for a named properties, if it is a finite set.

Selections

This section contains information about the selection methods that are available for handling selections on the finalized geometry.

SYNTAX

This section describes the general syntax for selections on the finalized geometry. For selections in the geometry sequence, see `Geometry Object Selection Methods` under `model.geom()` and `Selections` under `Editing a Geometry Feature`. Many objects use selections, but most of them only support a subset of the assignment methods described here. The methods supported by the named selections in `model.selection()` are listed in model.selection(). Other objects that use a selection support the methods relevant for the type of feature they represent. For example, a physics boundary condition feature requires a boundary selection. Therefore is does not support *selection*`.global()`, which makes the selection global, or *selection*`.allGeom()`, which makes the selection apply to the whole geometry at all levels. Using an unsupported assignment method results in an error.

The *selection* part here represents any valid selection syntax that ends with `...selection()`, such as `model.component(`*<ctag>*`).physics(`*<ptag>*`).feature(`*<ftag>*`).selection()`.

There can also be a filtering of the entities assigned to a selection. Again, take a physics boundary condition as an example. Some boundary conditions only apply to the boundaries exterior to the domains where the physics interface is active, other boundary conditions only to boundaries interior to where the physics interface is active, and so on. Therefore *selection*`.entities(`*dim*`)` can sometimes return less entities than have been assigned using *selection*`.set(`*<entlist>*`)`. On the other hand *selection*`.inputEntities()` always returns all entities used in the assignment *selection*`.set(`*<entlist>*`)`. *selection*`.inputEntities()` returns the domains used as input to the selection. If the selection is of the type *interior*, *exterior*, or *meshinterior*, this method returns the unfiltered list of domains at the higher dimension that are used as the input. If the selection is not a selection of domains at a certain level, or the selection is not of the types `Explicit` or `FromGeom` (derived from a geometry feature), this method returns null.

Some selections only allow a single geometric entity, a single domain, a single boundary, edge, or point. Such selections are called *single selections*. Single selections cannot be defined by another selection and therefore do not support *selection*`.named(`*<stag>*`)`.

selection`.global()` sets the selection to be the global selection.

selection`.geom(`*<gtag>*`)` sets the selection to be all domains in the geometry *<gtag>*.

selection`.geom(`*<gtag>*`,`*dim*`)` specifies that subsequent calls to `all`, `set`, `add`, and `remove` refer to domains at the dimension *dim* on the geometry *<gtag>*. If there is only one possible geometry, using *selection*`.geom(`*dim*`)` is equivalent. Also, if there is only one allowed dimension *dim*, then `all`, `set` and `remove` can be used directly as it is then unambiguous to which geometry and dimension their arguments apply to.

selection`.geom(`*<gtag>*`,`*highdim*`,`*lowdim*`,`*typelist*`)` specifies that subsequent calls to `all`, `set`, `add`, and `remove` refer to domains of dimension *highdim* on the geometry *<gtag>*. The domains that are obtained are those that are both of dimension *lowdim* and of any of the types listed in *<typelist>*. It is required that `highdim > lowdim`. The available types are:

- `exterior`: All domains of dimension *lowdim* that lie on the exterior of the domains at dimension *highdim*.
- `interior`: All domains of dimension *lowdim* that lie in the interior of the domains at dimension *highdim*.
- `meshinterior`: All mesh boundaries of dimension *lowdim* that lie in the interior of the domains at dimension *highdim*.

selection`.allGeom()` sets the selection to a whole geometry. Can be used instead of *selection*`.geom(`*<gtag>*`)` when the geometry tag is unambiguous.

selection`.geom(`*dim*`)` specifies that subsequent calls to `all`, `set`, `add`, and `remove` refer to domains at the dimension *dim*. Can be used instead of *selection*`.geom(`*<gtag>*`,`*dim*`)` when the geometry tag is unambiguous.

selection`.all()` sets the selection to use all geometric entities in the geometry at the dimension where the selection applies.

selection`.allVoids()` sets the selection to use all voids (finite voids and an infinite void, if present) in the geometry at the dimension where the selection applies. Voids can be present in models that use the boundary element method, for example. In a geometry with voids, *selection*`.all()` selects all domains, not the voids.

selection`.set(`*<entlist>*`)` sets the selection to use the geometric entities in *<entlist>*. Note that the list of domain numbers is always sorted in ascending order and duplicates are removed before storing the numbers in the selection object.

selection`.add(`*<entlist>*`)` adds the geometric entities in *<entlist>* in the geometry to the set of geometric entities that the selection uses to obtain the selection.

selection`.remove(`*<entlist>*`)` removes the geometric entities in *<entlist>* in the geometry from the set of geometric entities that the selection uses.

selection`.inherit(`*boolean*`)` indicates whether the selection should include all geometric entities that are specified by any of the other methods and all geometric entities at lower dimensions that are adjacent to the ones already specified.

selection`.named(`*<stag>*`)` specifies that the selection is defined by the selection `model.selection(`*<stag>*`)`.

selection`.isGlobal()` returns true if the selection is global.

selection`.isGeom()` returns true if the selection is a whole geometry.

selection`.geom()` returns the geometry tag of the selection as a string. If the selection is global, `null` is returned.

selection`.dimension()` returns the dimensions on a geometry where the selection applies as an integer array.

selection`.entities(`*dim*`)` returns the geometric entities of the selection on the given geometry at the given dimension as an integer array. The entities are represented using unique positive integers, except (if the model geometry contains voids) for finite voids, which get unique negative integer numbers, and for an infinite void, which is represented with the entity number 0.

selection`.interiorEntities(`*dim*`)` returns the interior mesh domains as an integer array.

selection`.isInheriting()` returns true if the selection is inherited to lower dimension levels.

selection`.inputDimension()` returns the dimension of the domains used as input to the selection.

selection`.inputEntities()` returns the entities used as input to the selection.

If the selection is defined by another selection, *selection*`.named()` returns the tag of that selection. Otherwise *selection*`.named()` returns an empty string.

Selections of the class `XDLocalSelection` have the following additional methods:

selection`.extraDim()` returns the tag of a feature of type `AttachDimension` in `model.extraDim()`, or an empty string if no extra dimension attachment is used.

selection`.extraDim(<`*attachdimtag*`>)` sets the extra dimension attachment feature. <*attachdimtag*> must be the tag of a feature of type `AttachDimension` in `model.extraDim()` or an empty string to indicate no extra dimension attachment.

selection.extraDimSel(<*xdgeomtag*>) returns the selection in extra dimension geometry <xdgeomtag>. <xdgeomtag> should be the tag of the geometry in one of the extra dimensions attached by the extra dimension attachment feature defined by *selection*.extraDim().

extraDimSel() returns all extra dimension geometry tags that are valid arguments of extraDimSel(<*xdgeomtag*>) as a string array.

NOTES

The methods global(), geom(<*gtag*>), geom(<*gtag*>,*dim*), geom(<*gtag*>,*highdim*,*lowdim*,*typelist*), and geom(*dim*) clear the data set by other methods.

Not all assignment methods are supported by all model entities. The list of supported methods also serves as a guide for the restriction to those named selections that can be used by that entity. All access methods are always supported.

SEE ALSO

model.geom()

Selection Color Themes

Use model.colorTheme to specify a color theme for selection colors.

Use model.colorTheme(<*theme*>) to set the color theme to be used in graphics. Using automatic indicates that the theme specified in the preferences will be used.

Use model.colorTheme() to return the current color theme. The value automatic indicates that the color theme specified in the preferences is used.

See also the color and customcolor properties for selections and geometry features.

The loadFile and saveFile Methods

The methods loadFile() and saveFile() are now available to load and save files for the following features:

- model.param() and model.result().param()
- model.variable() and model.component(<*ctag*>).variable()
- model.result().table()

You can use the following syntax for loadFile:

loadFile(String path) where the path is the path to any file type that COMSOL Multiphysics supports.

loadFile(String path, char delim) where delim is the delimiter used in the file.

loadFile(String path, String sheet, String range), where the string sheet is the name of the sheet to read from (null or empty means the first in the file), and range is range of cells to read. The range can be a single cell, which then indicates the top-left cell to read. If range is empty, it starts in the top-left corner.

For the saveFile method, the following syntax is available:

saveFile(String path)

saveFile(String path, char delim)

saveFile(String path, String sheet, String range, boolean includeHeaders, boolean overwrite), where includeHeaders determines whether to include headers or not, and overwrite determines if nonempty existing cells in a spreadsheet can be overwritten in the file. For example, a call like

```
model.param().saveFile(tempFile, "sheet", "C7", false, true);
```

starts saving at cell C7, does not include headers, an allows overwriting of nonempty cells.

For `model.result().table`, there are no delimiter functions.

Inserting Features from Other Models

These methods are related to inserting features from other models.

SCANNING MODELS

The `scanModel` method can be used to scan a model for contents:

```
String[][] com.comsol.model.util.ModelUtil.scanModel(String filename, String type,
String... extraAttributes)
```

The corresponding methods for protected models:

```
String[][] com.comsol.model.util.ModelUtil.scanProtectedModel(String filename, String
type, String password, String... extraAttributes)
```

These methods scan the model file for a certain node type and collect the tag and label of all found nodes. As an option it is possible to include values of other attributes to the result. The returned result is a double string array with all found nodes in the outer level and the sequence of found attributes in the inner level, starting with tag and label. The optional attributes follow after the tag and label, and available attributes depend on the type of nodes being scanned for. Many nodes support the attribute `op`, which is the subtype of the node, for example the kind of plot (surface, multislice, and so on).

The scan command is much quicker than loading an MPH-file, so it can be used prior to an insert command to get the complete list of components or physics in the file. The following example:

```
String[][] materials = ModelUtil.scanModel("mymodel.mph", "Material", "op");
```

will produce an output like:

```
{{"mat1", "Material 1", "Common"}, {"mat2", "Material 2", "Common"}}
```

The following input arguments are available:

- `filename`: The file path to the model.
- `type`: The type of the node to search.
- `password`: Only for `scanProtectedModel`: The password required to open the file.
- `extraAttributes`: Optional, a list of attributes in addition to the tag and label to include in the result.

These methods return a double string array with the result.

INSERT MATERIALS

The `insert` method can be used to insert materials with the following syntax:

```
String[][] com.comsol.model.MaterialList.insert(String filename, String[] materials,
String... password)
String[][] com.comsol.model.ComponentMaterialList.insert(String filename, String[]
materials, String... password)
```

Using this method, you can insert materials from an MPH-file into the material list of this model and return the result of the operation as a double string array of length 3.

The first array contains the messages from insert, the second array contains paths to the inserted objects, and the third array contains paths to the inserted references. A pasted reference is an object that an inserted object refers

to, and it is not necessarily contained by any of the inserted objects. The following example inserts the materials tagged `mat5` and `mat10` into the model's global materials:

```
model.material().insert("mymodel.mph", new String[]{"mat5", "mat10"});
```

The next example inserts the materials tagged `mat5` and `mat10` into the materials of component `comp1`:

```
String[][] ret = model.component("comp1").material().insert("mymodel.mph", new
String[]{"mat5", "mat10"});
```

It will produce the following output:

```
{{}, {"/MaterialList/mat5", "/MaterialList/mat10"}, {}}
```

The following input arguments are available:

- `filename`: The filename.
- `materials`: The tags of the materials to insert.
- `password`: Optional password required to open the file.

.The `insert` method returns results from the insert operation.

ModelUtil

Model object utility methods such as methods to create and remove model objects, showing progress information, and listing and saving preferences. See also `model`.

SYNTAX

This section describes general methods that handle the environment for the model object. It also describes methods for the client/server machinery.

```
import com.comsol.model.*;
import com.comsol.model.util.*;
```

The import statements above make all model and model utility methods available.

`ModelUtil.create(`*<tag>*`)`: The `create` method creates a model with tag *<tag>*. Returns a reference to the model. If there is already a model with this tag the previous model is removed.

`ModelUtil.remove(`*<tag>*`)`: The `remove` method removes the model tagged *<tag>*.

`ModelUtil.clear()`: The `clear` method removes all models.

`ModelUtil.tags()`: The `tags` method obtains the current list of model tags.

`ModelUtil.model(`*<tag>*`)`: The `model` method returns a reference to the model tagged *<tag>*.

`ModelUtil.closeWindow(`*<windowtag>*`)`: The `closeWindow` method closes the window tagged *<windowtag>*.

`ModelUtil.closeWindows()`: The `closeWindows` method closes all windows on the server.

`ModelUtil.createApplication(`*<tag>*`,`*<appname>*`)`: The `createApplication` method creates a new application model with the tag *<tag>* and the name *<appname>* using the given application file reference.

`ModelUtil.createUnique(`*<prefix>*`)`: The `createUnique` method creates a model with a unique tag that begins with the prefix *<prefix>*.

`ModelUtil.getComsolVersion()`: The `getComsolVersion` method returns the current COMSOL Multiphysics version as a string.

`ModelUtil.getOpenGeometryKernel()`: The `getOpenGeometryKernel` method returns the geometry kernel to use when opening models. Valid values are `model` for the geometry kernel used by the model file, and `comsol` to convert the geometry to the COMSOL kernel.

`ModelUtil.getDefaultGeometryKernel()`: The `getDefaultGeometryKernel` method returns the default geometry kernel in new models. Valid values are `comsol` for the COMSOL kernel and `cadps` for the CAD kernel (Parasolid kernel). The CAD kernel requires the CAD Import Module.

`ModelUtil.setOpenGeometryKernel(`*`<openkernel>`*`)`: The `setOpenGeometryKernel` method specifies the geometry kernel to use when opening models. Valid values are `model` for the geometry kernel used by the model file, and `comsol` to convert the geometry to the COMSOL kernel.

`ModelUtil.setDefaultGeometryKernel(`*`<defaultkernel>`*`)`: The `setDefaultGeometryKernel` method specifies the default geometry kernel to use in new models with the string *`<defaultkernel>`*. Valid values are `comsol` for the COMSOL kernel and `cadps` for the CAD kernel (Parasolid kernel). The CAD kernel requires the CAD Import Module.

`ModelUtil.getEntityPath(`*`<entity>`*`,`*`<divider>`*`)`: The `getEntityPath` method creates the path from the root of the model object for the given entity *`<entity>`*. *`<divider>`* specifies a divider to use between entities in path.

`ModelUtil.load(`*`<tag>`*`,`*`<filename>`*`)`: The `load` method loads a model from a file *`<filename>`* in the client's file system and names it *`<tag>`*. Loading a file from a directory sets the model directory. The model directory is used for saving files if you do not provide an absolute path to the file. The model directory is the directory where the model is saved. If the model has not been saved there is no model directory. You can get the model directory from a saved model using `model.getFilePath`.

`ModelUtil.loadCopy(`*`<tag>`*`,`*`<filename>`*`)`: The `loadCopy` method loads a copy of a model from a file *`<filename>`* in the client's file system and names it *`<tag>`*. The `loadCopy` method is the same as `load` except that the loaded model is not associated with the file, so `model.save()` does not work. You have to specify the filename the first time you save it again.

`ModelUtil.loadOnServer(`*`<tag>`*`,`*`<filename>`*`)`: The `loadOnServer` method works like `ModelUtil.load` except that the filename is a path on the server computer. The client does not have to have access to the file.

`ModelUtil.loadProtected(`*`<tag>`*`,`*`<filename>`*`,`*`<password>`*`)`: The `loadProtected` method works like `ModelUtil.loadOnServer` but with password protection.

`ModelUtil.loadProtectedOnServer(`*`<tag>`*`,`*`<filename>`*`,`*`<password>`*`)`: The `loadProtectedOnServer` method works like `ModelUtil.loadOnServer` but with password protection.

`ModelUtil.loadRecovery(`*`<tag>`*`,`*`<foldername>`*`)`: The `loadRecovery` method loads a model from a recovery directory or folder structure in the client's file system and names it *`<tag>`*.

`ModelUtil.showPlots(bool)`: The `showPlots` method applies when connected to a graphics server, and `ModelUtil.showPlots(false)` will disable plotting. It will not close any existing plot windows. Use `ModelUtil.closeWindow(`*`<tag>`*`)` or `ModelUtil.closeWindows()` to do that.

`ModelUtil.showProgress(bool)`: The `showProgress` method with a Boolean input turns on or off showing of progress in a window or on a file when running lengthy tasks when connected to a server. The return value is a Boolean value that is true if showing progress is possible.

`ModelUtil.showProgress(`*`<filename>`*`)`: The `showProgress` method with a filename input turns on logging of progress to the file *`<filename>`* in the client's file system. If *`<filename>`* is *`null`* progress is logged to the standard output.

`ModelUtil.initStandalone(bool)`: The `initStandalone` method initializes the environment for using the COMSOL API from a standalone Java® application. You should *not* use this command from the LiveLink™ *for* MATLAB®. Set the argument to true if support for plotting in a GUI using Java Swing widgets should be available.

`ModelUtil.initStandalone(bool,<guiToolkit>)` allows to specify that support for using a given Java GUI toolkit should be available. The optional *<guiToolkit>* parameter can have the values `"swing"` or `"swt"` telling that Swing widgets or widgets from the Standard Widget Toolkit (SWT) can be used.

`ModelUtil.getPreference(<prefsName>)`: The `getPreference` method returns the value of a preference.

`ModelUtil.setPreference(<prefsName>, <value>)`: The `setPreference` method sets the value of a preference.

`ModelUtil.listPreferences()`: The `listPreferences` method returns a string with a listing of the preferences names and their descriptions.

`ModelUtil.loadPreferences()`: The `loadPreferences` method loads the preferences from file. Use this is standalone Java application which do not load the preferences at launch time.

`ModelUtil.savePreferences()`: The `savePreferences` method saves the preferences to file.

`ModelUtil.uniquetag()`: The `uniquetag` method returns a unique model tag that is not in use.

`ModelUtil.modelsUsedByOtherClients()`: The `modelsUsedByOtherClients` method returns the tags of models used by other clients.

License Commands

`ModelUtil` provides functionality to check availability for and control the checkout of COMSOL product licenses.

`ModelUtil.hasProduct(String... product)`: The `hasProduct` method checks if the current license allows to run the specified COMSOL products given as the input (as an array of strings).

`ModelUtil.hasProductForFile(String file)`: The `hasProductForFile` method checks if the current license allows the specified COMSOL products needed to use that COMSOL MPH file.

`ModelUtil.hasProductForFileonServer(String file)`: The `hasProductForFileonServer` method is similar to `hasProductForFile` but checks if the license allows the specified COMSOL products needed for a file on the server.

`ModelUtil.checkoutLicense(String... product)`: The `checkoutLicense` method checks out licenses for the COMSOL products given as the input (as an array of strings).

`ModelUtil.checkoutLicenseForFile(String file)`: The `checkoutLicenseForFile` method checks out the licenses needed to use that COMSOL MPH file.

`ModelUtil.checkoutLicenseForFileonServer(String file)`: The `checkoutLicenseForFileonServer` method is similar to `checkoutLicenseForFile` but checks out the licenses needed to use that COMSOL MPH file on the server.

The following table lists the available products for which licenses can be checked for availability and checked out using the names in the **Name** column:

PRODUCT	NAME
AC/DC Module	ACDC
Acoustics Module	ACOUSTICS
Batteries & Fuel Cells Module	BATTERIESANDFUELCELLS
CAD Import Module	CADIMPORT, CADREADER
CFD Module	CFD

PRODUCT	NAME
Chemical Reaction Engineering Module	CHEM
Cluster computing functionality	CLUSTERNODE
Corrosion Module	CORROSION
Design Module	DESIGN
ECAD Import Module	ECADIMPORT
Electrochemistry Module	ELECTROCHEMISTRY
Electrodeposition Module	ELECTRODEPOSITION
Fatigue Module	FATIGUE
File Import for CATIA V5	CATIA5
Geomechanics Module	GEOMECHANICS
Heat Transfer Module	HEATTRANSFER
LiveLink™ *for* AutoCAD®	LLAUTOCAD
LiveLink™ *for* PTC® Creo® Parametric™	LLCREOPARAMETRIC
LiveLink™ *for* Excel®	LLEXCEL
LiveLink™ *for* Inventor®	LLINVENTOR
LiveLink™ *for* MATLAB®	LLMATLAB
LiveLink™ *for* Revit®	LLREVIT
LiveLink™ *for* PTC® Pro/ENGINEER®	LLPROENGINEER
LiveLink™ *for* Solid Edge®	LLSOLIDEDGE
LiveLink™ *for* SOLIDWORKS®	LLSOLIDWORKS
MEMS Module	MEMS
Microfluidics Module	MICROFLUIDICS
Mixer Module	MIXER
Molecular Flow Module	MOLECULARFLOW
Multibody Dynamics Module	MULTIBODYDYNAMICS
Nonlinear Structural Materials Module	NONLINEARSTRUCTMATERIALS
Optimization Module	OPTIMIZATION
Particle Tracing Module	PARTICLETRACING
Pipe Flow Module	PIPEFLOW
Plasma Module	PLASMA
Ray Optics Module	RAYOPTICS
RF Module	RF
Rotordynamics Module	ROTORDYNAMICS
Semiconductor Module	SEMICONDUCTOR
Structural Mechanics Module	STRUCTURALMECHANICS
Subsurface Flow Module	SUBSURFACEFLOW
Wave Optics Module	WAVEOPTICS

Client-Server Commands

`ModelUtil` provides functionality to control COMSOL client-server options. You can connect/disconnect and control connections from multiple clients to a server using, for example, the `connect` and `disconnect` methods.

`ModelUtil.connect()` connects to a COMSOL server (COMSOL Multiphysics server or COMSOL Server™). The COMSOL command arguments `-Dcs.host=`*`<host>`* and `-Dcs.port=`*`<port>`* can provide the hostname and

port number. In case those are not provided, and the both client and server access the same file system, the host and port can be automatically transferred.

`ModelUtil.connect(<host>,<port>)` connects to a COMSOL server. The arguments *<host>* and *<port>* provide the hostname (a string) and port number (an integer) for the COMSOL server.

`ModelUtil.connect(<host>,<port>,<user>,<password>)` connects to a COMSOL server. The arguments *<host>*, *<port>*, *<user>* and *<password>* provide the hostname (a string), port number (an integer), user (a string), and password (a string) for the COMSOL server.

`ModelUtil.connect(<host>,<port>,<encryption>)` and `ModelUtil.connect(<host>,<port>,<encryption>,<user>,<password>)` connects to a COMSOL server using encryption. With the Boolean *<encryption>* set to false, it uses the `ws` WebSocket URI scheme; when set to true, it uses the secure `wss` (SSL) WebSocket URI scheme.

`ModelUtil.disconnect()` disconnects from a COMSOL server.

`ModelUtil.setServerBusyHandler(<ServerBusyHandler>)`: Use the `setServerBusyHandler` method to register a `ServerBusyHandler`. Several clients can be connected to the same server, but only one client at a time can ask the server to perform an operation. The default behavior when attempting to call the server when it is busy is to throw an exception. By registering a `ServerBusyHandler` it is possible to make the client wait until the server is free again, and to set a time-out for how long to wait.

`ServerBusyHandler` is a class which controls how long a client waits for a busy server to become free again. It also has hooks to perform any action on the client side before starting to wait and just after stopping to wait. Implement a subclass in Java to `ServerBusyHandler` to change the default behavior.

`ServerBusyHandler()` creates a server-busy handler that waits for the server to be free without any time-out.

`ServerBusyHandler(<timeOut>)` creates a server-busy handler that waits for the server to be free. The time to wait, *<timeOut>*, is given in milliseconds.

`postWaitForServer(<boolean>)` is a hook to perform any action right after waiting for the server to become free.

`preWaitForServer(<host>, <port>)` is a hook to perform any action before beginning to wait for the server to become free.

`ModelUtil.setModelChangedHandler(<ModelChangedHandler>)`: The `setModelChangedHandler` method registers a handler of changes to models made by other clients. If any other client changes any model in use by this client, the model change handler is notified.

`ModelChangedHandler` is an interface for handling updates of the client when another client has modified any models in use by this client. Implement the interface in Java to change the default behavior.

`handleModelChangeOnServer(<modelChangeInfo>)` is called when another client has changed any models in use by this client.

`ModelChangeInfo` is a class with information about changes to models by other clients.

`getModelTags()` returns the tags of the models that have changed.

model

Model object methods that set up basic parts of a model object such as the model history and saving model files.

SYNTAX

`model` is a model object that you can create, for example, using `ModelUtil.create(<tag>)`.

`model.baseSystem(<system>)`: The `baseSystem` methods sets the unit system for the entire model to the given system. The default is the SI system, which has the tag `SI`. Other supported unit systems are `bft` (British engineering units), `cgs`, `mpa`, `emu`, `esu`, `fps`, `ips`, and `psi`.

`model.clearThumbnail()`: The `clearThumbnail` method clears the model thumbnail image.

`model.dateModified()`: The `dateModified` method returns the modification date of the model.

`model.disableUpdates()`: The `disableUpdates` method returns the current status of the disable state for the model object.

`model.disableUpdates(boolean)` Temporarily disables and re-enables the update of variables in entities that automatically generates other entities (for example, `physics` or `coordSystem`). Disable updates to speed up the evaluation of long execution sequences. Leaving this flag disabled can cause strange side effects during modeling. For example, some parameter values in a feature of a physics interface might not be valid until an update has been made. The model inputs are such parameters, which end with the suffix `_src`. Trying to set a value to any of these parameters with updates disabled might give an error message. Other effects are that the generated variables are unknown to the unit evaluator and equation view readings can be incomplete. When the disabled state goes from `true` to `false`, the program performs a full update of the variables, so the model is in a fully functional state.

`model.fontFamily(<family>)`: The `fontFamily` method sets the font family to be used in plots. The font `default` is always available. If using Windows, most system fonts can also be used.

`model.fontSize(<size>)`: The `fontSize` method sets the font size to be used in plots.

`model.getComsolVersion()`: The `getComsolVersion` method returns the COMSOL Multiphysics version used to save the model or the current version if the model has never been saved. There is also a `ModelUtil.getComsolVersion()` method, which returns the current version as a string.

`model.getFilePath()` returns the absolute path of the model or an empty string if the model has not been saved.

`model.getLastComputationTime(string time_format)`: The `getLastComputationTime` method returns the last computation time for the model or application as a string. Use `model.getLastComputationTime()` to get the time measured in ms, which you can then use as an input to `model.setLastComputationTime`. Other supported time formats are `"hr:min:sec"`, `"h:min:s"`, and `"detailed"`, which returns the time in seconds and also includes more readable units for longer times.

`model.getUsedProducts()`: The `getUsedProducts` method returns the products that this model uses.

`model.hist().complete(bool)` enables or disables history logging for methods where the arguments typically are very large objects.

`model.hist().isComplete()` returns true if history logging is enabled for methods where the arguments typically are very large objects.

`model.hist().disable()` Disables logging of top-level API calls to the history. Use this method sparingly; the normal state is that the history is logged.

`model.hist().enable()` Removes the most recent disabling of top-level API calls to the history. Calling `enable()` can be viewed as removing an entry from a stack of disable records; logging only occurs if the stack is empty.

`model.isReadOnly()`: The `isReadOnly` method returns whether the file where the model is saved is read-only and cannot be overwritten or not. The file can be read-only for two reasons:

- The COMSOL process does not have permission to write to the file.
- On Windows, the file can be locked by another COMSOL instance.

If the model has not been saved, this method returns false.

`model.lastModifiedBy()`: The `lastModifiedBy` method returns the last user to modify the model.

`model.modelPath(<path>)`: The `modelPath` method sets the model path. The model path is used for reading files required by the model, if no path is provided to the file. *<path>* is a list of directories separated by semicolon. When reading an external file, COMSOL Multiphysics attempts to find a file in the following locations:

1. The absolute path as given in the filename. If the path given in the filename is relative, it is resolved relative to the following directories.
2. The model directory, if provided.
3. If searching for a geometry part, the user part libraries. These are given by the preference property `geometry.library.userpartlibraries`.
4. If searching for a geometry part, the COMSOL Multiphysics installation's parts directory.
5. The directories defined by `model.modelPath` (ordered and semicolon separated).
6. The directories in the `cs.path` setting (ordered and semicolon separated).
7. The current directory, which is given by the Java system property `user.dir` and is the directory where you launch COMSOL Multiphysics, unless you have changed the value of `user.dir`.

The model directory is used for saving and exporting files if you do not provide an absolute path to the file.

`model.modelPath()` returns the model path; that is, the path to the location where the model was last saved, if such a location exists, or the path set in a call to `model.modelPath`.

`model.resetHist()`: the `resetHist` method rebuilds the model from scratch to generate a compacted model's Java- or M-file history (that is, creating a compact history). If the model has errors, or has invalid property values, the method fails and the old history is kept.

`model.save(<filename>)`. The `save` method saves the model as a multiphysics model file in *<filename>*. If you do not provide a path, the model is saved in the directory from where you have launched COMSOL Multiphysics.

`model.save(<filename>,<type>)` saves the multiphysics model in *<filename>*. If the type is `java`, a model file for use with Java® is saved. If the type is `m`, this command saves a model file as an M-file for use with the LiveLink™ *for* MATLAB®. If the type is `vba`, this command saves a model file as a VBA-file for use with VBA (Visual Basic for Applications) in Microsoft Excel®.

`model.setLastComputationTime(long` *time*`)`: The `setLastComputatonTime` method sets the last computation time for the model or application as the measured computation time (in ms) that you provide as the input.

`model.setThumbnail(<image_filename>)`: The `setThumbnail` method imports the image file at the given path and sets it as the model's thumbnail image.

SEE ALSO

`model.modelNode()`, `model.unitSystem()`

model.attr()

Model entity list methods such as copying, duplicating, clearing, and removing model entities.

SYNTAX

`model.attr()` returns a *model entity list*. The string *attr* denotes a method name for accessing the model entity list.

`model.attr().clear()` removes all tagged model entities.

`model.attr().copy(<tag>, <copytag>)` creates a new model entity with the tag `<tag>`, which is a copy of the model entity with the tag `<copytag>`. The `<copytag>` should be combination of tags separated by slashes to uniquely identify the entity. For example, `pg1/surf1/htgh1` identifies `model.result("pg1").feature("surf1").feature("htgh1")`. How to interpret the combined tag depends on the context. The difference between `duplicate` and `copy` is that `copy` can use a source anywhere in the model, whereas `duplicate` requires that the source is in the same list. Not all model entities support the `copy` operation. The difference between `copy` and `copyTo` is that `copyTo` copies the entity to a specific position in the list, whereas `copy` copies to a default position in the list. Not all model entities support the `copyTo` operation.

`model.attr().copy(<tag>, <copytag>, <modeltag>)` creates a copy and assigns it to the model `<modeltag>`.

`model.attr().copyTo(<tag>, <copytag>, <insertafter>)` creates a copy and inserts it in the list after the entity with tag `<insertafter>`. If `<insertafter>` is an empty string, the entity is inserted first in the list. Not all model entities support the `copyTo` operation.

`model.attr().duplicate(<tag>, <copytag>)` creates a new model entity with the tag `<tag>` which is a duplicate of the model entity with tag `<copytag>`. Not all model entities support the `duplicate` operation.

`model.attr().duplicateTo(<tag>, <copytag>, <insertafter>)` creates a new model entity and inserts it in the list after the entity with tag `<insertafter>`. If `<insertafter>` is an empty string, the entity is inserted first in the list. Not all model entities support the `duplicateTo` operation.

`model.attr().get(<tag>)`. The `get` method returns the entity with tag `<tag>` from the entity list `model.attr()`.

`model.attr().remove(<tag>)`. The `remove` method removes the model entity with tag `<tag>`.

`model.attr().size()`. The `size` method returns the number of model entities.

`model.attr().tags()`. The `tags` method returns a string array with the tags of all model entities.

`model.attr().uniquetag(<tag>)`. The `uniquetag` method returns a unique tag in the list context.

SEE ALSO

`model`

model.attr(<tag>)

Model entity methods for adding and accessing name, tag, version, comments, date created, and the author information for a model entity.

SYNTAX

`model.attr(<tag>)` returns a ***model entity*** with tag `<tag>`. The string `attr` denotes a method name for accessing a model entity with tag `<tag>`.

`model.attr(<tag>).active(bool)` makes the entity with tag `<tag>` active or inactive.

`model.attr(<tag>).author()` returns the author of the entity.

`model.attr(<tag>).author(<author>)` sets the author of the entity.

`model.attr(<tag>).comments()` returns the comments of the entity.

`model.attr(<tag>).comments(<comments>)` sets the comments of the entity.

`model.attr(<tag>).dateCreated()` returns the creation date of the entity.

`model.attr(<tag>).isActive()` returns true if the entity with tag `<tag>` is active.

`model.attr(<tag>).label()` returns the label of the entity.

`model.attr(<tag>).label(<label>)` sets the label of the model entity. The label is an arbitrary nonempty string.

`model.attr(<tag>).resetAuthor(<author>)` sets the author of the entity and all its children. In particular, when used on the model itself, the method sets the author on all model entities of the model.

`model.attr(<tag>).tag()` returns the tag of the entity.

`model.attr(<tag>).tag(<newtag>)` assigns the new tag `<newtag>` to the entity `<tag>`.

`model.attr(<tag>).timeCreated()` and `model.attr(<tag>).timeModified()` return the creation time of the entity and the time when the entity was last modified, respectively. The times are reported in milliseconds since January 1, 1970, 00:00:00 GMT.

`model.attr(<tag>).version(<version>)` sets the version of the entity. The version is a user-defined string.

`model.attr(<tag>).version()` returns the version of the entity.

`model.attr(<tag>).help()` and `model.attr(<tag>).help(string)`, where `string` is the name of a type within the model object, return a query URL string for looking up HTML documentation help text for the model entity of the given type using a COMSOL Documentation server running either locally or online at doc.comsol.com.

`model.attr(<tag>).docMarker()` and `model.attr(<tag>).docMarker(string)`, where `string` is the name of a type within the model object, return the topic key for the model entity of the given type to use as the argument to the public static method `com.comsol.doc.client.DocRemoteClient.showHelp(String)` of the COMSOL Documentation application, which shows documentation with the help of a COMSOL Documentation server. If the COMSOL Documentation application is closed, it will automatically relaunch the next time you call the `showHelp(String)` method. If desired, it is possible to close a COMSOL Documentation application launched in this way programmatically by calling the method `com.comsol.doc.client.DocRemoteClient.shutdown()`.

SEE ALSO

model

model.batch()

Create batch jobs.

SYNTAX

Jobs

`model.batch().create(<tag>,jobtype);` creates a batch job tagged `<tag>` of type `jobtype`, where `jobtype` is `Parametric`, `Batch`, or `Cluster`.

`model.batch().remove(<tag>)` removes a batch job.

`model.batch().size()` returns number of batch jobs.

`model.batch().tags()` returns the tags of the batch jobs.

`model.batch(<tag>).attach(<stag>)` attaches a batch job with tag `<tag>` to a study with tag `<stag>`, which makes it visible under that study.

`model.batch(<tag>).create(<jtag>,<oper>)` creates a batch job sequence.

`model.batch(<tag>).detach(<stag>)` detaches a batch job from a study with tag `<stag>`.

`model.batch(<tag>).remove(<ttag>)` removes the task.

`model.batch(<tag>).run()` runs the batch job.

`model.batch(<tag>).set(jprop,<jvalue>)` sets the property *jprop* to the value *<jvalue>*.

`model.batch(<tag>).study(<stag>)` assigns a batch job to a study tag *<stag>*.

`model.batch(<tag>).study()` returns the study tag of batch job with tag *<tag>*.

`model.batch(<tag>).feature(<ttag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

Batch Job Properties

The `Parametric` job type has the following properties:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`accumtable`	String	`new`	Accumulated probe table.
`accumtableall`	`on`|`off`	`off`	Use all probes for the accumulated probe table.
`control`	String	`user`	Controlling study.
`param`	String array		Name of parameter and its value (output).
`pdistrib`	`on`|`off`	`off`	Distributed (in parallel) the parameter values.
`pname`	String array		Parameter name(s) to vary.
`plist`	String array		Parameter values.
`plot`	`on`|`off`	`off`	Update a plot group while solving.
`plotgroup`	String	default	Update this plot group while solving.
`pwork`	int	1	Limit for the number of work groups.
`pworkactive`	`on`|`off`	`off`	Use a limit for the number of work groups.
`stopcond`	String		A stop condition expression.
`err`	`on`|`off`	`off`	Stop sweep if error.
`error`	String array		The logged error.
`useaccumtable`	`on`|`off`	`off`	Produce an accumulated probe table while solving.

The `Optimization` job type sets its property through the `Optimization` study node, which has the following properties:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`optobj`	String		Objective function to be optimized.
`descr`	String		Description of optimization objective function.
`objectivetype`	`minimization` | `maximization`	`minimization`	Sets whether the objective should be minimized or maximized.
`objectivesolution`	`auto` | `first` | `last` | `sum` | `min` | `max`	`auto`	Determines how the objective should be evaluated for studies with more than one available PDE solution, for example, time-dependent problems.
`pname`	String array		Names of control parameters.
`initval`	String array		Initial values for control parameters.
`lbound`	String array		Lower bounds on control parameters.
`ubound`	String array		Upper bounds on control parameters.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
optsolver	coordsearch | montecarlo | neldermead | bobyqa	neldermead	Optimization solver.
useseed	on|off	off	Use random seed for Monte Carlo solver.
randseed	int	0	Random seed for Monte Carlo solver.
nsolvemax	int	1000	Maximum number of objective evaluations.
opttol	double	1e-2	Optimization tolerance.
useobjtable	on|off	off	Produce a table with all objective evaluations.
objtable	String	new	Reference to table with objective evaluations.
convinfo	off | on | detailed	on	Detail of log messages from optimization solver.

The Batch job type has the following properties:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
control	String	user	Name of controlling study.
np	integer	auto	Number of cores to use.
graphics	on|off	off	Enable graphics.
maxallow	integer	1	Maximum allowed number of batch jobs to start simultaneously.
maxrestart	integer	0	Maximum number of restarts before a batch job is failed.
maxalive	integer	300	Maximum number of seconds before the batch job must say it is running.
starttime	now | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23	now	The time, as an hour for a 24-hour clock, when the batch job should start.
batchdir	String	home directory	The directory to store files used by the batch job.
client	on|off	off	Run the batch job as client.
port	integer	2036	The host port number.
host	String	localhost	Name of host.
batchfile	String	batchmodel.mph	Name of batch model file.
clear	on|off	on	Clear the previous model file.
clearmesh	on|off	off	Clear meshes before saving model.
clearsolution	on|off	off	Clear solutions before saving model.
savefile	on|off	on	Save model after run.
specbatchdir	on|off	off	Specify different directory for batch process than used by the current process.
rundir	String	home directory	The directory used by the batch job when specbatchdir is on.
speccomsoldir	on|off	off	Specify different directory for the COMSOL installation than used by the current process.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
comsoldir	String	COMSOL installation directory	The COMSOL installation directory used by the batch job when speccomsoldir is on.
synchsolutions	on|off	off	Synchronize solutions after batch job finishes.
synchaccumprobetable	on|off	off	Synchronize accumulated probe tables after batch job finishes.
probesel	all | none | manual	all	The probes to compute.
probes	String array		Probes to compute.
useaccumtable	on|off	off	Use the accumulated probe table.
accumtable	String	new	Name of table to use.
accumtableall	on|off	on	Use all probes.
client	on|off	off	Run as client.
host	String	localhost	Name of server.
port	integer		Server port number.

The Cluster job type has the following properties:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
batch	String		Tag of batch job to run.
clustertype	general | whpc2008 | wccs2003 | sge | slurm | none	general	The type of cluster job.
control	String	user	Name of controlling study.
corespernode	integer	0	Minimum number of cores per node on whpc2008.
exclusive	on|off	on	Demand exclusive right to nodes on whpc2008 and SLURM.
filetransfercmd	none | scp | user	none	Command to transfer files.
filetransferfromusercmd	String		Command to transfer files from remote location.
filetransfertousercmd	String		Command to transfer files to remote location.
hostfile	String		Path to hostfile.
memorypernode	integer	0	Minimum amount of memory per node on whpc2008 and SLURM.
mpd	on|off	off	If an mpd is running on the computer or not.
mpiargs	String		Additional MPI arguments.
mpibootstrap	String		Name of bootstrap server.
mpirsh	String		Path to rsh or ssh.
nn	integer	1	Number of processes to start.
nodegran	node | socket| core	node	Node granularity on whpc2008.
nodegroup	String		Name of Named selection of Compute nodes in whpc2008.
perhost	integer	1	Number of processes / host.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
postcmd	String		DOS/Linux command to execute after the batch job finished.
precmd	String		DOS/Linux command to execute prior to the batch job.
priority	Highest | AboveNormal | Normal | BelowNormal | Lowest	Normal	Priority of job on wccs2003 and whpc2008.
remote	on|off	off	Run on remote server.
remotecmd	none | ssh | user	none	Command to use when invoking a command on a remote server.
remotehosts	String		List of remote hostnames.
remoteos	native | windows | linux	native	OS used on remote hosts.
remoteusercmd	String		Command to run on remote server.
reqnodes	String array		Requested nodes on wccs2003, whpc2008, and SLURM.
runtime	DD:HH:MM | Infinite	Infinite	Maximum time to run before stopping on wccs2003, whpc2008, and SLURM.
schedargs	String		Additional scheduler arguments.
scheduler	String	localhost	Name of the scheduler on wccs2003, whpc2008, and SLURM.
scpargs	String		Additional SCP arguments.
scpcmd	scp | putty | user	scp	SCP command.
scpkey	String		SCP key file.
scppath	String		Directory where SCP resides.
scpuser	String		Username used by SCP.
scpusercmd	String		Command for copying files to remote location.
sgegran	host | slot | manual	host	Node granularity on SGE.
sgenn	integer	1	Number of slots in SGE.
sgepriority	integer	0	Priority of job on SGE and SLURM.
sgequeue	String		Name of SGE and SLURM queue.
sshargs	String		Additional SSH arguments.
sshcmd	ssh | putty | user	ssh	SSH command.
sshkey	String		SSH key file.
sshpath	String		Directory where SSH resides.
sshporthost	String		Port host.
sshports	String		Ports that should be forwarded by SSH.
sshuser	String		Username used by SSH.
sshusercmd	String		User-defined SSH command.
user	String		Username on wccs2003, whpc2008, and SLURM.

Tasks

`model.batch(<tag>).create(<ttag>,tasktype);` creates a task of type *tasktype* tagged *<ttag>*. Find options for *tasktype* in Table 2-3 below.

TABLE 2-3: BATCH TASK TYPE OPTIONS

TASK TYPE	DESCRIPTION
Geomseq	A geometry sequence to build.
Meshseq	A meshing sequence to build.
Solutionseq	A solver sequence to compute.
Jobseq	A job sequence to run.
Postseq	A post sequence to run.
Evalnumericalseq	A numerical results seq (derived value) to run (replaced Numericalseq).
Numericalseq	A numerical results seq to run (deprecated).
Exportseq	An export sequence to run.
Save	Saves the state of the model at this point in the job sequence.
Class	Runs the main function of a compiled class with the system property cs.currentmodel set to the name of the model calling the class.
Data	Created by batch jobs to store external process information.

Task Type Properties

`model.batch(<tag>).feature(<ttag>).set(ttprop,<tpvalue>)` sets the task type property *ttprop* to the value *<tpvalue>*.

Task type properties can have the values listed in Table 2-4.

TABLE 2-4: TASK TYPE PROPERTY VALUES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
clear	on|off	on	Clear the currently stored data.
filename	String		Name of file to store or open.
openfile	String array	none	Name of file that was saved.
param	String array		Name of parameter and its value.
files	String array		Name of files for each parameter.
input	String array		Input to class file.
seq	String	all	Name of sequence to run.
num	String array		Name of numerical result feature that generated value.
paramvalue	String array		Computed numerical result.
store	on|off	off	Copy solution.
psol	String	none	Tag of solver sequence where solutions are stored.

The Data Task Type

The Data task type contains child nodes with process information of type Process; see Table 2-5.

TABLE 2-5: DATA CHILD NODES

TASKTYPE	DESCRIPTION
Process	Contains information about running processes.

`model.batch(<tag>).feature(<ttag>).feature(<ptag>).set(ptype, <pvalue>)` sets the property `ptype` to the value `<pvalue>`. `ptype` can have the values listed in Table 2-6

TABLE 2-6: PTYPE PROPERTY VALUES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`cmd`	String		The command that started the external process.
`filename`	String		Name of file where model is stored.
`operation`	`update` | `progress` | `cancel` | `stop` | `clear` | `rerun`	`update`	Name of operation to perform on the process.
`status`	String		Current status of the process.

EXAMPLE

Create a parametric sweep over a geometry sequence that creates a batch job that runs a parametric sweep that runs a solver.

Code for Use with Java

```
model.batch().create("sweep1","Parametric");
model.batch("sweep1").set("pname","a");
model.batch("sweep1").set("plist",new double[]{1,2});
model.batch("sweep1").create("sol","Solutionseq");
model.batch("sweep1").feature("sol").set("seq","sol3");
model.batch().create("batch1","Batch");
model.batch("batch1").create("task","Jobseq");
model.batch("batch1").feature("task").set("seq","sweep1");
model.batch().create("sweep2","Parametric");
model.batch("sweep2").set("pname","b");
model.batch("sweep2").set("plist",new double[]{1,2,3});
model.batch("sweep2").create("gtask","Geomseq");
model.batch("sweep2").feature("gtask").set("seq","geom1");
model.batch("sweep2").create("task","Jobseq");
model.batch("sweep2").feature("task").set("seq","batch1");
model.batch("sweep2").run();
```

Determine the parameter names and values from a parametric sweep that has already been run.

```
model.batch(pname).feature(fname).getString("psol")
```

where `pname` is the name of the parametric sweep feature that ran and `fname` is the name of the solution feature that stored the solutions. Use

```
model.sol(sname).feature().tags()
```

to find out the tags of the stored solutions. Use

```
model.sol(sname).feature(fname).getString("sol")
```

to find the solver sequence for a parameter. Use

```
model.sol(sname).getParamNames()
```

and

```
model.sol(sname).getParamVals()
```

Code for Use with MATLAB

```
model.batch.create('sweep1','Parametric');
model.batch('sweep1').set('pname','a');
model.batch('sweep1').set('plist',[1,2]);
model.batch('sweep1').create('sol','Solutionseq');
model.batch('sweep1').feature('sol').set('seq','sol3');
model.batch.create('batch1','Batch');
model.batch('batch1').create('task','Jobseq');
model.batch('batch1').feature('task').set('seq','sweep1');
```

```
model.batch.create('sweep2','Parametric');
model.batch('sweep2').set('pname','b');
model.batch('sweep2').set('plist',[1,2,3]);
model.batch('sweep2').create('gtask','Geomseq');
model.batch('sweep2').feature('gtask').set('seq','geom1');
model.batch('sweep2').create('task','Jobseq');
model.batch('sweep2').feature('task').set('seq','batch1');
model.batch('sweep2').run;
```

Determine the parameter names and values from a parametric sweep that has already been run.

```
model.batch(pname).feature(fname).getString('psol')
```

where `pname` is the name of the parametric sweep feature that ran and `fname` is the name of the solution feature that stored the solutions. Use

```
model.sol(sname).feature().tags
```

to find out the tags of the stored solutions. Use

```
model.sol(sname).feature(fname).getString('sol')
```

to find the solver sequence for a parameter. Use

```
model.sol(sname).getParamNames
```

and

```
model.sol(sname).getParamVals
```

SEE ALSO

`model.sol()`, `model.study()`

model.bem()

Create a boundary element (BEM) model.

SYNTAX

```
model.bem().create(<tag>, "CoefficientPDE");
model.bem(<tag>).set(<prop>, <value>);
model.bem(<tag>).selection();
```

`model.bem(<tag>).selection();` defines the selection for single-sided BEM boundaries. In addition, the following variants are available for double-sided boundaries:

- Use `model.bem(<tag>).selection("cont");` for a selection of double-sided boundaries where the field is continuous.
- Use `model.bem(<tag>).selection("discont");` for a selection of double-sided boundaries where the field is allowed to be discontinuous.
- Use `model.bem(<tag>).selection("edge");` for a selection of BEM edges in 3D.

For a complete list of methods available under `selection()`, see `Selections`.

The following general properties are available for `model.bem`:.

TABLE 2-7: GENERAL PROPERTIES FOR BEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
background	Expression	0	Background field.
edgefluxname	String		Name of edge flux variable.
edgegradname	String[]		Names of edge gradient variables.

TABLE 2-7: GENERAL PROPERTIES FOR BEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
edgeradius	Expression		Radius of cylinders represented as edges.
fluxname	String		Name of boundary flux variable.
infval	Expression	0	Value at infinity (for Laplace equation).
normal	String[]		Boundary normals pointing out of BEM domain.
opname	String		Name of postprocessing operator.
varname	String		Name of field variable.
varnameback	String		Name of field variable on backside of double-sided boundaries.
varnamefront	String		Name of field variable on frontside of double-sided boundaries.

In addition, the following properties for the coefficient of the equation are available:.

TABLE 2-8: EQUATION COEFFICIENT PROPERTIES FOR BEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
a	String	0	Absorption coefficient.
al	String[]	{0,0,0}	Conservative flux convection coefficient.
be	String[]	{0,0,0}	Convection coefficient.
c	String	1	Diffusion coefficient.
cedge	String	1	Diffusion coefficient in cylinders represented as edges.
m	String	0	Condition at infinity for Helmholtz equation.

The following integration order properties are available:.

TABLE 2-9: INTEGRATION ORDER PROPERTIES FOR BEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
intorderclose	String		Integration rule for close non-adjacent pairs of mesh elements.
intorderedge	String		Integration rule for pairs of mesh elements with a common edge (3D only).
intorderfar	String		Integration rule for distant pairs of mesh elements.
intordersame	String		Integration rule for pairs of mesh elements that coincide.
intordervertex	String		Integration rule for pairs of mesh elements with a common vertex.
intorderweak	String		Integration for weak equations.

The following symmetry properties are available:.

TABLE 2-10: SYMMETRY PROPERTIES FOR BEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
sym1	off | scp | user	off	Use of symmetry plane orthogonal to x-axis.
sym1plane	Expression	0	Position of symmetry plane orthogonal to x-axis.
sym2	off | scp | user	off	Use of symmetry plane orthogonal to y-axis.
sym2plane	Expression	0	Position of symmetry plane orthogonal to y-axis.
sym3	off | scp | user	off	Use of symmetry plane orthogonal to z-axis.
sym3plane	Expression	0	Position of symmetry plane orthogonal to z-axis.

Finally, the following far-field approximation properties are available:.

TABLE 2-11: FAR-FIELD APPROXIMATION PROPERTIES FOR BEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
dampingparameter	Double	1	Damping parameter.
farfieldapprox	none | ACA | ACA+	none	Far-field approximation method.
farfieldboxsplitlimit	Integer	20	Number of mesh elements at which box splitting stops.
farfieldmindist	Double	0.5	Minimum relative distance of boxes using far-field approximation.
farfieldsvd	on | off	on	Use SVD compression in far-field approximation.
farfieldtol	Double	1e-3	Tolerance used in far-field approximation.
usedamping	on | off	off	Use damping parameter with iterative solver.

EXAMPLE

The following example shows how to solve for a Helmholtz equation with outgoing waves at infinity in the exterior of a geometry. The example requires that the dependent variables u and bemflux already exist on the exterior boundaries.

Code for Use with Java

```
model.intRule().create("ir1", "material1");
model.intRule("ir1").create("o1").order(4);

model.bem().create("bem1", "CoefficientPDE");
model.bem("bem1").selection().geom("geom1", 2).set(<list of exterior boundary numbers>);
model.bem("bem1").set("varname", "u");
model.bem("bem1").set("fluxname", "bemflux");
model.bem("bem1").set("normal", new String[]{"-nx", "-ny", "-nz"});
model.bem("bem1").set("a", "-1");
model.bem("bem1").set("m", "-1");
model.bem("bem1").set("opname", "bemop");
model.bem("bem1").set("intorderfar", "ir1");
model.bem("bem1").set("intorderclose", "ir1");
model.bem("bem1").set("intordersame", "ir1");
model.bem("bem1").set("intorderedge", "ir1");
model.bem("bem1").set("intordervertex", "ir1");
model.bem("bem1").set("intorderweak", "ir1");
```

Code for Use with MATLAB

```
model.intRule().create('ir1', 'material1');
model.intRule('ir1').create('o1').order(4);

model.bem.create('bem1', 'CoefficientPDE');
model.bem('bem1').selection.geom('geom1', 2).set(<list of exterior boundary numbers>);
model.bem('bem1').set('varname', 'u');
model.bem('bem1').set('fluxname', 'bemflux');
model.bem('bem1').set('normal', {'-nx', '-ny', '-nz'});
model.bem('bem1').set('a', '-1');
model.bem('bem1').set('m', '-1');
model.bem('bem1').set('opname', 'bemop');
model.bem('bem1').set('intorderfar', 'ir1');
model.bem('bem1').set('intorderclose', 'ir1');
model.bem('bem1').set('intordersame', 'ir1');
model.bem('bem1').set('intorderedge', 'ir1');
model.bem('bem1').set('intordervertex', 'ir1');
model.bem('bem1').set('intorderweak", 'ir1');
```

SEE ALSO

`model.coeff()`

model.capeopen()

Create constants and functions interfacing to a CAPE-OPEN compliant thermodynamics package.

SYNTAX

Creating a CAPE-OPEN property package feature.

```
model.capeopen().create(<ptag>, "PropertyPackage");
```

Setting and getting properties in a CAPE-OPEN property package feature:

```
model.capeopen().feature(<ptag>).set(<prop>, <value>);
model.capeopen().feature(<ptag>).getString(<prop>);
```

TABLE 2-12: PROPERTIES SUPPORTED BY CAPE-OPEN PROPERTY PACKAGE

NAME	TYPE	DESCRIPTION
manager_id	String	CAPE-OPEN manager ID.
manager_version	String	CAPE-OPEN manager version.
package_id	String	CAPE-OPEN package ID.
package_desc	String	CAPE-OPEN package description. Only for display in GUI.

```
model.capeopen().feature(<ptag>).storePersistenceData();
```

Calling this method after a property package feature has been created, and `manager_id` and `package_id` have been set, stores information about how the CAPE-OPEN package was created in the COMSOL model. If the model is later opened on a computer with the CAPE-OPEN manager installed but without the property package, this information can be used to create the required property package.

```
model.capeopen().feature(<ptag>).create(<ftag>, <type>);
```

Creates a CAPE-OPEN constant, function, or flash calculation feature. Possible types are `CompoundConstant`, `TemperatureDependentProperty`, `PressureDependentProperty`, `OnePhaseProperty`, `TwoPhaseProperty`, and `FlashCalculationProperty`.

```
model.capeopen().feature(<ptag>).feature(<ftag>).set(<prop>, <value>);
model.capeopen().feature(<ptag>).feature(<ftag>).getString(<prop>);
model.capeopen().feature(<ptag>).feature(<ftag>).getStringArray(<prop>);
model.capeopen().feature(<ptag>).feature(<ftag>).getStringMatrix(<prop>);
```

Set and get properties in a CAPE-OPEN constant, function, or flash calculation feature.

TABLE 2-13: PROPERTIES SUPPORTED BY ALL CAPE-OPEN CONSTANT, FUNCTION, AND FLASH CALCULATION FEATURES

NAME	TYPE	DESCRIPTION
prop_basis	String	Basis (“mass” or “mole”) for evaluated properties. Only relevant for some properties.

`model.capeopen().feature(<ptag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

CAPE-OPEN Constant Features

CAPE-OPEN constant features are features with the type `"CompoundConstant"`, and are used to define constants that get their value from a thermodynamics package.

TABLE 2-14: PROPERTIES SUPPORTED BY CAPE-OPEN CONSTANT FEATURES

NAME	TYPE	DESCRIPTION
funcname	String	Name of constant; that is, a variable name that can be used in expressions.
compound	String	Identifier for compound in the CAPE-OPEN property package.
property	String	Identifier for property in the CAPE-OPEN property package.
value	String	Numerical value of constant. This value is only displayed in the GUI. When the constant is evaluated in an expression the value is obtained by calling the CAPE-OPEN property package.

CAPE-OPEN Function Features

A CAPE-OPEN function feature defines a function that can be used to evaluate properties that depend, for example, on temperature or pressure. Different types are `TemperatureDependentProperty`, `PressureDependentProperty`, `OnePhaseProperty`, and `TwoPhaseProperty`.

TABLE 2-15: PROPERTIES SUPPORTED BY CAPE-OPEN FUNCTION FEATURES

NAME	TYPE	DESCRIPTION
funcname	String	Name of function.
derivatives	String array	Names of partial derivatives of function.
compounds	String array	Identifiers for compounds in the CAPE-OPEN property package.
comp_basis	String	Basis (“mass” or “mole”) for amounts of compounds. Only relevant for functions of type “OnePhaseProperty” or “TwoPhaseProperty.”
property	String	Identifier for the property to evaluate in the CAPE-OPEN property package.
phase	String	Identifier for phase in the CAPE-OPEN property package. Only for features of type “OnePhaseProperty.”
phase1	String	Identifier for first phase in the CAPE-OPEN property package. Only for features of type “TwoPhaseProperty.”
phase2	String	Identifier for second phase in the CAPE-OPEN property package. Only for features of type “TwoPhaseProperty.”
args	String matrix	Names, units, and descriptions for the function arguments. Only for display in GUI.
unit	String	Unit of the function. Only for display in GUI.

Functions of type `TemperatureDependentProperty` and `PressureDependentProperty` have a single argument, which is the temperature or pressure, respectively.

Functions of type `OnePhaseProperty` have temperature and pressure as their first two arguments. If there is more than one compound, there are additional arguments for the fraction of each compound.

Functions of type `TwoPhaseProperty` have temperature and pressure as their first two arguments. If there is more than one compound, there are additional arguments for the fraction of each compound in each phase.

CAPE-OPEN Flash Calculation Features

CAPE-OPEN flash calculation features are used as an interface for flash calculations, which take amounts of different compounds and two conditions (for example, temperature and pressure) as input and compute the fraction of each compound that is present in each phase.

TABLE 2-16: PROPERTIES SUPPORTED BY CAPE-OPEN FLASH CALCULATION FEATURES

NAME	TYPE	DESCRIPTION
compounds	String array	Identifiers for compounds in the CAPE-OPEN property package.
cond1	String	First flash condition.
cond2	String	Second flash condition.
temperature	String	Name of function evaluating the temperature (if temperature is not one of the flash conditions).
pressure	String	Name of function evaluating the pressure (if pressure is not one of the flash conditions).
inphase	String	Base name for functions evaluating presence of each phase. Function names for each phase are formed by appending _<phase> to the base name.
amounts	String	Base name for functions evaluating amount of each phase. Function names for each phase are formed by appending _<phase> to the base name.
composition	String	Base name for functions evaluating fraction of each compound in each phase. Function names are formed by appending _<phase>_<compound> to the base name.
soltype	String	Solution type ("undefined", "normal," or "retrograde").
args	String matrix	Names, units, and descriptions for the function arguments. Only for display in GUI.
phases	String array	Names of all phases. Only for display in the GUI. The phases used in the flash calculation are determined by the CAPE-OPEN property package.

Each flash calculation feature defines a number of functions. All of the functions take the values of two flash conditions as their first two arguments, followed by arguments for the total amount of each compound.

SEE ALSO

`model.func()`

model.coeff()

Creating equations in the coefficient form. See also `model.shape()`, `model.weak()`.

SYNTAX

```
model.coeff().create(<tag>,<fields>);
model.coeff(<tag>).field(<fields>);
model.coeff(<tag>).field(<pos>,<fields>);
model.coeff(<tag>).intRule(<irlist>);
model.coeff(<tag>).intRule(<pos>,<irule>);
model.coeff(<tag>).create(<ftag>);
model.coeff(<tag>).feature(<ftag>).getAllowedPropertyValues(property);
model.coeff(<tag>).feature(<ftag>).set(ctype,<cvalue>);

model.coeff(<tag>).field();
model.coeff(<tag>).intRule();
model.coeff(<tag>).feature(<ftag>).getType(ctype);

model.coeff(<tag>).hasProperty(String pname);
model.coeff(<tag>).properties();
model.coeff(<tag>).feature(<ftag>).set(String pname, int value);
model.coeff(<tag>).feature(<ftag>).set(String pname, int pos, int value);
model.coeff(<tag>).feature(<ftag>).set(String pname, int pos, int[] value);
model.coeff(<tag>).feature(<ftag>).set(String pname, int pos1, int pos2, int value);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, String value, int index);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, String value, int firstIndex,
                  int secondIndex);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, String[] value, int index);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, double value, int index);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, double value, int firstIndex,
                  int secondIndex);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, double[] value, int index);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, int value, int index);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, String value, int index);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, String value, int index);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, int value, int firstIndex,
                  int secondIndex);
model.coeff(<tag>).feature(<ftag>).setIndex(String name, int[] value, int index);
```

The `set()` methods index/position arguments are 1-based. The `setIndex()` methods index/position arguments are 0-based.

DESCRIPTION

`model.coeff(`*<tag>*`)` returns the coefficient form equations with tag *<tag>*.

`model.coeff().create(`*<tag>*`,`*<fields>*`)` creates coefficient form equations with tag *<tag>* using the fields *<fields>*. The field tags refer to the fields defined by `model.field()`. The shape functions referred to by the fields are internally also used to find the derivatives of the field variables if converting the coefficient features to weak form. By default, all coefficients are designed to be noncontributing to the equation under consideration. For example, `model.coeff().create("foo",new String[]{"u","v"})`.

`model.coeff(`*<tag>*`).field(`*<fields>*`)` sets the coefficient form field variables. *<fields>* is a string with a field tag or a vector of field tags — for example, `new String[]{"u","v"}`. Reassigning the fields has the side effect that the size of the coefficients change if the number of field variables changes.

`model.coeff(`*<tag>*`).field(`*<pos>*`,`*<fields>*`)` edits the field at position *<pos>* in the field vector *<fields>*.

`model.coeff(`*<tag>*`).intRule(`*<irlist>*`)` assigns integration rules to the coefficient form equations. The list must have the same length as the number of field variables defined by the fields or have length 1. In the latter case all equations use the same integration rule. The number of field variables is not necessarily the same as the number of strings specified in `model.coeff(`*<tag>*`).field()`.

`model.coeff(`*<tag>*`).intRule(`*<pos>*`,`*<irule>*`)` edits the integration rule at position *<pos>* in the vector *<irule>*.

`model.coeff(<tag>).feature(<ftag>)` is a coefficient form feature with tag *<ftag>* in the coefficient form equations with tag *<tag>*.

`model.coeff(<tag>).create(<ftag>)` creates a new coefficient form feature with tag *<ftag>*.

`model.coeff(<tag>).feature(<ftag>).set(ctype,<cvalue>)` sets the value of the coefficient of type *ctype* to *<value>*. All string data types that are listed in Table 2-2 are supported; which argument types are applicable depends on the coefficient. *ctype* is one of `c`, `al`, `ga`, `be`, `a`, `f`, `da`, `ea`, `q`, and `g`. These coefficients are available at all dimensions. In addition at level `edim==sdim-1`, the coefficients `q` and `g` are allowed, corresponding to `a` and `f`, respectively. All coefficients have a default 0 contribution.

`model.coeff(<tag>).feature(<ftag>).selection().named(<seltag>)` assigns the coefficient form equations to the named selection *<seltag>*.
`model.coeff(<tag>).feature(<ftag>).selection().set(...)` defines a local selection that assigns the coefficient form equations to geometric entities. For a complete list of methods available under `selection()`, see `model.selection()`. Only selections at a single geometry level is allowed in the selection.

`model.coeff(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

`model.coeff(<tag>).field()` returns the fields as a string array.

`model.coeff(<tag>).intRule()` returns the integration rule tags as a string array.

`model.coeff(<tag>).feature(<ftag>).get`*Type*`(ctype)` returns the coefficient value. See the section `get* and Selection Access Methods` for available methods.

`model.coeff(<tag>).feature(<ftag>).selection().named()` returns the named selection tag, and `model.coeff(<tag>).feature(<ftag>).selection().get`*Type*`()` returns domain information. See `model.selection()` for available methods.

Special Properties for the Wave Form PDE

If you create a Wave Form PDE using, for example,

```
model.physics().create("wahw", "WaveFormPDE", "geom1", new String[][]{{"u"}});
```

then the following properties are available using the `setIndex` syntax:

TABLE 2-17: WAVE FORM PDE PROPERTIES

PROPERTY	VALUE	DEFAULT	INDEX	DESCRIPTION
`fluxmethod`	`fluxLF` | `fluxGeneral`	`fluxLF`	0	Flux method: Lax-Friedrichs or a general numerical flux.
`gstar`	double	1	0	General numerical flux.
`tau`	double	1	0	Lax-Friedrichs parameter.
`filteractive`	0 | 1	0	0	Activate filter parameters.
`filter`	double	36	0	Filter parameter α.
`filter`	double	0.6	1	Filter parameters η_c.
`filter`	double	3	2	Filter parameter s.

For example, to set the filter parameter s to 2.5, use

```
model.physics("wahw").feature("wafeq1").setIndex("filter", "2.5", 2);
```

EXAMPLE

Define two uncoupled Poisson-like equations on the domain `dtag`.

Code for Use with Java

```
model.coeff().create("c1",new String[]{"u","v"});
model.coeff("c1").intRule(new String[]{"gp1","gp1"});
CoeffFeature f1 = model.coeff("c1").create("f1");
f1.set("c",1,new String[]{"1","0.1","2"});
f1.set("c",2,"3");
f1.set("f",new String[]{"2","1"});
f1.selection().geom("g1",2);
f1.selection().set(1);
```

Code for Use with MATLAB

```
model.coeff.create('c1',{'u','v'});
model.coeff('c1').intRule({'gp1','gp1'});
f1 = model.coeff('c1').create('f1');
f1.set('c',1,{'1','0.1','2'});
f1.set('c',2,'3');
f1.set('f',{'2','1'});
f1.selection.geom('g1',2);
f1.selection.set(1);
```

model.common()

.The common list contains nodes that have different purposes depending on the node type. The type is assigned when the node is created. All other properties are set and accessed using generic `set` and `get` methods as described under set() and get* and Selection Access Methods. The different types may or may not use a selection. The following node types are currently defined:

TABLE 2-18: COMMON FEATURE TYPES

TYPE	PURPOSE	DESCRIPTION
Matrix	Variable utility	Define a matrix of variables. Uses a selection.
MatrixInverse	Variable utility	Compute the inverse of a matrix. Uses a selection.
MatrixDiagonalization	Variable utility	Diagonalize a symmetric 3-by-3 matrix. Uses a selection.
MatrixDecomposition	Variable utility	Use SVD to decompose a matrix. Uses a selection.
ParticipationFactors	Physics variables	Set up participation factor evaluation.
ResponseSpectrum	Physics variables	Set up response spectrum evaluation.
AmbientThermalProperties	Physics variables	Set up ambient thermal conditions using meteorological data.
GlobalReducedModelInputs	Control variables	Define global control variables for use as inputs to model reduction
DensityTopology	Control variables	Define a control variable field and a filtered density field for topology optimization.
`CommonInputDefault`	Common model inputs	Set default values of input quantities required by materials.
`CommonInputDef`	Common model inputs	Override values of input quantities on selected entities.
PrescribedDeformation	Moving mesh	Prescribe a mesh deformation on domains. Uses a selection.
RotatingDomain	Moving mesh	Prescribe rotation of a domain. Uses a selection.
DeformingDomain	Moving mesh	Specify free deformation of domains. Uses a selection.

TABLE 2-18: COMMON FEATURE TYPES

TYPE	PURPOSE	DESCRIPTION
FixedBoundary	Moving mesh	Prescribe zero displacement of a deforming domain boundary. Uses a selection.
PrescribedMeshDisplacement	Moving mesh	Prescribe displacement of a deforming domain boundary. Uses a selection.
PrescribedNormalMeshDisplacement	Moving mesh	Prescribe a normal displacement of a deforming domain boundary. Uses a selection.
PrescribedNormalMeshVelocity	Moving mesh	Prescribe the normal velocity of a deforming domain boundary. Uses a selection.
Slip	Moving mesh	Prescribe mesh slip behavior of a deforming domain boundary. Uses a selection.
Symmetry	Moving mesh	Prescribe symmetry on a deforming domain boundary. Uses a selection.

SYNTAX

```
model.component(<ctag>).common().create(<tag>,type);
model.component(<ctag>).common(<tag>).set(property, <value>);
model.component(<ctag>).common(<tag>).image()
```

DESCRIPTION

`model.component(<ctag>).common().create(<tag>,type)` creates a common feature node with the given tag and type.

`model.component(<ctag>).common(<tag>).set(property, <value>)` sets a named property in the common feature with tag `<tag>` in component `<ctag>`.

Matrix

`model.component(<ctag>).common().create(<tag>,"Matrix")` creates a matrix variable feature. For a Matrix definition, the following properties are available.

TABLE 2-19: PROPERTIES FOR MATRIX

PROPERTY	VALUE	DEFAULT	DESCRIPTION
format	full | symmetric | hermitian	full	Matrix format.
matrix	string matrix	{{"1", "0", "0"}, {"0", "1", "0"}, {"0", "0", "1"}}	The matrix elements of a square matrix.
size	Integer	3	Matrix size. Valid values: 1–9, representing 1x1 to 9x9 matrices.

MatrixInverse

`model.component(<ctag>).common().create(<tag>,"MatrixInverse")` creates a matrix inverse feature. For a MatrixInverse definition, the following properties are available.

TABLE 2-20: PROPERTIES FOR MATRIXINVERSE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
format	full | symmetric | hermitian	full	Matrix format.
matrix	string matrix	{{"1", "0", "0"}, {"0", "1", "0"}, {"0", "0", "1"}}	The matrix elements of the square matrix to invert.
size	Integer	3	Matrix size. Valid values: 1–9, representing 1x1 to 9x9 matrices.

MatrixDiagonalization

`model.component(<ctag>).common().create(<tag>,"MatrixDiagonalization")` creates a matrix diagonalization feature. For a MatrixDiagonalization definition, the following properties are available.

TABLE 2-21: PROPERTIES FOR MATRIXDIAGONALIZATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`computeExponential`	`true` | `false`	`false`	Compute matrix exponential.
`ignoreJacobianContributions`	`true` | `false`	`true`	Ignore solution dependencies.
`matrix`	string matrix	`{{"1", "0", "0"}, {"0", "1", "0"}, {"0", "0", "1"}}`	The matrix elements of the square matrix to diagonalize.

MatrixDecomposition

`model.component(<ctag>).common().create(<tag>,"MatrixDecomposition")` creates a matrix decomposition (SVD) feature. For a MatrixDecomposition definition, the following properties are available.

TABLE 2-22: PROPERTIES FOR MATRIXDECOMPOSITION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`computeLeftSingularVectors`	`true` | `false`	`true`	Compute left singular vectors.
`computeRightSingularVectors`	`true` | `false`	`true`	Compute right singular vectors.
`computeRotationMatrix`	`true` | `false`	`true`	Compute rotation matrix.
`computeStretchMatrix`	`true` | `false`	`true`	Compute stretch matrix.
`format`	`full` | `symmetric` | `hermitian`	`full`	Matrix format.
`matrix`	string matrix	`{{"1", "0", "0"}, {"0", "1", "0"}, {"0", "0", "1"}}`	The matrix elements of the square matrix to decompose.
`size`	Integer	3	Matrix size. Valid values: 1–9, representing 1x1 to 9x9 matrices.

ParticipationFactors

`model.component(<ctag>).common().create(<tag>,"ParticipationFactors")` creates a participation factors feature setting up variables for participation factor evaluation. For a ParticipationFactors definition, the following properties are available.

TABLE 2-23: PROPERTIES FOR PARTICIPATIONFACTORS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`cor`	`com` | `user`	`com`	Center of rotation definition: Center of mass or user defined.
`point`	string array	`{"0", "0", "0"}`	The point for the center of rotation, if `cor` is set to `user`.

ResponseSpectrum

`model.component(<ctag>).common().create(<tag>,"ResponseSpectrum")` creates a response spectrum feature preparing a structural model for response spectrum evaluation. For a Response Spectrum feature, the following properties are available.

TABLE 2-24: PROPERTIES FOR RESPONSESPECTRUM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`eigStudy`	string	`"none"`	Tag of a Study containing at least one Eigenfrequency study step, or "none".

AmbientThermalProperties

`model.component(<ctag>).common().create(<tag>,"AmbientThermalProperties")` creates an ambient thermal properties feature. Ambient thermal properties can be set manually, or imported from meteorological data. For an Ambient Thermal Properties feature, Table 2-25 lists the properties that are available for the default setting of the `AmbientData` property.

TABLE 2-25: PROPERTIES FOR AMBIENTTHERMALPROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`AmbientData`	`UserDef` | `MeteorologicalData` | `MeteorologicalData2017`	`UserDef`	Source of ambient data
`T_amb`	double	`293.15[K]`	Ambient temperature
`p_amb`	double	`1[atm]`	Ambient absolute pressure
`phi_amb`	double	`0`	Ambient relative humidity
`v_amb`	double	`0[m/s]`	Wind velocity
`Isn_amb`	double	`1000[W/m^2]`	Clear sky noon beam normal irradiance
`Ish_amb`	double	`0[W/m^2]`	Clear sky noon diffuse horizontal irradiance

GlobalReducedModelInputs

`model.component(<ctag>).common().create(<tag>,"GlobalReducedModelInputs")` creates a reduced model inputs feature defining control variables for use as inputs when training a reduced model. For a Global Reduced Model Inputs definition, the following properties are available.

TABLE 2-26: PROPERTIES FOR GLOBALREDUCEDMODELINPUTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`name`	string array	`{}`	Names of global scalar variables to be made available as reduced model inputs.
`expression`	string array	`{}`	Online value expressions, one for each variable in `name`.

CommonInputDefault

The Common Model Inputs feature is a default singleton feature (with tag `cminpt`) that cannot be removed. It controls the default values of model input quantities required as input values to materials and physics features. For the Common Model Inputs definition, the following properties are available.

TABLE 2-27: PROPERTIES FOR COMMONINPUTDEFAULT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`modified`	string matrix	`{{}}`	Pairs of quantity name and defining expression

CommonInputDef

`model.component(<ctag>).common().create(<tag>,"CommonInputDef")` creates a common model input definition feature overriding the value of a model input quantity on a selection. For a Model Input definition, the following properties are available.

TABLE 2-28: PROPERTIES FOR COMMONINPUTDEF

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`minpDefName`	string	`"dimensionless"`	Name of quantity to be defined
`minpScalar`	string	`""`	Scalar definition of current quantity
`minpVector`	string array	`{"1","2","3"}`	Vector definition of current quantity

Note that changing the `minpDefName` property resets the corresponding value property to a default value specific to the particular quantity.

PrescribedDeformation

`model.component(<ctag>).common().create(<tag>,"PrescribedDeformation")` creates a prescribed deformation feature for a moving mesh. For a PrescribedDeformation definition, the following property is available.

TABLE 2-29: PROPERTY FOR PRESCRIBEDDEFORMATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`prescribedDeformation`	string array	`{"0", "0", "0"}`	The prescribed deformation vector.

RotatingDomain

`model.component(<ctag>).common().create(<tag>,"RotatingDomain")` creates a rotating domain feature for a moving mesh. For a RotatingDomain definition, the following properties are available.

TABLE 2-30: PROPERTY FOR ROTATINGDOMAIN

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`angularVelocity`	string	`"0"`	The angular velocity when `rotationType` is set to `rotationalVelocity`.
`appliedMoment`	string	`"0"`	The applied moment when `rotationType` is set to `rigidBody`.
`initialAngle`	string	`"0"`	The initial angle when `rotationType` is set to `rotationalVelocity` or `rigidBody`.
`initialAngularVelocity`	string	`"0"`	The initial angular velocity when `rotationType` is set to `rigidBody`.
`momentOfInertia`	string	`"0"`	The moment of inertia when `rotationType` is set to `rigidBody`.
`revolutionsPerTime`	string	`"0"`	The revolutions per time when `rotationType` is set to `rotationalVelocity`.
`rotationAngle`	string	`"0"`	The rotational angle when `rotationType` is set to `userDefined`.
`rotationAxis`	string array	`{"0", "0", "0"}`	The rotation axis.
`rotationAxisBasePoint`	string array	`{"0", "0", "0"}`	The rotation axis base point.
`rotationType`	`userDefined` | `rotationalVelocity` | `rigidBody`		
`rotationalVelocityExpression`	`generalAngularVelocity` | `constantAngularVelocity` | `constantRevolutionsPerTime` | `generalRevolutionsPerTime`	`constantAngularVelocity`	The rotational velocity expression to use when `rotationType` is set to `rotationalVelocity`.

DeformingDomain

`model.component(<ctag>).common().create(<tag>,"DeformingDomain")` creates a deforming domain feature for a moving mesh. For a DeformingDomain definition, the following properties are available.

TABLE 2-31: PROPERTY FOR DEFORMINGDOMAIN

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`initialDeformation`	string array	`{"0", "0", "0"}`	The initial deformation of the domain.
`smoothingType`	`laplace` | `winslow` | `hyperelastic` | `yeoh`	`laplace`	The mesh smoothing type: Laplace, Winslow, hyperelastic, or Yeoh.

FixedBoundary

`model.component(<ctag>).common().create(<tag>,"FixedBoundary")` creates a fixed boundary feature for a moving mesh. This feature has a boundary selection only.

PrescribedMeshDisplacement

`model.component(<ctag>).common().create(<tag>,"PrescribedMeshDisplacement")` creates a prescribed mesh displacement feature for a moving mesh. For a PrescribedMeshDisplacement definition, the following property is available.

TABLE 2-32: PROPERTY FOR PRESCRIBEDMESHDISPLACEMENT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`prescribedMeshDisplacement`	string array	`{"0", "0", "0"}`	The prescribed mesh displacement.

PrescribedNormalMeshDisplacement

`model.component(<ctag>).common().create(<tag>,"PrescribedNormalMeshDisplacement")` creates a prescribed normal mesh displacement feature for a moving mesh. For a PrescribedNormalMeshDisplacement definition, the following property is available.

TABLE 2-33: PROPERTY FOR PRESCRIBEDNORMALMESHDISPLACEMENT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`prescribedNormalDisplacement`	string	`"0"`	The prescribed normal mesh displacement.

PrescribedNormalMeshVelocity

`model.component(<ctag>).common().create(<tag>,"PrescribedNormalMeshVelocity")` creates a prescribed normal mesh velocity feature for a moving mesh. For a PrescribedNormalMeshVelocity definition, the following property is available.

TABLE 2-34: PROPERTY FOR PRESCRIBEDNORMALMESHVELOCITY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`prescribedNormalVelocity`	string	`"0"`	The prescribed normal mesh velocity.

Slip

`model.component(<ctag>).common().create(<tag>,"Slip")` creates a mesh slip feature for a moving mesh. This feature has a boundary selection only.

Symmetry

`model.component(<ctag>).common().create(<tag>,"Symmetry")` creates a symmetry feature for a moving mesh. This feature has a boundary selection only.

DensityTopology

`model.component(<ctag>).common().create(<tag>,"DensityToplogy")` creates a density model feature for topology optimization.

The `DensityTopology` feature requires the Optimization Module

For a DensityTopology definition, the following properties are available.

TABLE 2-35: PROPERTIES FOR DENSITYTOPOLOGY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`beta`	double	8	The projection slope when `projectionType` is set to `TanhProjection`.
`discretization`	`linear` | `constant`		The discretization: linear or constant.
`filterType`	`Helmholtz` | `No_filter`	`Helmholtz`	The filter type for filtering of the density: Helmholtz filtering or no filtering.
`interpolationType`	`SIMP` | `Darcy` | `Linear_interp` | `RAMP`	`SIMP`	The interpolation type: SIMP, Darcy, linear, or RAMP.
`L_min`	positive double	`h`	Filter radius when `filterType` is set to `Helmholtz`.
`p_SIMP`	double	3	SIMP exponent, when `interpolationType` is set to `SIMP`.
`projectionType`	`No_projection` | `TanhProjection`	`No_projection`	The projection type: No projection or hyperbolic tangent projection.
`q_Darcy`	double	0.01	Darcy interpolation, when `interpolationType` is set to `Darcy`.
`q_RAMP`	double	3	RAMP parameter, when `interpolationType` is set to `RAMP`.
`theta0`	double	0.5	Initial value for the discretization.
`theta_beta`	double	0.5	The projection point when `projectionType` is set to `TanhProjection`.
`theta_min`	double	0.001	Minimum penalized volume fraction, when `interpolationType` is set to `SIMP`.

model.component()

Model component nodes.

A component node has one of three types:

- Component: Component nodes in the model builder tree have this type.
- ExtraDim: Extra dimension nodes under global definitions have this type.
- MeshComponent: Mesh parts nodes under global definitions have this type.

All three types are included, if present, in the list returned by `model.component()`.

The `model.component` syntax replaces the earlier `model.modelNode` syntax, which is still available for backward compatibility and as an alternative when you use only one component. See `model.modelNode()`.

SYNTAX

```
model.component().create(<tag>);
model.component().create(<tag>, <basetag>);
model.component().create(<tag>, <type>);
model.component().create(<tag>, true);

model.component(<tag>).getType();
model.component(<tag>).scope();
model.component(<tag>).baseSystem();
model.component(<tag>).baseSystem(<system>);
model.component(<tag>).sorder();
model.component(<tag>).sorder(<stype>);
model.component(<tag>).defineLocalCoord();
model.component(<tag>).defineLocalCoord(boolean);
```

DESCRIPTION

`model.component(<tag>)` represents a component node in the model tree.

`model.component().create(<tag>)` creates a component node with the given tag.

`model.component().create(<tag>, <basetag>)` creates an extra dimension component node with the tag *<tag>* associated to the base component node *<basetag>*.

`model.component().create(<tag>, <type>)` creates a component node with the tag *<tag>* of one of the following types, set as the string *<type>*: `Component`, for a normal geometry component; `ExtraDim`, for an extra dimension; or `MeshComponent`, for a mesh component. For example, to create a mesh component:

```
model.component().create("mcomp1", "MeshComponent");
model.component("mcomp1").geom().create("mgeom1", 3);
model.component("mcomp1").mesh().create("mpart1", "mgeom1");
```

`model.component().create(<tag>, true)` creates a model component node and also defines all four frames (the spatial, material, geometry, and mesh frame).

`model.component(<tag>).getType()` returns the type of component that the component with the tag *<tag>* is an instance of: `Component`, for a normal model component; `ExtraDim` for an extra dimension component; and `MeshComponent` for a mesh component.

`model.component(<tag>).scope()` returns the fully qualified scope name.

`model.component(<tag>).baseSystem(<system>)` use the given base system as unit system for the component node. This overrides the global unit system specified for the entire model object. To use global system again, set the base system of the component node to `null`.

`model.component(<tag>).sorder()` returns the geometry shape order used for the component node and its descendants.

`model.component(<tag>).sorder(<stype>)` Sets the geometry shape order. Allowed values are automatic, linear, quadratic, cubic, quartic, and quintic, and the default is automatic. With automatic shape order, the physics interfaces under the component node decide the most optimum shape order. The shape order set here is also used for the discretization of the mesh displacement when using ALE functionality.

`model.component(<tag>).defineLocalCoord()` returns true if local coordinate variables exist. By default, this is the case.

`model.component(<tag>)).defineLocalCoord(boolean)` sets a flag that determines whether local coordinate variables exist.

EXAMPLE

Create a component node and assign it to a geometry and an analytic function.

Code for Use with Java

```
model.component().create("comp1");
model.component("comp1").geom().create("geom1", 3);
model.component("comp1").func().create("an1", "Analytic");;
```

Code for Use with MATLAB

```
model.component.create('comp1');
model.component('comp1').geom.create('geom1', 3);
model.component('comp1').func.create('an1', 'Analytic');
```

model.constr()

Creating and modifying constraints in a model.

SYNTAX

```
model.constr().create(<tag>,<shtags>);
model.constr().create(<tag>,<nglobal>);
model.constr(<tag>).shape(<shtags>);
model.constr(<tag>).shape(<pos>,<shtags>);
model.constr(<tag>).global(<nglobal>);
model.constr(<tag>).create(<ftag>);
model.constr(<tag>).feature(<ftag>).getAllowedPropertyValues(property);
model.constr(<tag>).feature(<ftag>).set(ctype,<value>);

model.constr(<tag>).shape();
model.constr(<tag>).global();
model.constr(<tag>).feature(<ftag>).getType(ctype);

model.constr(<tag>).hasProperty(String pname);
model.constr(<tag>).properties();
model.constr(<tag>).set(String pname, int value);
model.constr(<tag>).set(String pname, int pos, int value);
model.constr(<tag>).set(String pname, int pos, int[] value);
model.constr(<tag>).set(String pname, int pos1, int pos2, int value);
model.constr(<tag>).setIndex(String name, String value, int index);
model.constr(<tag>).setIndex(String name, String value, int firstIndex, int secondIndex);
model.constr(<tag>).setIndex(String name, String[] value, int index);
model.constr(<tag>).setIndex(String name, double value, int index);
model.constr(<tag>).setIndex(String name, double value, int firstIndex, int secondIndex);
model.constr(<tag>).setIndex(String name, double[] value, int index);
model.constr(<tag>).setIndex(String name, int value, int index);
model.constr(<tag>).setIndex(String name, String value, int index);
model.constr(<tag>).setIndex(String name, String value, int index);
model.constr(<tag>).setIndex(String name, int value, int firstIndex, int secondIndex);
model.constr(<tag>).setIndex(String name, int[] value, int index);
```

The `set()` methods index/position arguments are 1-based. The `setIndex()` methods index/position arguments are 0-based.

DESCRIPTION

`model.constr(<tag>)` returns the constraint with tag `<tag>`.

`model.constr().create(<tag>,<shtags>)` creates a constraint with tag *<tag>* using the shape functions *<shtags>*.

`model.constr().create(<tag>,<nglobal>)` creates a global constraint with tag *<tag>* expecting *<nglobal>* components.

`model.constr(<tag>).shape(<shtags>)` points to the shape functions associated with the constraint. Reassigning the shape functions can have the side effect of modifying the constraints since the number of constraints can change as the size of each constraint vector can change.

`model.constr(<tag>).global(<nglobal>)` specifies that the constraint is global and sets the expected number of components.

`model.constr(<tag>).feature(<ftag>)` is a feature in the constraint with tag *<tag>*.

`model.constr(<tag>).create(<ftag>)` creates a constraint feature.

`model.constr(<tag>).feature(<ftag>).set(ctype,<value>)` sets the parameter *ctype* to *<value>*, where *ctype* is either `constr` or `constrf`, and *<value>* is a single constraint expression or a list of constraint expressions. The number of elements in the constraint expression depends on the number of global constraint components or shape functions specified, and on the shape function type. A Lagrange shape function or global constraint component requires a single item, whereas a vector shape function requires one item for each space dimension. The supported `set` methods are the ones for double string arrays defined in Table 2-2.

`model.constr(<tag>).feature(<ftag>).selection().named(<seltag>)` assigns the constraint to the named selection *<seltag>*.
`model.constr(<tag>).feature(<ftag>).selection().set(...)` defines a local selection that assigns the constraint to geometric entities. For a complete list of methods available under `selection()`, see `model.selection()`. Only selections at a single geometry level is allowed in the selection.

`model.constr(<tag>).shape()` returns the shape function tags as a string array.

`model.constr(<tag>).global()` returns the number of components if the constraint is global, otherwise –1.

`model.constr(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

`model.constr(<tag>).feature(<ftag>).getType(ctype)` returns the constraint or constraint force value. For available methods, see `get* and Selection Access Methods`.

`model.constr(<tag>).feature(<ftag>).selection().named()` returns the named selection tag, and `model.constr(<tag>).feature(<ftag>).selection().getType()` returns domain information. For available methods, see `Selections`.

`model.constr(<tag>).feature(<ftag>).selection(<estype>).set(...)` defines a subselection of a given lower-dimensional excluded selection type that should be excluded from the constraint selection. Excluded selection type can be `exclude0` for points, `exclude1` for edges, and `exclude2` for excluded face subselections. The constraint is not enforced on the specified excluded subselections. Excluded subselections have to have lower dimension than the constraint selection. For a complete list of methods available under `selection(<estype>)`, see model.selection().

EXAMPLES

Code for Use with Java

Set several constraint by using multiple constraints:

```
model.constr().create("c1",new String[]{"shu","shv"});
```

```
ConstrFeature f = model.constr("c1").create("f1");
f.set("constr",new String[]{"u-1","v"});
f.selection().geom("geom1",1);
f.selection().all();
```

Vector elements need a set of constraints:

```
model.constr().create("c2",new String[]{"shE"});
ConstrFeature f = model.constr("c2").create("f1");
f.set("constr",new String[]{"Ex-1","Ey-0","Ez-0"});
f.selection().geom("geom1",1);
f.selection().all();
```

Code for Use with MATLAB

```
model.constr.create('c1',{'shu','shv'});
f = model.constr('c1').create('f1');
f.set('constr',{'u-1','v'});
f.selection.geom('geom1',1);
f.selection.all;
```

Vector elements need a set of constraints:

```
model.constr.create('c2',{'shE'});
f = model.constr('c2').create('f1');
f.set('constr',{'Ex-1','Ey-0','Ez-0'});
f.selection.geom('geom1',1);
f.selection.all;
```

SEE ALSO

`model.shape()`

model.coordSystem()

Add coordinate systems, perfectly matched layers, infinite elements, and absorbing layers. Perfectly matched layers, infinite elements, and absorbing layers are all available with a set of add-on products only.

The syntax that includes the component level, such as `model.component(<ctag>).coordSys()...` is the default and is used throughout this chapter. To use the earlier `model.coordSys()...` syntax, clear the **Use component syntax** check box on the **Methods** page in the **Preferences** dialog box.

SYNTAX

```
model.component(<ctag>).coordSystem().create(<tag>,<gtag>,type);
model.component(<ctag>).coordSystem(<tag>).set(property, <value>);
model.component(<ctag>).component(<ctag>).coordSystem(<tag>).
      setIndex(property, <value>, row);
model.component(<ctag>).coordSystem(<tag>).setIndex(property, <value>, row, col);
model.component(<ctag>).coordSystem(<tag>).selection();

model.component(<ctag>).coordSystem(<tag>).coord()
model.component(<ctag>).coordSystem(<tag>).isOrthonormal()
model.component(<ctag>).coordSystem(<tag>).isLinear()
model.component(<ctag>).coordSystem(<tag>).image()
```

DESCRIPTION

`model.component(<ctag>).coordSystem().create(<tag>,<gtag>,type)` creates a coordinate system with tag *<tag>* on geometry *<gtag>* of type *type*. There are the following types of coordinate systems: mapped system (`Mapping`), base-vector system (`VectorBase`), rotated system (`Rotated`), boundary system (`Boundary`), scaling system (`Scaling`), cylindrical system (`Cylindrical`), and system from geometry (`SystemFromGeometry`). The

boundary system only applies to boundaries. In addition, the perfectly matched layers (PMLs), infinite elements, and absorbing layers are also implemented as types of coordinate systems: `PML`, `InfiniteElement`, and `AbsorbingLayer`, respectively.

`model.component(`*`<ctag>`*`).coordSystem(`*`<tag>`*`).selection().named(`*`<seltag>`*`)` assigns the coordinate system to the named selection *`<seltag>`*.
`model.component(`*`<ctag>`*`).coordSystem(`*`<tag>`*`).selection().set(...)` defines a local selection that assigns the coordinate system to geometric entities. For a complete list of methods available under `selection()`, see `Selections`. The selection method is only available for coordinate systems of the following types: `Scaling`, `PML`, `InfiniteElement`, and `AbsorbingLayer`.

`model.component(`*`<ctag>`*`).coordSystem(`*`<tag>`*`).set("orthonormal","on")` specifies that this is a orthonormal system. This affects the internal calculation of systems, so some simplifications on expressions can be made. It is recommended to use this option when possible. Boundary systems, rotated systems, and cylindrical system are always orthonormal..

TABLE 2-36: COMMON PROPERTIES FOR COORDINATE SYSTEMS

PROPERTY	VALUE	DESCRIPTION
`name`	string	Coordinate system name.

Mapping

`model.component(`*`<ctag>`*`).coordSystem().create(`*`<tag1>`*`,`*`<gtag>`*`,"Mapping")` creates a mapped system. In a mapped system you specify the coordinate mapping given in some of the available frame coordinates (usually `x`, `y`, `z`).

TABLE 2-37: PROPERTIES FOR MAPPING SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`coord`	string matrix	`[(x1,x2,x3)]`	Coordinate names.
`map`	string array	`(x,y,z)`	The map.
`orthonormal`	Boolean	`false`	If the system is orthonormal.
`frametype`	string (mesh | material | spatial | geometry)	`spatial`	The frame type.

`model.component(`*`<ctag>`*`).coordSystem(`*`<tag1>`*`).setIndex("map", "x+1", 0)` sets the mapping of the first coordinate system coordinate to be a function of the first frame coordinate, `x`.

`model.component(`*`<ctag>`*`).coordSystem(`*`<tag1>`*`).setIndex("map", "y+1", 2)` sets the mapping of the third coordinate system coordinate to be a function of the second frame coordinate `y`.

VectorBase

`model.component(`*`<ctag>`*`).coordSystem().create(`*`<tag2>`*`,"VectorBase")` creates a base-vector system. In a base-vector system you specify the base vectors given as components of a frame system. If the components are independent of frame coordinates this is a linear system and can be applied for any frame.

TABLE 2-38: PROPERTIES FOR BASE VECTOR SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`coord`	string matrix	`[(x1,x2,x3)]`	Coordinate names.
`base`	string matrix	`[(1,0,0)(0,1,0)(0,0,1)]`	Base vectors.
`makeorthonormal`	Boolean	`false`	Make the system orthonormal.
`orthonormal`	Boolean	`false`	If the system is orthonormal or not.
`outofplane`	string	“2” in 2D, “1,2” in 1D	Out-of-plane index.

TABLE 2-38: PROPERTIES FOR BASE VECTOR SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

`model.component(<ctag>).coordSystem(<tag2>).setIndex("base", "1", 0, 1)` sets the first base vector's second component to one. As an alternative, it is possible to specify the full base-vector matrix using the following syntax:

`model.component(<ctag>).coordSystem(<tag2>).set("base", new String[][]{{"0","1","0"},{"0","0","1"},{"1","0","0"}})` sets the base vector matrix so the first base vector is equal to the *y*-axis of the frame system, the second is the *z*-axis, and so on. In 2D, you only use a two rows and two columns from the full base vector matrix for the in-plane base vectors. As an option, it is therefore possible to specify which of the coordinate system base vectors that corresponds to the out-of-plane axis in the frame system. Internally, this base vector always gets the components `{"0","0","1"}`. The third column is also set using these components. To make a general 3D system in 2D, you must use the mapped system.

`model.component(<ctag>).coordSystem(<tag2>).set("outofplane", "2")` sets the third base vector to represent the out-of-plane vector (z-axis in 2D). The value is zero based. In 1D the out-of-plane index is set using the syntax "1,2" to set second and third base vectors to represent the out-of-plane vector.

Rotated

`model.component(<ctag>).coordSystem().create(<tag3>,"Rotated")` creates a rotated system. In 3D you specify the *Z-X-Z* Euler angles, which corresponds to sequential rotation first about the *z*-axis, then the *x*-axis, and finally the *z*-axis again. In 2D you can only rotate about the out-of-plane axis.

TABLE 2-39: PROPERTIES FOR ROTATED SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
coord	string matrix	[(x1,x2,x3)]	Coordinate names
angle	string array	(0,0,0)	Rotation angles
outofplane	string	"2" in 2D, "1,2" in 1D	Out of plane index
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

`model.component(<ctag>).coordSystem(<tag3>).setIndex("angle","12[deg]",0)` sets the first rotation about the *z*-axis to 12 degrees. In 3D, there are three angles, so the third argument determines which angle that you specify, using 0-based indexing (that is, 0 means the first angle). The default unit for angles are radians.

Boundary

`model.component(<ctag>).coordSystem().create(<tag4>,<gtag>,"Boundary")` creates a new boundary system, which is a local base vector system on 2D boundaries ($\mathbf{t}$, $\mathbf{n}$) and on 3D boundaries ($\mathbf{t}_1$, $\mathbf{t}_2$, $\mathbf{n}$). There is always one boundary system added by default for each geometry.

TABLE 2-40: PROPERTIES FOR BOUNDARY SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`coord`	string matrix	`[(x1,x2,x3)]`	Coordinate names,
`frametype`	string (`mesh` | `material` | `spatial` | `geometry`)	`spatial`	Frame type,
`reversenormal`	Boolean	`false`	Reverse normal direction.
`tangent`	string array		Tangent direction.
`mastersystem`	string (`manual` | `globalCartesian` | *<tag>*)	`globalCartesian`	Which system to create first tangential direction from.
`mastercoordsyscomp`	string	"2" in axisymmetry, "3" otherwise	Which axis to create first tangential direction from.

`model.component(<ctag>).coordSystem(<tag4>).set("reversenormal","on")` flips the normal direction for this system, so that it is opposite to the normal direction given by the geometry.

`model.component(<ctag>).coordSystem(<tag4>).set("mastersystcomp","2")` sets the first tangential direction from the second axis of the specified master system.

`model.component(<ctag>).coordSystem(<tag4>).set("mastersystem","manual")` specifies that no master system is used and that the tangential direction must be entered by the user.

`model.component(<ctag>).coordSystem(<tag4>).setIndex("tangent","1")` sets the first component of the first tangential direction.

In addition, you can add `ReverseNormal` and `DomainNormal` subfeatures to reverse the normal for some boundaries and switch the normal direction on the exterior of some domains, respectively.

`model.component(<ctag>).coordSystem(<tag4>).create(<rntag>, "ReverseNormal")` creates a `ReverseNormal` subfeature. To it, you then assign a boundary selection. For boundary 3, for example, use `model.component(<ctag>).coordSystem(<tag4>).feature(<rntag>).selection().set(3);`

`model.component(<ctag>).coordSystem(<tag4>).create(<dntag>, DomainNormal")` creates a `DomainNormal` subfeature. To it, you then assign a domain selection. For domain 2, for example, use `model.component(<ctag>).coordSystem(<tag4>).feature(<dntag>).selection().set(3);`. There is one property for the `DomainNormal` subfeature: normalDirection, which can be a string `outward` (the default) or `inward`.

Cylindrical

`model.component(<ctag>).coordSystem().create(<tag5>,<gtag>,"Cylindrical")` creates a cylindrical coordinate system, which you can use in 2D and 3D where rotational symmetry about the axis is required. You can specify the origin, axis direction and radial base vector.

TABLE 2-41: PROPERTIES FOR CYLINDRICAL SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`coord`	string matrix	`[(r, phi, a)]`	Coordinate names.
`origin`	string array	`(0,0,0)`	Origin of system.
`axis`	string array	`(0,0,1)`	Axis direction.

TABLE 2-41: PROPERTIES FOR CYLINDRICAL SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
radialbasevector	string array	(1,0,0)	Radial base vector direction a j = 0.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

`model.component(<ctag>).coordSystem(<tag5>).set("origin", new String[]{"1","0","0"})` sets the origin to (1,0,0).

Spherical

`model.component(<ctag>).coordSystem().create(<tag6>,<gtag>,"Spherical")` creates a spherical coordinate system, which you can use in 3D to define a field or property using spherical coordinates. You can specify the origin, zenith axis ($\theta = 0$), and azimuth axis ($\theta = \pi/2$, $\varphi = 0$).

TABLE 2-42: PROPERTIES FOR SPHERICAL SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
coord	string matrix	[(r, phi, a)]	Coordinate names
origin	string array	(0,0,0)	Origin of system
axis	string array	(0, 0, 1)	Zenith axis direction
radialbasevector	string array	(1, 0, 0)	Azimuth axis direction
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

`model.component(<ctag>).coordSystem(<tag6>).set("origin", new String[]{"1","0","0"})` sets the origin to (1,0,0).

FromGeometry

`model.component(<ctag>).coordSystem().create(<tag7>,<gtag>,"FromGeometry")` creates a coordinate system taken from a work plane in a 3D geometry or defined in a 3D geometry part that is included in the geometry as a part instance. You can specify which work plane to use:.

TABLE 2-43: PROPERTIES FOR SYSTEM FROM GEOMETRY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
coord	string matrix	[(r, phi, a)]	Coordinate names.
frametype	string (mesh | material | spatial | geometry)	material	The frame type.
workplane	String	xyplane	Name of work plane to use. The default value represents a global Cartesian coordinate system.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

Scaling

`model.component(<ctag>).coordSystem().create(<tag8>,<gtag>,"Scaling")` creates a scaling coordinate system that maps the geometry, as represented by the independent coordinates of an underlying frame, onto a virtual geometry represented by virtual scaling system coordinates. Physics interfaces that support infinite elements or perfectly matched layers accept the scaling system coordinates as being the physical domain, in which the underlying frame coordinates are seen as a parameterization. Therefore, using a scaling coordinate system you can arbitrarily deform the domain.

TABLE 2-44: PROPERTY FOR SCALING SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`map`	string array	`(x,y,z)`	Coordinate mapping.

`model.component(<ctag>).coordSystem(<tag8>).setIndex("map", "y+1", 1)` sets the second coordinate mapping to $y+1$.

Combined

`model.component(<ctag>).coordSystem().create(<tag9>,<gtag>,"Combined")` creates a combined coordinate system that makes it possible to use different coordinate systems in different domains, for example. To add a coordinate system to the combined system and define it on domain 2, use

```
model.component(<ctag>").coordSystem(<tag9>).create(<tag91>, "VectorBase");
model.component("comp3").coordSystem(<tag9>).feature(<tag91>).selection().
      set(new int[]{2});
```

You can specify the frame and the coordinate names for the combined system:

TABLE 2-45: PROPERTIES FOR A COMBINED SYSTEM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`coord`	string matrix	`[(r, phi, a)]`	Coordinate names.
`frametype`	string (`mesh` | `material` | `spatial` | `geometry`)	`material`	The frame type.

PML

`model.component(<ctag>).coordSystem().create(<tag10>,<gtag>,"PML")` creates a PML (perfectly matched layer), which acts as an artificial absorbing layer in a domain for a wave simulation. You can specify the type and scaling of the PML using the following properties:

TABLE 2-46: PROPERTIES FOR PML

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`imagFunction`	`none`, or any defined function.	`none`	Imaginary part of stretching function when `stretchingType` is set to `userDefined`.
`PMLfactor`	double	1	PML scaling factor.
`PMLgamma`	double	1	PML scaling curvature factor.
`r0`	double array	`0; 0` (2D) `0; 0; 0` (3D)	Center coordinates for cylindrical PMLs.
`raxis`	double array	`0; 0; 0`	Center axis direction for cylindrical PMLs in 3D,
`realFunction`	`none`, or any defined function.	`none`	Real part of stretching function when `stretchingType` is set to `userDefined`.
`ScalingType`	`Cartesian` | `Cylindrical` | `Spherical`	`Cartesian`	The PML scaling type. Spherical is only available in 3D.

TABLE 2-46: PROPERTIES FOR PML

PROPERTY	VALUE	DEFAULT	DESCRIPTION
stretchingType	polynomial | rational | userDefined	polynomial	The coordinate stretching type for the PML scaling.
typicalWavelength	double	1	Typical wavelength for the waves.
wavelengthSourceType	fromPhysics | userDefined	fromPhysics	Take the wavelength from the physics or a user-defined wavelength.

InfiniteElement

`model.component(<ctag>).coordSystem().create(<tag11>,<gtag>,"InfiniteElement")` creates an infinite element, which acts as an unbounded domain for a simulation. You can specify the type and scaling of the infinite element using the following properties:

TABLE 2-47: PROPERTIES FOR INFINITE ELEMENT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
r0	double array	0; 0 (2D) 0; 0; 0 (3D)	Center coordinates for cylindrical infinite elements.
raxis	double array	0; 0; 0	Center axis direction for cylindrical infinite elements in 3D,
pole	double	dGeomChar	Pole distance
ScalingType	Cartesian | Cylindrical | Spherical | userDefined	Cartesian	The scaling type for the infinite element. Spherical is only available in 3D.
width	double	1e3*dGeomChar	Physical width.
directions	integer	1	Number of stretching directions (for userDefined scaling).
d	string array	x; y, z	Distance function for stretching directions (1–3).
dmax	double array	1; 1, 1	Thickness function for stretching directions (1–3).

AbsorbingLayer

`model.component(<ctag>).coordSystem().create(<tag12>,<gtag>,"AbsorbingLayer")` creates an absorbing layer, which acts as an effective nonreflecting-like boundary condition in transient simulations using a time-explicit solver. You can specify the type and scaling of the absorbing layer using the following properties:

TABLE 2-48: PROPERTIES FOR ABSORBING LAYER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
r0	double array	0; 0 (2D) 0; 0; 0 (3D)	Center coordinates for cylindrical absorbing layers.
raxis	double array	0; 0; 0	Center axis direction for cylindrical absorbing layers in 3D,
pole	double	dGeomChar	Pole distance
ScalingType	Cartesian | Cylindrical | Spherical | userDefined	Cartesian	The scaling type for the absorbing layer. Spherical is only available in 3D.
width	double	1e3*dGeomChar	Physical width.
directions	integer	1	Number of stretching directions (for userDefined scaling).

TABLE 2-48: PROPERTIES FOR ABSORBING LAYER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
d	string array	x; y, z	Distance function for stretching directions (1–3).
dmax	double array	1; 1, 1	Thickness function for stretching directions (1–3).

EXAMPLE

Create a cylindrical coordinate system with a radial base vector direction that is (0, 1, 0); that is, a coordinate that points in the global *y*-direction:

Code for Use with Java

```
model.component("comp1").coordSystem().create("sys2", "geom1", "Cylindrical");
model.component("comp1").coordSystem("sys2").setIndex("radialbasevector", "1", 1);
model.component("comp1").coordSystem("sys2").setIndex("radialbasevector", "0", 0);
```

Code for Use with MATLAB

```
model.component('comp1').coordSystem.create('sys2', 'geom1', 'Cylindrical');
model.component('comp1').coordSystem('sys2').setIndex('radialbasevector', '1', 1);
model.component('comp1').coordSystem('sys2').setIndex('radialbasevector', '0', 0);
```

model.cpl()

Add component couplings.

SYNTAX

```
model.component(<ctag>).cpl().create(<tag>,type,<gtag>);
model.component(<ctag>).cpl(<tag>).set(property,<value>);
model.component(<ctag>).cpl(<tag>).set("opname",<opname>)
model.component(<ctag>).cpl(<tag>).selection(property).named(<seltag>);
model.component(<ctag>).cpl(<tag>).selection(property).set(...);
model.component(<ctag>).cpl(<tag>).create(<subtag>,subtype);
model.component(<ctag>).cpl(<tag>).feature(<subtag>).getAllowedPropertyValues(property);
model.component(<ctag>).cpl(<tag>).feature(<subtag>).set(property,<value>);

model.component(<ctag>).cpl(<tag>).getType(property,<value>);
model.component(<ctag>).cpl(<tag>).feature(<subtag>).properties();
model.component(<ctag>).cpl(<tag>).feature(<subtag>).getType(property,<value>);
model.component(<ctag>).cpl(<tag>).hasProperty(String pname);
model.component(<ctag>).cpl(<tag>).image();

model.component(<ctag>).cpl(<tag>).set(String pname, int value);
model.component(<ctag>).cpl(<tag>).set(String pname, int pos, int value);
model.component(<ctag>).cpl(<tag>).set(String pname, int pos, int[] value);
model.component(<ctag>).cpl(<tag>).set(String pname, int pos1, int pos2, int value);
model.component(<ctag>).cpl(<tag>).setIndex(String name, String value, int index);
model.component(<ctag>).cpl(<tag>).setIndex(String name, String value, int firstIndex,
      int secondIndex);
model.component(<ctag>).cpl(<tag>).setIndex(String name, String[] value, int index);
model.component(<ctag>).cpl(<tag>).setIndex(String name, double value, int index);
model.component(<ctag>).cpl(<tag>).setIndex(String name, double value, int firstIndex,
      int secondIndex);
model.component(<ctag>).cpl(<tag>).setIndex(String name, double[] value, int index);
model.component(<ctag>).cpl(<tag>).setIndex(String name, int value, int index);
model.component(<ctag>).cpl(<tag>).setIndex(String name, String value, int index);
model.component(<ctag>).cpl(<tag>).setIndex(String name, String value, int index);
model.component(<ctag>).cpl(<tag>).setIndex(String name, int value, int firstIndex,
      int secondIndex);
model.component(<ctag>).cpl(<tag>).setIndex(String name, int[] value, int index);
```

The `set()` methods index/position arguments are 1-based. The `setIndex()` methods index/position arguments are 0-based.

DESCRIPTION

`model.component(<ctag>).cpl().create(<tag>,type,<gtag>)` creates a component coupling of type *type* on the geometry *<gtag>*. The supported types are `GeneralExtrusion`, `LinearExtrusion`, `BoundarySimilarity`, `IdentityMapping`, `GeneralProjection`, `LinearProjection`, `Integration`, `Average`, `Maximum`, and `Minimum`. The component coupling operators provide coupling of values, typically from a source to a destination between or within model components.

`model.component(<ctag>).cpl(<tag>).selection().named(<seltag>)` assigns the component coupling's source to the named selection *<seltag>*. `model.cpl(<tag>).selection().set(...)` defines a local selection that assigns the component coupling's source to geometric entities. For a complete list of methods available under `selection()`, see `Selections`.

`model.component(<ctag>).cpl(<tag>).set(property,<value>)` specifies properties relevant for the selected component coupling type, see below.

`model.component(<ctag>).cpl(<tag>).set("opname",<opname>)` sets the operator name of the component coupling. The default component coupling operator name is *<tag>*.

`model.component(<ctag>).cpl(<tag>).selection(property).named(<seltag>)` assigns the component coupling's selection property to the named selection *<seltag>*.
`model.component(<ctag>).cpl(<tag>).selection(property).set(...)` defines a local selection that assigns the component coupling's selection property to geometric entities. For a complete list of methods available under `selection()`, see `model.selection()`.

`model.component(<ctag>).cpl(<tag>).create(<subtag>,subtype)` creates a subfeature of type *subtype*. This can only be done when the component coupling *type* is `BoundarySimilarity`. The supported values of subtype are `OnePointMap`, `TwoPointMap`, and `EdgeMap`.

`model.component(<ctag>).cpl(<tag>).selection().named()` returns the named source selection of the coupling.

`model.component(<ctag>).cpl(<tag>).selection().getType(...)` queries the source selection.

`model.component(<ctag>).cpl(<tag>).properties()` returns the list of assigned properties as a string array.

`model.component(<ctag>).cpl(<tag>).getType(property)` returns the value of a specified property.

`model.component(<ctag>).cpl(<tag>).selection(property).named()` returns the named selection tag of the selection property.

`model.component(<ctag>).cpl(<tag>).selection(property).getType(...)` queries a selection property.

`model.component(<ctag>).cpl(<tag>).feature(<subtag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

Use `model.component(<ctag>).cpl(<tag>).image()` method to create a plot or export images. See Plotting and Exporting Images.

Notation: `srcedim` = dimension of source selection; `srcsdim` = space dimension of source geometry.

EXTRUSION COUPLINGS

An extrusion coupling operator `oper` maps an expression `e` defined on (a part of) the source selection to an expression `oper(e)` that can be evaluated on (a part of) the destination geometries. For each point p_s in the source

selection, there can be zero, one or several corresponding points p_d in the destination. The inverse mapping $p_s = m(p_d)$ is always one-to-one. The value of `oper(e)` at the point p_d is defined as the value of `e` at the point p_s.

The inverse mapping m is specified as the composition of a *destination map* m_d and the inverse of a *source map* m_s: $p_s = m(p_d) = m_s^{-1}(m_d(p_d))$. In other words, $m_s(p_s) = m_d(p_d)$ — both the destination map and the source map into the same *intermediate space*. For all operator types except `GeneralExtrusion`, the intermediate space coincides with the source geometry. The source map is always one-to-one. By default, the source map is the identity.

The operator type determines the type of destination map:

TABLE 2-49: EXTRUSION COUPLING TYPES

COUPLING TYPE	DESTINATION MAP
`GeneralExtrusion`	Nonlinear map described by expressions.
`LinearExtrusion`	Linear map described by vertex mapping.
`BoundarySimilarity`	Similarity transformation described by mapping of boundaries. Also used by copy mesh.
`IdentityMapping`	Identity map.

For most of these coupling types, a source map described by (possibly nonlinear) expressions can be used.

TABLE 2-50: EXTRUSION COUPLING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`exttol`	double	`0.3`	Extrapolation tolerance in mesh search.
`method`	`usetol` | `closest`	`usetol`	Mesh search method.
`usenan`	`on` | `off`	`off`	Use NaN instead of error message when source point is outside selection.

If `method=usetol`, `oper(e)` is defined when the source point p_s is within the source selection, or if it is slightly outside. The tolerance is given in the property `exttol`, which is a distance in mesh element local coordinates; that is, it is a measure relative to the mesh element size. If `oper(e)` is not defined, an error message is given (if `usenan=off`), or the value `NaN` is returned (if `usenan=on`).

If `method=closest`, a brute force search method is used, which makes `oper(e)` defined everywhere (the nearest point to p_s in the source selection is used).

Depending on the coupling type, additional properties are available (see below).

GeneralExtrusion

A *general extrusion* coupling operator maps an expression defined on a source to an expression that can be evaluated on any destination geometry where the destination map expressions are valid.

TABLE 2-51: GENERAL EXTRUSION MAP PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`dstmap`	string array	spatial coordinates	Expressions for destination map $m_d(p_d)$.
`srcframe`	`mesh` | `material` | `spatial`	`spatial`	Frame for source mesh.
`usesrcmap`	`on` | `off`	`off`	Use source map.
`srcmap`	string array	spatial coordinates	Expressions for source map $m_s(p_s)$.

Trailing empty expressions in the properties `dstmap` and `srcmap` are ignored. The remaining expressions must be equal in number, and this determines the dimension `idim` of the intermediate space. Requirement: `srcedim <= idim <= srcsdim`. Changing the source selection has the side effect of changing `dstmap` and `srcmap` so that this requirement is satisfied. By default, `idim=srcsdim`.

The source mesh is viewed in the frame `srcframe`. The source mapping is taken to be linear within each source mesh element.

If `usesrcmap=off`, the `srcmap` property is not used. In this case, `dstmap` is a mapping from the destination to the source (viewed in the frame `srcframe`), and `idim=srcsdim`.

LinearExtrusion

A *linear extrusion* coupling operator linearly maps an expression defined on a source to an expression that can be evaluated in the destination.

TABLE 2-52: LINEAR EXTRUSION MAP PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`srcvertexN`	Selection		Source vertex number N
`dstgeom`	string	source geometry	Destination geometry
`dstvertexN`	Selection		Destination vertex number N
`srcframe`	`mesh` | `material` | `spatial`	spatial	Frame for evaluation of source vertex coordinates
`dstframe`	`mesh` | `material` | `spatial`	spatial	Frame for evaluation of destination vertex coordinates
`usesrcmap`	`on` | `off`	`off`	Use source map
`srcmap`	string[srcsdim]	spatial coordinates	Expressions for source map $m_s(p_s)$

The number of selections `srcvertexN` and `dstvertexN` is `4`. These are used only for `1<=N<=dim+1`, where `dim` is a number less than or equal to `min(srcsdim,dstsdim)`. The remaining `4-dim` selections should be empty.

The destination map is the following linear (affine) map from the destination geometry to the source geometry:

1. First, if `dim<dstsdim`, an orthogonal projection onto the affine space spanned by the destination vertices. The number of destination vertices is `dim+1`. Thus, `dim=2` gives a plane, and `dim=1` gives a line.
2. Then, a linear (affine) map mapping the destination vertices onto the source vertices.

BoundarySimilarity (3D)

A *boundary similarity* coupling operator maps an expression defined on a part of a boundary to another part of a boundary with the same shape.

TABLE 2-53: BOUNDARY SIMILARITY PROPERTIES IN 3D

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`destination`	Selection		Destination face.
`usesrcmap`	`on` | `off`	`off`	Use source map.
`srcmap`	string[srcsdim]	spatial coordinates	Expressions for source map $m_s(p_s)$.

The destination transformation is a similarity transformation that maps a destination face (`destination`) onto a set of source faces (the source selection). The mesh is always viewed in the mesh frame.

By default, the algorithm automatically chooses a transformation when symmetries make several transformations possible. To control this choice, one of the following subfeatures can be added in 3D.

TABLE 2-54: SUBFEATURE TYPES

SUB FEATURE	REMARKS
`EdgeMap`	Specify how one source edge is mapped.
`OnePointMap`	Specify how one source vertex is mapped.
`TwoPointMap`	Specify how two source vertices are mapped.

EdgeMap

An *edge map* specifies that a certain destination edge should be mapped onto a certain source edge. Their relative direction is given by the property `direction`. The edges must be adjacent to the given faces.

TABLE 2-55: PROPERTIES FOR EDGEMAP SUBFEATURE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`srcedge`	Selection		Source edge
`dstedge`	Selection		Destination edge
`direction`	`auto` | `same` | `opposite`	`auto`	Edge direction

OnePointMap

A *one-point map* specifies that a certain destination vertex should be mapped onto a certain source vertex.

TABLE 2-56: PROPERTIES FOR ONEPOINTMAP SUBFEATURE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`srcpoint1`	Selection		Vertex on source face
`dstpoint1`	Selection		Vertex on destination face

TwoPointMap

A *two-point map* specifies that two destination vertices should be mapped onto two source vertices.

TABLE 2-57: PROPERTIES FOR ONEPOINTMAP SUBFEATURE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`srcpoint1`	Selection		Vertex 1 on source face
`srcpoint2`	Selection		Vertex 2 on source face
`dstpoint1`	Selection		Vertex 1 on destination face
`dstpoint2`	Selection		Vertex 2 on destination face

BoundarySimilarity (2D)

TABLE 2-58: BOUNDARY SIMILARITY PROPERTIES IN 2D

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`destination`	Selection		Destination edge
`direction`	`auto` | `same` | `opposite`	`auto`	Edge direction
`usesrcmap`	`on` | `off`	`off`	Use source map
`srcmap`	string[srcsdim]	spatial coordinates	Expressions for source map $m_s(p_s)$

The destination transformation is a similarity transformation that maps a destination edge (`destination`) onto a set of source edges (the source selection). Their relative direction is given by the property `direction`. The mesh is always viewed in the mesh frame.

IdentityMapping

An *identity mapping* coupling operator maps between geometric entities that overlap, possibly when viewed in different frames. The destination transformation is an identity mapping between the given frames.

TABLE 2-59: IDENTITY MAPPING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`dstframe`	`mesh` | `material` | `spatial`	`spatial`	Frame for evaluation of destination coordinates
`srcframe`	`mesh` | `material` | `spatial`	`spatial`	Frame for evaluation of source coordinates

PROJECTION COUPLINGS

A projection coupling operator `oper` maps an expression `e` defined on (a part of) the source selection to an expression `oper(e)` that can be evaluated on (a part of) the destination geometries. It does so by performing

integration along curves in the source selection. These curves correspond to lines in an *intermediate space*, whose dimension is equal to `srcedim`. There is a *source map* m_s mapping the source selection into the intermediate space, and a *destination map* m_d mapping the destination geometries into the subspace of intermediate space where the last coordinate is zero. The source map is always one-to-one. The value of `oper(e)` at a destination point p_d is defined as follows:

1. In the intermediate space, consider the line that is parallel to the last coordinate axis and goes through the point $m_d(p_d)$.
2. Map this line to a curve in the source selection using the inverse of the source map.
3. Integrate the expression `e` over this curve.

This implies that the value of `oper(e)` at the destination point p_d is the integral of `e` along a curve through the source point $p_s = m_s^{-1}(m_d(p_d))$.

The coupling type determines the type of the maps:

TABLE 2-60: PROJECTION OPERATOR TYPES

COUPLING TYPE	MAP TYPES
`GeneralProjection`	Nonlinear map described by expressions
`LinearProjection`	Linear map described by vertex mapping

TABLE 2-61: PROJECTION COUPLING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`intorder`	int	4	Order of integration formula

Additional properties are available depending on the coupling type, see below.

GeneralProjection

Use a *general projection* component coupling to define integration along curves.

TABLE 2-62: GENERAL PROJECTION COUPLING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`dstmap`	string[srcedim-1]	spatial coordinates	Expressions for destination map $m_d(p_d)$
`srcframe`	`mesh` | `material` | `spatial`	`spatial`	Frame for source mesh.
`srcmap`	string[srcedim]	spatial coordinates	Expressions for source map $m_s(p_s)$

LinearProjection

A *linear projection* coupling operator defines a mapping between destination and source that is given by a linear map defined by vertices. Let v be the vector from the first source vertex to the last source vertex. The value of `oper(e)` at a point p_d is equal to the integral of `e` over the line through the point p_s=$m_s^{-1}(m_d(p_d))$ with direction vector v.

TABLE 2-63: LINEAR PROJECTION COUPLING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`srcvertexN`	Selection		Source vertex number N.
`dstgeom`	string	source geometry	Destination geometry.
`dstvertexN`	Selection		Destination vertex number N.
`srcframe`	`mesh` | `material` | `spatial`	`spatial`	Frame for evaluation of source vertex coordinates.
`dstframe`	`mesh` | `material` | `spatial`	`spatial`	Frame for evaluation of destination vertex coordinates.

The number of selections `srcvertexN` is 4. These are used only for `1<=N<=srcedim+1`. The remaining selections should be empty. The number of source vertices is `srcedim+1`. The source map is a linear (affine) map that maps the source vertices onto the points 0, e_1, e_2,..., e_{srcedim} in the intermediate space, where e_i is the ith unit vector.

The number of selections `dstvertexN` is 4. These are used only for `1<=N<=srcedim`. The remaining selections should be empty. The number of destination vertices is `srcedim`. The destination map is the following linear (affine) map from the destination geometry to the intermediate space:

1. First, if `srcedim-1<dstsdim`, an orthogonal projection onto the affine space spanned by the destination vertices. Thus, `srcedim=3` gives a plane, and `srcedim=2` gives a line.
2. Then, a linear (affine) map mapping the destination vertices onto the points 0, e_1, e_2,..., $e_{\text{srcedim-1}}$ in the intermediate space, where e_i is the ith unit vector.

INTEGRATION COUPLINGS

Integration

By default, an ***integration*** coupling operator *`oper`* integrates an expression `e` over the source selection. The resulting value *`oper`*`(e)` can be used anywhere. If `method=summation`, the expression is instead summed over the nodes in the source selection.

TABLE 2-64: INTEGRATION COUPLING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`intorder`	string	4	Integration order.
`frame`	`mesh` | `material` | `spatial`	`spatial`	Frame to integrate in (determines volume element).
`method`	`integration` | `summation`	`integration`	Method of computation.

Average

An ***average*** coupling operator `oper` integrates an expression `e` over the source selection and divides with the measure of the source selection. The resulting value `oper(e)` can be used anywhere.

TABLE 2-65: AVERAGE COUPLING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`intorder`	string	4	Integration order.
`frame`	`mesh` | `material` | `spatial`	`spatial`	Frame to integrate in (determines volume element).

Maximum/Minimum

A ***maximum*** or ***minimum*** coupling operator `oper` finds the maximum or minimum of an expression `e` over the source selection. The resulting value `oper(e)` can be used anywhere. An optional second argument is evaluated at the point where the first argument has its maximum or minimum. Use `x`, `y`, or `z`, for example, to get the coordinate location of the maximum or minimum.

TABLE 2-66: MAXIMUM/MINIMUM COUPLING PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`intorder`	string	4	Integration rule.
`points`	`node` | integration | lagrange	`node`	Type of point.
`intorder`	string	4	Integration order.
`lagrange`	string	2	Lagrange order.

The maximum/minimum is approximated by evaluating the expression in the specified points.

model.elem()

Creating and modifying different types of elements.

SYNTAX

```
model.elem().create(<tag>,eltype);
model.elem(<tag>).set(<ftag>,value);
model.elem(<tag>).field().create(<ftag>,"record");
model.elem(<tag>).field(<ftag>).set(<ftag>,value);
model.elem(<tag>).field().create(<atag>,"array");
model.elem(<tag>).field(<atag>).pos().create("string",value);
model.elem(<tag>).field(<atag>).pos().create("array");
model.elem(<tag>).field(<atag>).pos(pos).create("string",value);
model.elem(<tag>).src().create(<fttag>);
model.elem(<tag>).src(<fttag>).set(<ftag>,value);
model.elem(<tag>).src(<fttag>).field().create(<ftag>,"array");
model.elem(<tag>).geomdim().create(<fttag>);
```

DESCRIPTION

`model.elem().create(<tag>,eltype)` creates a new element of type `eltype`, for example `elinterp`, `elpric`, `elvar`, `elode`, and so on.

`model.elem(<tag>).set(<ftag>,value)` sets the field tagged *<ftag>* to `value`. Examples of fields and values are, `file` and `solution_interp.txt`, `global` and `1`, and so on.

`model.elem(<tag>).field().create(<ftag>,"record")` creates a new field tagged *<ftag>* of type record under the element tagged *<tag>*.

`model.elem(<tag>).field(<ftag>).set(sname,value)` sets the field tagged `sname` to `value`. The field is located under the record field tagged *<ftag>*.

`model.elem(<tag>).field(<ftag>).field().create(<rtag>,"record")` creates a new record field tagged `<rtag>` that is a field under the record field *<ftag>*.

`model.elem(<tag>).field().create(<atag>,"array")` creates a new array field tagged *<atag>*.

`model.elem(<tag>).field(<atag>).pos().create("array")` adds a new element of type array to the array tagged *<atag>*.

`model...field(<atag>).pos(1).pos().create("string","1")` adds a new array element of type string with value `1` to the first array element of the array stored in the field *<atag>*.

In the text below, all occurrences of `src` can be replaced with `geomdim`.

`model.elem(<tag>).src().create(<fttag>)` creates a `src` feature tagged *<fttag>* under the element. A feature must have a domain selection.

`model.elem(<tag>).src(<fttag>).selection().dim(2).set(gname)` assigns all domains of dimension `2` from geometry `gname` to the selection of feature *<fttag>*.

`model.elem(<tag>).src(<fttag>).set(<ftag>,value)` sets the field *<ftag>* to `value` under the feature *<fttag>*.

`model.elem(<tag>).src(<fttag>).field().create(rname,"record")` adds a new record field `rname` under the feature *<fttag>*.

EXAMPLES

Specifies an interpolation element that takes its data from a file named `solution_data.txt`.

Code for Use with Java

```
model.elem().create("fun1","elinterp");
model.elem("fun1").set("name",new String[]{"sol"});
model.elem("fun1").set("file","solution_data.txt");
model.elem("fun1").set("fileindex",new String[]{"1"});
model.elem("fun1").set("defvars",new String[]{"true"});
model.elem("fun1").set("method",new String[]{"linear"});
model.elem("fun1").set("extmethod",new String[]{"const"});
```

Code for Use with MATLAB

```
model.elem.create('fun1','elinterp');
model.elem('fun1').set('name',{'sol'});
model.elem('fun1').set('file','solution_data.txt');
model.elem('fun1').set('fileindex',{'1'});
model.elem('fun1').set('defvars',{'true'});
model.elem('fun1').set('method',{'linear'});
model.elem('fun1').set('extmethod',{'const'});
```

The example below creates two integration couplings.

Code for Use with Java

```
model.elem().create("elem1","elcplscalar");
model.elem("elem1").set("var",new String[]{"aa","bb"});
model.elem("elem1").set("global",new String[]{"1","2"});
model.elem("elem1").src().create("feat1");
model.elem("elem1").src("feat1").selection().geom("g",2).set(new int[]{1});
model.elem("elem1").src("feat1").set("expr",new String[][]{{"1"},{"2"}}
model.elem("elem1").src("feat1").set("ipoints",new String[][]{{"2"},{"2"}}
model.elem("elem1").src("feat1").set("frame",new String[][]{{"spatial"},{"spatial"}};
```

Code for Use with MATLAB

```
model.elem.create('elem1','elcplscalar');
model.elem('elem1').set('var',{'aa','bb'});
model.elem('elem1').set('global',{'1','2'});
model.elem('elem1').src.create('feat1');
model.elem('elem1').src('feat1').selection.geom('g',2).set(1);
model.elem('elem1').src('feat1').set('expr',{{'1'},{'2'}}
model.elem('elem1').src('feat1').set('ipoints',{{'2'},{'2'}}
model.elem('elem1').src('feat1').set('frame',{{'spatial'},{'spatial'}};
```

This complicated example creates a `constr` element with two constraints (usually done with constraint features):

Code for Use with Java

```
model.elem().create("elem1","elsconstr");
feat = model.elem("elem1").geomdim().create("feat1");
feat.selection().geom("g",2).set(new int[]{1});
feat.set("constr",new String[][][]{{{"Ex","Ey","Ez"}}});
feat.set("cshape",new String[]{"1"})
feat.field().create("shelem","record");
feat.field("shelem").set("case",new String[0]);
feat.field("shelem").set("mind",new String[0]);
feat.field("shelem").field().create("default","array");
feat.field("shelem").field("default").pos().create("array");
feat.field("shelem").field("default").pos(1).pos().create("array");
feat.field("shelem").field("default").pos(1).pos(1).pos().create("string","edg");
feat.field("shelem").field("default").pos(1).pos(1).pos().create("string","shcurl");
feat.field("shelem").field("default").pos(1).pos(1).pos().create("record");
feat.field("shelem").field("default").pos(1).pos(1).pos(3).set("order","2");
feat.field("shelem").field("default").pos(1).pos(1).pos(3)
.set("compnames",new String[]{"Ex","Ey","Ez"});
feat.field("shelem").field("default").pos(1).pos(1).pos(3).set("frame","ref");
feat.field("shelem").field("default").pos(1).pos(1).pos().create("string","edg2");
feat.field("shelem").field("default").pos(1).pos(1).pos().create("string","shcurl");
feat.field("shelem").field("default").pos(1).pos(1).pos().create("record");
```

```
feat.field("shelem").field("default").pos(1).pos(1).pos(6).set("order","2");
feat.field("shelem").field("default").pos(1).pos(1).pos(6)
.set("compnames",new String[]{"Ex","Ey","Ez"});
feat.field("shelem").field("default").pos(1).pos(1).pos(6).set("frame","ref");
```

Code for Use with MATLAB

```
model.elem.create('elem1','elsconstr');
feat = model.elem('elem1').geomdim().create('feat1');
feat.selection().geom('g',2).set(1);
feat.set('constr',{{{'Ex','Ey','Ez'}}});
feat.set('cshape',{'1'})
shelem = feat.field.create('shelem','record');
shelem.set('case','');
shelem.set('mind','');
shelem.field().create('default','array');
shelem.field('default').pos.create('array');
shelem.field('default').pos(1).pos.create('array');
shelem.field('default').pos(1).pos(1).pos.create('string','edg');
shelem.field('default').pos(1).pos(1).pos.create('string','shcurl');
shelem.field('default').pos(1).pos(1).pos.create('record');
shelem.field('default').pos(1).pos(1).pos(3).set('order','2');
shelem.field('default').pos(1).pos(1).pos(3).set('compnames',{'Ex','Ey','Ez'});
shelem.field('default').pos(1).pos(1).pos(3).set('frame','ref');
shelem.field('default').pos(1).pos(1).pos.create('string','edg2');
shelem.field('default').pos(1).pos(1).pos.create('string','shcurl');
shelem.field('default').pos(1).pos(1).pos.create('record');
shelem.field('default').pos(1).pos(1).pos(6).set('order','2');
shelem.field('default').pos(1).pos(1).pos(6).set('compnames',{'Ex','Ey','Ez'});
shelem.field('default').pos(1).pos(1).pos(6).set('frame','ref');
```

For all records, the statement

```
model...set("frame","ref");
```

is the equivalent to

```
model...field().create("frame","string","ref");
```

The statement

```
model...set("expr",new String[][]{{"1"},{"2"}});
```

is equivalent to

```
model...field().create("expr","array");
model...field("expr").pos().create("array").
model...field("expr").pos(1).create("string","1");
model...field("expr").pos().create("array").
model...field("expr").pos(2).create("string","1");
```

so the `set` method is often a much more convenient way to create simple fields.

model.elementSet()

Mesh element sets.

SYNTAX

```
model.elementSet().create(<tag>);
model.elementSet(<tag>).set(<var>,<expr>);
model.elementSet(<tag>).remove(<var>);
model.elementSet(<tag>).model(<mtag>);

model.elementSet(<tag>).varnames();
model.elementSet(<tag>).get(<var>);
model.elementSet(<tag>).model();
model.elementSet(<tag>).scope();
```

DESCRIPTION

`model.elementSet(<tag>)` returns an element set. It contains one or several definitions of sets of mesh elements. Each element set is identified with an *element set variable* name — the variable evaluates to 1 on mesh elements that belong to the element set, and it evaluates to 0 on other mesh elements. The variable has a defining expression that is evaluated at the midpoint of each mesh element to determine whether the mesh element belongs to the element set. This evaluation is done once at the beginning of the solution process, so the expression must not depend on variables that change during the solution process. All element sets in `model.elementSet(<tag>)` are subsets of the selection `model.elementSet(<tag>).selection()`.

`model.elementSet().create(<tag>)` creates a new element set with tag *<tag>*.

`model.elementSet(<tag>).set(<var>,<expr>)` sets the defining expression for the element set variable *<var>* to *<expr>*.

`model.elementSet(<tag>).remove(<var>)` removes the element set variable *<var>*.

`model.elementSet(<tag>).model(<mtag>)` sets the model component node.

`model.elementSet(<tag>).selection().selMethod` manipulates the geometric entity selection; see Selections for a description of the available methods.

`model.elementSet(<tag>).varnames()` returns all element set variables as a string array.

`model.elementSet(<tag>).get(<var>)` returns the defining expression of element set variable *<var>*.

`model.elementSet(<tag>).model()` returns the model component node tag.

`model.elementSet(<tag>).scope()` returns the fully qualified scope name.

EXAMPLE

Let A be an element set consisting of all mesh triangles that are not adjacent to boundaries 3 or 4 in square, plus all mesh triangles that are adjacent to boundaries 1 or 2. Let the dependent variable u be defined on A. Solve Poisson's equation with Dirichlet conditions on boundaries 1 and 2:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
model.component("comp1").geom().create("geom1", 2);
model.component("comp1").geom("geom1").create("sq1", "Square");
model.component("comp1").mesh().create("mesh1", "geom1");
model.component("comp1").mesh("mesh1").run();
model.elementSet().create("es1");
model.elementSet("es1").set("A", "!bndadj(3,4) || bndadj(1,2)");
model.elementSet("es1").selection().geom(2).all();
model.shape().create("sh1", "material1");
model.shape("sh1").create("f1", "shlag");
model.shape("sh1").feature("f1").set("basename", "u").set("order", 1);
model.shape("sh1").selection().geom(2).all();
model.shape("sh1").elementSet("A");
```

```
model.field().create("field1", "u");
model.field("field1").shape(new String[]{"sh1"});
model.intRule().create("ir1", "material1");
model.intRule("ir1").create("o2").order(2);
model.weak().create("weak1");
model.weak("weak1").weak("if(A,ux*test(ux)+uy*test(uy)-test(u),0)");
model.weak("weak1").intRule("ir1");
model.weak("weak1").selection().geom(2).all();
model.constr().create("constr1", new String[]{"sh1"});
model.constr("constr1").create("f1");
model.constr("constr1").feature("f1").set("constr",1,new String[]{"u"});
model.constr("constr1").feature("f1").set("constrf",1,new String[]{"test(u)"});
model.constr("constr1").feature("f1").selection().geom(1).set(1,2);
model.study().create("std1");
model.study("std1").create("stat", "Stationary");
model.study("std1").run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
model.component('comp1').geom.create('geom1', 2);
model.component('comp1').geom('geom1').create('sq1', 'Square');
model.component('comp1').mesh.create('mesh1', 'geom1');
model.component('comp1').mesh('mesh1').run;
model.elementSet.create('es1');
model.elementSet('es1').set('A', '!bndadj(3,4) || bndadj(1,2)');
model.elementSet('es1').selection().geom(2).all;
model.shape.create('sh1', 'material1');
model.shape('sh1').create('f1', 'shlag');
model.shape('sh1').feature('f1').set('basename', 'u').set('order', 1);
model.shape('sh1').selection.geom(2).all;
model.shape('sh1').elementSet('A');
model.field.create('field1', 'u');
model.field('field1').shape({'sh1'});
model.intRule.create('ir1', 'material1');
model.intRule('ir1').create('o2').order(2);
model.weak.create('weak1');
model.weak('weak1').weak('if(A,ux*test(ux)+uy*test(uy)-test(u),0)');
model.weak('weak1').intRule('ir1');
model.weak('weak1').selection().geom(2).all;
model.constr.create('constr1', {'sh1'});
model.constr('constr1').create('f1');
model.constr('constr1').feature('f1').set('constr',1,{'u'});
model.constr('constr1').feature('f1').set('constrf',1,{'test(u)'});
model.constr('constr1').feature('f1').selection().geom(1).set([1,2]);
model.study.create('std1');
model.study('std1').create('stat', 'Stationary');
model.study('std1').run;
```

SEE ALSO

`model.shape()`

model.extraDim()

Create attachments of extra dimensions.

SYNTAX

```
model.extraDim().create(<tag>, type);
model.extraDim(<tag>).set(property,<value>);
model.extraDim(<tag>).model(<mtag>);
model.extraDim(<tag>).selection();
model.extraDim(<tag>).selection("point");
model.extraDim(<tag>).properties();
model.extraDim(<tag>).getType(property);
model.extraDim(<tag>).model();
```

DESCRIPTION

`model.extraDim().create(<tag>, type)` creates an extra dimension feature of the given type. The supported types are `AttachDimension`, `PointsToAttach`, and `Integration`.

`model.extraDim(<tag>).set(property,<value>)` specifies properties relevant for the selected extra dimension feature type.

- Properties for `AttachDimension`: `extradim`
- `PointsToAttach` has no properties.
- Properties for `Integration`: `opname`, `intrule`, `intorder`, `frame`, `axisym`

`model.extraDim(<tag>).model(<mtag>)` sets the model component node. For features of type `AttachDimension`, this defines the base model component node. For features of type `PointsToAttach` and `Integration`, this defines the extra dimension component node.

```
model.extraDim(<tag>).selection();
```

Returns the selection of the feature (for features of type AttachDimension and Integration).

`model.extraDim(<tag>).selection("point")` returns the selection of points to attach (for features of type `PointsToAttach`).

`model.extraDim(<tag>).properties()` returns the list of assigned properties as a string array.

`model.extraDim(<tag>).getType(property)` returns the value of the specified property.

`model.extraDim(<tag>).model()` returns the model component node tag.

model.field()

Create and define properties for fields with shape functions that defined field variables.

SYNTAX

```
model.field().create(<tag>,<fname>);
model.field(<tag>).field(<fname>);
model.field(<tag>).shape(<shlist>);

model.field(<tag>).field();
model.field(<tag>).shape();
model.field(<tag>).geom();
```

DESCRIPTION

`model.field().create(<tag>,<fname>)` creates a field with tag *<tag>* with the field name *<fname>*.

`model.field(<tag>).field(<fname>)` sets the field name.

`model.field(<tag>).shape(<shlist>)` sets the shape functions defining the field variables. *<shlist>* is a list of shape function tags. Each shape function defines one or more field variables. Together the shape functions specify which field variables there are in the field.

`model.field(<tag>).field()` returns the field name as a string.

`model.field(<tag>).shape()` returns the shape function tags as a string array.

`model.field(<tag>).geom()` returns the geometry associated with the field.

SEE ALSO

`model.shape()`, `model.coeff()`

model.form()

Create settings forms for use in the Model Builder.

SYNTAX

```
model.form().create(<tag>,<fname>);
```

```
model.form(<tag>).update();
```

DESCRIPTION

`model.form().create(<tag>,<fname>)` creates a new form instance using the Application Builder Form Feature with the tag *<fname>*.

`model.form(<tag>).update()` updates the Settings Form instance *<tag>* with the current definition of the Application Builder Form Feature it references.

To change the value of an input field in a settings form you can change the value of the source data tied to the input field and let the data binding update the value of the input field.

SEE ALSO

`model.methodCall()`

model.frame()

Create and define properties for different types of frames: spatial frames, material frames, mesh frames, and geometry frames.

SYNTAX

```
model.frame().create(<tag>,<gtag>);
model.frame(<tag>).coord(<coordlist>);
model.frame(<tag>).coord(<pos>,<coord>);
model.frame(<tag>).meshFrame();
model.frame(<tag>).materialFrame();
model.frame(<tag>).geometryFrame();
model.frame(<tag>).spatialFrame();
model.frame(<tag>).sshape.create(<stag>,type);
model.frame(<tag>).sshape(<stag>).type(type);
model.frame(<tag>).sshape(<stag>).sorder(order);
model.frame(<tag>).sshape(<stag>).coorddof(<dofs>);
model.frame(<tag>).sshape(<stag>).coorddof(<pos>,<dof>);
model.frame(<tag>).sshape(<stag>).refframe(<ftag>);
model.frame(<tag>).sshape(<stag>).coordexpr(<exprs>);
model.frame(<tag>).sshape(<stag>).coordexpr(<pos>,<expr>);

model.frame(<tag>).coord();
model.frame(<tag>).identifier();
model.frame(<tag>).varNameSuffix();
model.frame(<tag>).geom();
model.frame(<tag>).isMeshFrame();
model.frame(<tag>).isGeometryFrame();
model.frame(<tag>).isMaterialFrame();
model.frame(<tag>).isSpatialFrame();
model.frame(<tag>).sshape(<stag>).type();
model.frame(<tag>).sshape(<stag>).sorder();
model.frame(<tag>).sshape(<stag>).coorddof();
model.frame(<tag>).sshape(<stag>).refframe();
model.frame(<tag>).sshape(<stag>).coordexpr();
```

DESCRIPTION

`model.frame().create(<tag>,<gtag>)` creates a new frame and assigns it to geometry *<gtag>*.

`model.frame(<tag>).coord(<coordlist>)` defines *<coordlist>* as a list of independent variables. (Formerly `sdim`.)

`model.frame(<tag>).coord(<pos>,<coord>)` edits the coordinate at position *<pos>* in the coordinate list.

`model.frame(<tag>).meshFrame()` sets this frame to be the mesh frame. Each geometry requires exactly one mesh frame. The first one added becomes the mesh frame. When assigning one frame to be the mesh frame, this flag is cleared in the previous frame being the mesh frame.

`model.frame(<tag>).geometryFrame()` sets this frame to be the geometry frame. Each geometry requires exactly one geometry frame. The first one added becomes the geometry frame. When assigning one frame to be the geometry frame, this flag is cleared in the previous frame being the geometry frame.

`model.frame(<tag>).materialFrame()` sets this frame to be the material frame. Each geometry requires exactly one material frame. The first one added becomes the material frame. When assigning one frame to be the material frame, this flag is cleared in the previous frame being the material frame.

`model.frame(<tag>).spatialFrame()` sets this frame to be the spatial frame. Each geometry requires exactly one spatial frame. The first one added becomes the spatial frame. When assigning one frame to be the spatial frame, this flag is cleared in the previous frame being the spatial frame.

`model.frame(<tag>).sshape().create(<stag>,type)` creates a frame feature of the given type. Possible types are `fixed` (default), `moving_abs`, `moving_rel`, and `moving_expr`.

`model.frame(<tag>).sshape(<stag>).type(type)` sets the type of the frame feature.

`model.frame(<tag>).sshape(<stag>).sorder(order)` sets the geometry shape order for *<stag>* to *order*.

`model.frame(<tag>).sshape(<stag>).coorddof(<dofs>)` sets the spatial coordinates for `<stag>` when the `moving_rel` type is used.

`model.frame(<tag>).sshape(<stag>).coorddof(<pos>,<dof>)` edits the coordinate name at position `<pos>` in the degree of freedom list.

`model.frame(<tag>).sshape(<stag>).refframe(<ftag>)` sets the reference frame for `<stag>` when the `moving_rel` type is used.

`model.frame(<tag>).sshape(<stag>).coordexpr(<exprs>)` sets the expressions for the mesh displacement for `<stag>`.

`model.frame(<tag>).sshape(<stag>).coordexpr(<pos>,<expr>)` edits the expression at position `<pos>` in the expression list.

`model.frame(<tag>).sshape(<stag>).selection().named(<seltag>)` assigns the frame feature to the named selection `<seltag>`.
`model.frame(<tag>).sshape(<stag>).selection().set(...)` defines a local selection that assigns the frame feature to geometric entities. For a complete list of methods available under `selection()`, see `model.selection()`. All types of selections are supported except the global one and selections containing interior mesh boundaries.

`model.frame(<tag>).coord()` returns the coordinate names as a string array.

`model.frame(<tag>).identifier()` returns the frame's identifier as a string.

`model.frame(<tag>).varNameSuffix()` returns the variable name suffix as a string.

`model.frame(<tag>).geom()` returns the geometry name as a string.

`model.frame(<tag>).isMeshFrame()` returns true if this frame is the mesh frame.

`model.frame(<tag>).isGeometryFrame()` returns true if this frame is the geometry frame.

`model.frame(<tag>).isMaterialFrame()` returns true if this frame is the material frame.

`model.frame(<tag>).isSpatialFrame()` returns true if this frame is the spatial frame.

`model.frame(<tag>).sshape(<stag>).type()` returns the type as a string.

`model.frame(<tag>).sshape(<stag>).sorder()` returns the spatial approximation order as an integer.

`model.frame(<tag>).sshape(<stag>).coorddof()` returns the spatial coordinates as a string array.

`model.frame(<tag>).sshape(<stag>).refframe()` returns the reference frame as a string.

`model.frame(<tag>).sshape(<stag>).coordexpr()` returns the spatial coordinate expressions as a string array.

`model.frame(<tag>).sshape(<stag>).selection().named()` returns the named selection tag.

`model.frame(<tag>).sshape(<stag>).selection().get<Type>()` returns domain information. For available methods, see `model.selection()`.

SEE ALSO

`model.shape()`

model.func()

Add different types of functions.

SYNTAX

```
model.func().create(<tag>,<type>);
model.func(<tag>).create(<tag>,<type>);
model.func(<tag>).createPlot(<pgtag>)
model.func(<tag>).label(<label>)
model.func(<tag>).model(<mtag>)
model.func(<tag>).set(property,<value>);
model.func(<tag>).set("funcname",<funcname>)
model.func(<tag>).discardData()
model.func(<tag>).importData()
model.func(<tag>).refresh()
model.func(<tag>).image()

model.func(<tag>).model()
model.func(<tag>).getType(property);
model.func(<tag>).functionNames()
model.func(<tag>).getAllowedPropertyValues(property);
```

DESCRIPTION

`model.func().create(<tag>,<type>)` creates a new function of type *<type>* with the tag *<tag>*. The types can be one of the following strings: `Analytic`, `Elevation`, `External`, `Image`, `Interpolation`, `MATLAB` (requires LiveLink™ *for* MATLAB®), `Piecewise`, `GaussianPulse`, `Ramp`, `Random`, `Rectangle`, `Step`, `Triangle`, and `Wave`. In addition, `model.create(<tag>,"FunctionSwitch")` creates a function switch. You can add other functions to a function switch:

```
model.func().create("sw1", "FunctionSwitch");
model.func("sw1").create("int1", "Interpolation");
model.func("sw1").create("an1", "Analytic");
model.func("sw1").create("rn1", "Random");
```

`model.func(<tag>).createPlot(<pgtag>)` creates a plot group with the tag *pgtag* with a plot of the function. The method returns the plot group.

`model.func(<tag>).label(<label>)` sets a label for the function.

`model.func(<tag>).model(<mtag>)` sets the model component node of the function.

`model.func(<tag>).set(property,<value>)` sets the value of a property of the function. See the available properties for each type of function below.

`model.func(<tag>).set("funcname",<funcname>)` sets the operator name of the function. The default operator name is *<tag>*.

`model.func(<tag>).model()` returns the model component node tag.

`model.func(<tag>).getType(property)` retrieves a value of a function property.

`model.func(<tag>).importData()` imports the file that the function references into the model. This is possible for interpolation, elevation, and image functions. The `importData()` method also works for some physics features.

`model.func(<tag>).discardData()` discards the data imported with `importData()`. This is possible for interpolation, elevation, and image functions. The `discardData()` method also works for some physics features.

`model.func(<tag>).refresh()` reevaluates the file for functions that read files (Elevation, Image, and Interpolation).

Use the `model.func(<tag>).image()` methods for plotting and exporting images showing plots of the functions. See Plotting and Exporting Images.

`model.func(<tag>).functionNames()` returns an array containing the function names that the function feature defines. Most functions always return an array of length one, but interpolation function features, for example, can define an arbitrary number of function names.

`model.func(<tag>).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

For functions on the component level, use the same syntax but add the component level, such as `model.component(<ctag>).func().create(<tag>,<type>)`

What properties are available depends on the type of function. The following function types are available:

Analytic

Generate an *analytic* function using a symbolic expression.

TABLE 2-67: ANALYTIC PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`argders`	Nx2 String array	`{}`	(argument, partial derivative) pairs if dermethod is manual.
`args`	string array	{}	The arguments to the function.
`complex`	Boolean	`false`	True if the function can produce complex results for real inputs.
`dermethod`	`automatic` | `manual`	`Automatic`	Automatic differentiation or manual control over the derivatives.
`expr`	string	None	The expression defining the function.
`funcname`	string	The tag name	The name of the function.
`periodic`	Boolean	`false`	True if the function should be extended to a periodic function.
`periodiclower`	string	0	The lower limit of the interval that is extended periodically.
`periodicupper`	string	1	The upper limit of the interval that is extended periodically.
`argunit`	string		A comma-separated list of required units for each argument.
`fununit`	string		The unit of the function's result.

Interpolation

Generate an *interpolation* function. You can use several interpolation and extrapolation methods..

TABLE 2-68: INTERPOLATION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`defineinv`	`on`|`off`	`off`	If source is table: Whether to define the inverse function.
`definerandom`	`on`|`off`	`off`	Whether to define a random function.
`defvars`	Boolean	false	If source is file and defvars is set, the space variables are used as default arguments to the function if no arguments are supplied in a call to it.
`extrap`	`const` | `interior` | `linear` | `value`	`const`	The extrapolation method.
`extrapvalue`	double	0	The extrapolation value if extrap is value.

TABLE 2-68: INTERPOLATION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`filename`	string		The file that contains the data if source is file.
`funcinvname`	string		If source is table and `defineinv` is on: The name of the inverse function.
`funcname`	string	The tag name	The name of the function if source is table.
`funcs`	string matrix		Used source is file; the first column contains function names and the second column contains the positions in the file where the corresponding function is defined
`interp`	`neighbor` | `linear` | `piecewisecubic` | `cubicspline`	`piecewisecubic`	The interpolation method.
`leftend`	double	0	The left end of the range for the random function, if `randomrange` = `manual`.
`modelres`	string		If sourcetype is model, specifies the model resource that contains the interpolation data
`nargs`	integer (1-3)	1	The number of function arguments if struct is spreadsheet or source is resultTable.
`primfunname`	`string`		Define a primitive function with the name give as `primfunname`.
`randomname`	`string`		Define a primitive function with the name give as `primfunname`.
`randomnargs`	integer	1	The number of arguments for the random function.
`randomrange`	`automatic`|`manual`	`automatic`	Whether to define a range for the random function.
`resultTable`	`string`		The tag of the result table to use (`tbl1`, for example).
`rightend`	double	1	The right end of the range for the random function, if `randomrange` = `manual`.
`scaledata`	`auto` | `on` | `off`	`auto`	Apply scaling of data if the bounding box of the interpolation points has a bad aspect ratio (`auto`), always apply the scaling (`on`), or turn off scaling altogether (`off`).
`source`	`table` | `file` | `resultTable`	`table`	If sourcetype is user, specifies whether the data is entered in a local table, read from a file, or taken from a results table.
`sourcetype`	`model` | `user`	`user`	Specifies if the data for the function is stored in the model or provided by the user.
`struct`	`grid` | `sectionwise` | `spreadsheet`	`spreadsheet`	The data format if source is file.
`table`	Nx2 String array	`Empty`	Contains the point/value pairs if the source is table.
`argunit`	string		A comma-separated list of required units for each argument.
`fununit`	string		The unit of the function's result.

Piecewise

Generate a *piecewise* interpolation function, which is created by splicing together several functions, each defined on one interval.

TABLE 2-69: PIECEWISE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`arg`	string	x	The argument to the function.
`extrap`	`const` | `interior` | `none` | `periodic` | `value`	`const`	The extrapolation method.
`extrapvalue`	double	0	The extrapolation value if extrap is value.
`funcname`	string	The tag name.	The name of the function.
`pieces`	Nx3 String array	Empty	(left, right, expression) for each interval.
`smooth`	`none` | `cont` | `contd1` | `contd2`	`none`	The type of smoothing.
`smoothzone`	double	0.1	The relative size of the smoothing zone if smoothing is enabled.
`argunit`	string		A comma-separated list of required units for each argument.
`fununit`	string		The unit of the function's result.

GaussianPulse

Generate a *Gaussian pulse* function. This function is the common bell-shaped curve (Gaussian function).

TABLE 2-70: GAUSSIAN PULSE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`funcname`	string	The tag name	The name of the function.
`location`	string	0	Where the pulse peaks.
`sigma`	string	1	The standard deviation of the underlying normal distribution.

Ramp

Generate a *ramp* function.

TABLE 2-71: RAMP PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`cutoffactive`	Boolean	false	If true, then the ramp ends when it reaches the cutoff value.
`cutoff`	double	1	If cutoffactive is true, the level where the ramp ends.
`funcname`	string	The tag name	The name of the function.
`location`	string	0	Where the ramp starts.
`slope`	string	1	The slope of the ramp.
`ncontder`	1 or 2	2	The number of continuous derivatives if smoothing is enabled.
`smoothzonecutoffactive`	Boolean	false	Smooth the transition where the ramp ends at the cutoff?
`smoothzonelocactive`	Boolean	false	Smooth the transition where the ramp starts?
`smoothzonecutoff`	double	0.1	The relative size of the smoothing zone for the cutoff, if smoothing is enabled.
`smoothzoneloc`	double	0.1	The relative size of the smoothing zone where the ramp starts, if smoothing is enabled.

Random

Generate a *random* function. The random function can have a uniform or normal distribution.

TABLE 2-72: RANDOM PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`funcname`	string	The tag name	The name of the function.
`mean`	string	0	The average value.
`nargs`	integer	1	The number of arguments.
`normalsigma`	string	1	The standard deviation if type is Normal.
`seed`	string	Unique for each random function	Random seed.
`seedactive`	Boolean	`false`	If true, the random seed will be used.
`type`	`uniform` | `normal`	`Uniform`	The distribution type.
`uniformrange`	string	1	The range if type is Uniform.

Rectangle

Generate a *rectangle*-shaped function.

TABLE 2-73: RECTANGLE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`funcname`	string	The tag name	The name of the function.
`lower`	string	`-0.5`	Where the high zone begins.
`ncontder`	1 or 2	2	The number of continuous derivatives if smoothing is enabled.
`smooth`	Boolean	`true`	Smooth the transitions?
`smoothzone`	string	`0.1`	The size of the smoothing zone on both sides of the transitions.
`upper`	string	`0.5`	Where the high zone ends.

Step

Generate a *step* function.

TABLE 2-74: STEP PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`from`	string	0	The value to the left of the location.
`funcname`	string	The tag name	The name of the function.
`location`	string	`0`	Where the step is located.
`ncontder`	1 or 2	2	The number of continuous derivatives if smoothing is enabled.
`smooth`	Boolean	`true`	Smooth the transition?
`smoothzone`	string	`0.1`	The size of the smoothing zone on both sides of location.
`to`	string	1	The value to the right of the location.

Triangle

Generate a *triangle*-shaped function.

TABLE 2-75: TRIANGLE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`funcname`	string	The tag name	The name of the function.
`lower`	string	`-0.5`	Where the high zone begins.
`ncontder`	1 or 2	2	The number of continuous derivatives if smoothing is enabled.

TABLE 2-75: TRIANGLE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
smooth	Boolean	true	Smooth the transitions?
smoothzone	string	0.1	Size of smoothing zone on both sides of the transitions.
upper	string	0.5	Where the high zone ends.

External

Generate an *external* function that interfaces to other external functions written in the C language.

TABLE 2-76: EXTERNAL PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
ders	Nx3 string array		(function name, argument, partial derivative) triplets.
funcs	string array		The functions defined by the library.
init	string		The string that is sent to the library when the function feature is initialized.
path	string		The path to the shared library that defines the functions.

An external function is a function defined in a shared library written by the user. The shared library must define the following three functions with C linkage:

- `int init(const char *str)` is called when the function is initialized with the string from the **Initialization data** field. It returns a nonzero value in case of success and zero in case of failure. This function might be called several times; it is always called before solving a model that uses the function.
- `int eval(const char *func, int nArgs, const double **inReal, const double **inImag, int blockSize, double *outReal, double *outImag)` is called for elementwise evaluation of the function `func` called with `nArgs` arguments of length `blockSize`. The array `inReal` contains the real parts of the arguments; it has length `nArgs`, and each element has length `blockSize`.

  If the arguments are all-real, then `inImag` is null; otherwise it contains the imaginary parts of the arguments. If the function evaluation is successful, 1 is returned if it resulted in an all-real array and 2 is returned if it resulted in a complex array. The function should return 0 in case of error. In case of a real result, the function values should be written to the array `outReal`. In case of a complex result, the real parts of the function should be written to `outReal` and the imaginary parts to `outImag`. The `outReal` and `outImag` arrays both have length `blockSize`. All matrices are allocated and deallocated by COMSOL.
- `const char *getLastError()` returns the last error that has occurred. A null or empty string is returned if no error has occurred. Calling `init()` or `eval()` must set the last error string to `""` or null. All memory allocation of this string is handled by the shared library. There is no localization of the error messages.

If you are using Microsoft Visual Studio to compile your library, you can declare the functions as `__declspec(dllexport)` to export them from the DLL.

An example of a library that defines a function called `extsinc` that computes the `sinc` function ($\sin(x)/x$):

```
#include <math.h>
#include <stdlib.h>
#include <string.h>

#ifdef _MSC_VER
#define EXPORT __declspec(dllexport)
#else
#define EXPORT
#endif

static const char *error = NULL;

EXPORT int init(const char *str) {
```

```
  return 1;
}

EXPORT const char * getLastError() {
  return error;
}

EXPORT int eval(const char *func,
                              int nArgs,
                              const double **inReal,
                              const double **inImag,
                              int blockSize,
                              double *outReal,
                              double *outImag) {
  int i, j;

  if (strcmp("extsinc", func) == 0) {
    if (nArgs != 1) {
      error = "One argument expected";
      return 0;
    }
    for (i = 0; i < blockSize; i++) {
      double x = inReal[0][i];
      outReal[i] = (x == 0) ? 1 : sin(x) / x;
    }
    return 1;
  }
  else {
    error = "Unknown function";
    return 0;
  }
}
```

To compile this function into a library, place it in `ext.c` and proceed as follows depending on platform:

See https://www.comsol.com/system-requirements for information about supported compiler versions.

- 64-bit Windows with Microsoft Visual Studio:
  - Start Microsoft Visual Studio > Visual Studio Tools > Visual Studio x64 Win64 Command Prompt (2010) from the Windows Start Menu.
  - `cd` to the directory that contains `ext.c`.
  - `cl /MT /c ext.c`
  - `link /OUT:ext.dll /DLL ext.obj`
- 64-bit Linux with Intel Compiler:
  - `cd` to the directory that contains `ext.c`.
  - `icc -fPIC -c ext.c`
  - `icc -shared -fPIC -Wl,-z -Wl,defs -o ext.so ext.o -ldl`
- 64-bit Mac with Intel Compiler:
  - `cd` to the directory that contains `ext.c`.
  - `icc -fPIC -c ext.c`
  - `icc -dynamiclib -fPIC -o ext.dylib ext.o`

For other compilers, refer to the compiler's documentation for instructions how to compile and create a shared library.

Elevation

Generate an *elevation* function by importing geospatial elevation data from digital elevation models (DEM files).

TABLE 2-77: ELEVATION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`extrap`	`const` | `interior` | `linear` | `value`	`const`	The extrapolation method.
`extrapvalue`	double	0	The extrapolation value if extrap is value.
`filename`	string		The name of the DEM file.
`funcname`	string	The tag name	The name of the function.
`interp`	`neighbor` | `linear`	`linear`	The interpolation method.

Image

Generate an *image function* from a BMP, GIF, JPEG, or PNG file.

TABLE 2-78: IMAGE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`argunit`	string		The unit of the function arguments.
`clipmaxx`	double	1000	If clipping is manual: The maximum pixel x-coordinate that is kept.
`clipminx`	double	0	If clipping is manual: The minimum pixel x-coordinate that is kept.
`clipmaxy`	double	1000	If clipping is manual: The maximum pixel y-coordinate that is kept.
`clipminy`	double	0	If clipping is manual: The minimum pixel y-coordinate that is kept.
`clipping`	`none` | `manual`	none	The clipping method.
`extrap`	`const` | `interior` | `linear` | `value`	`const`	The extrapolation method.
`extrapvalue`	double	0	The extrapolation value if extrap is value.
`fununit`	string		The unit of the function value.
`filename`	string		The name of the DEM file.
`flipx`	Boolean	false	If inplace is false: Whether to flip the image horizontally when mapping it to the xy-plane.
`flipy`	Boolean	false	If inplace is false: Whether to flip the image vertically when mapping it to the xy-plane.
`funcname`	string	The tag name	The name of the function.
`inplace`	Boolean	`false`	If true, the image is mapped to the xy-plane without scaling; 1 length unit corresponds to 1 pixel.
`interp`	`neighbor` | `linear`	`linear`	The interpolation method.
`manualexpr`	string	(r+g+b)/3	If scaling is manual: The scaling function expressed in terms of the red (r), green (g), and blue (b) pixel intensities.
`scaling`	`automatic` | `manual`	`automatic`	The method used for computing function values from pixel colors.
`xmax`	double	1	If inplace is false: The maximum x-coordinate of the region to which the image is mapped.

TABLE 2-78: IMAGE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
xmin	double	0	If inplace is false: The minimum x-coordinate of the region to which the image is mapped.
ymax	double	1	If inplace is false: The maximum y-coordinate of the region to which the image is mapped.
ymin	double	0	If inplace is false: The minimum y-coordinate of the region to which the image is mapped.

MATLAB

Declare use of function in *MATLAB*. This requires the LiveLink™ *for* MATLAB®.

TABLE 2-79: MATLAB PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
ders	Nx3 string array		(function name, argument, partial derivative) triplets.
funcs	string array		The functions defined by MATLAB.

Wave

Use a *wave* function to generate a wave-shaped function. The wave shape can be a sawtooth, sine wave, square wave, or triangle wave.

TABLE 2-80: WAVE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
amplitude	string	1	The amplitude.
dutycycle	string	0.5	The duty cycle of the function (a value between 0 and 1). Available for Square functions (as the fraction of a period that the function has the high value) and for Triangle functions (as the fraction of a period that the function is rising).
freq	string	1	The angular frequency.
funcname	string	The tag name	The name of the function.
ncontder	1 or 2	2	The number of continuous derivatives if smoothing is enabled.
phase	string	0	The phase.
smooth	Boolean	true	Smooth the transitions? (Only used for wave forms with discontinuous function values or derivatives.)
smoothzone	string	0.1	The size of smoothing zone on both sides of the transitions.
type	sawtooth | sine | square | triangle	sine	The type of waveform.

SEE ALSO

model.material()

model.geom()

Creating and specifying general properties for 1D, 2D, and 3D geometries.

SYNTAX

```
model.component(<ctag>).geom().create(<tag>,<sdim>);
model.component(<ctag>).geom().create(<tag>,<meshtag>,<filename>);
model.component(<ctag>).geom(<tag>).model(<mtag>);
model.component(<ctag>).geom(<tag>).model();
model.component(<ctag>).geom(<tag>).axisymmetric(boolean);
model.component(<ctag>).geom(<tag>).isAxisymmetric();
model.component(<ctag>).geom(<tag>).lengthUnit(<unit>);
model.component(<ctag>).geom(<tag>).lengthUnit();
model.component(<ctag>).geom(<tag>).angularUnit(<unit>);
model.component(<ctag>).geom(<tag>).angularUnit();
model.component(<ctag>).geom(<tag>).scaleUnitValue(boolean);
model.component(<ctag>).geom(<tag>).scaleUnitValue();
model.component(<ctag>).geom(<tag>).repairTol(<relTol>);
model.component(<ctag>).geom(<tag>).repairTol();
model.component(<ctag>).geom(<tag>).geomRep(geomrep);
model.component(<ctag>).geom(<tag>).geomRep();
model.component(<ctag>).geom().remove(<tag>);

model.component(<ctag>).geom(<tag>).create(<ftag>,type);
model.component(<ctag>).geom(<tag>).createAfter(<ftag>,<type>,<postag>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).create(<ftag2>,type);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property).selMethod;
model.component(<ctag>).geom(<tag>).feature(<ftag>).geom().geomMethod;
model.component(<ctag>).geom(<tag>).feature(<ftag>).active(boolean);
model.component(<ctag>).geom(<tag>).feature(<ftag>).isActive();
model.component(<ctag>).geom(<tag>).feature().move(<ftag>,<position>);
model.component(<ctag>).geom(<tag>).feature().remove(<ftag>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getAllowedPropertyValues(property);

model.component(<ctag>).geom(<tag>).run(<ftag>);
model.component(<ctag>).geom(<tag>).runPre(<ftag>);
model.component(<ctag>).geom(<tag>).runCurrent();

model.component(<ctag>).geom(<tag>).run();
model.component(<ctag>).geom().run();

model.component(<ctag>).geom(<tag>).current();
model.component(<ctag>).geom(<tag>).feature(<ftag>).status();
model.component(<ctag>).geom(<tag>).feature(<ftag>).message();

model.component(<ctag>).geom(<tag>).objectNames();
model.component(<ctag>).geom(<tag>).feature(<ftag>).objectNames();
model.component(<ctag>).geom(<tag>).obj(<objname>).geomInfoMethod
model.component(<ctag>).geom(<tag>).geomInfoMethod
model.component(<ctag>).geom(<tag>).selection(<seltag>).selMethod;
```

SYNTAX

```
model.component(<ctag>).geom(<tag>).measure().geomMeasurementMethod;
model.component(<ctag>).geom(<tag>).measureFinal().geomMeasurementMethod;

model.component(<ctag>).geom(<tag>).export(<filename>);
model.component(<ctag>).geom(<tag>).exportFinal(<filename>);

model.component(<ctag>).geom(<tag>).defeaturing(<tooltag>).defeaturingMethod;
model.component(<ctag>).geom(<tag>).feature(<ftag>).find();
model.component(<ctag>).geom(<tag>).feature(<ftag>).detail().selMethod;

model.component(<ctag>).geom(<tag>).insertFile(<filename>,<gtag>);
model.component(<ctag>).geom(<tag>).insertSequence(<mtag>,<gtag>);

model.component(<ctag>).geom().create(<tag>, "Subsequence", sDim);
model.component(<ctag>).geom(<tag>).inputParam().set(<name>, <expr>, <descr>);
model.component(<ctag>).geom(<tag>).localParam().set(<name>, <expr>, <descr>);
model.geom(<gtag>).create(<ftag>, "PartInstance");
model.geom(<gtag>).stepInto(<ftag>);
model.geom(<gtag>).feature(<ftag>).geom().run(<ftag2>);
```

The last group of syntaxes are only applicable for geometry subsequences (see Using Geometry Parts), but `model.geom(<gtag>).feature(<ftag>).geom()` also exists if `<ftag>` is a work plane feature.

```
model.geom().load(<tags>, <filename>, <subsequenceTagsInFile>);
model.geom(<gtag>).loaded();

model.geom(<gtag>).filename();
model.geom(<gtag>).filename(<filename>);
model.geom(<gtag>).tagInFile();
model.geom(<gtag>).dateModifiedInFile();
model.geom(<gtag>).commentsInFile();
model.geom(<gtag>).labelInFile();
model.geom(<gtag>).versionInFile();
model.geom(<gtag>).reload();
```

The last group of syntaxes are only applicable for geometry subsequences (see Using Geometry Parts).

DESCRIPTION

Geometry Sequences and Geometry Objects

`model.component(<ctag>).geom(<tag>)` returns a geometry sequence consisting of geometry features. The geometry sequence also contains geometry objects resulting from building the geometry sequence.

Creating and Deleting a Geometry

`model.component(<ctag>).geom().create(<tag>,<sdim>)` creates a geometry sequence of space dimension `<sdim>` and assigns it the tag `<tag>`.

`model.component(<ctag>).geom().create(<tag>,<meshtag>,<filename>)` creates a geometry sequence tagged `<tag>` and a corresponding meshing sequence tagged `<meshtag>`. The parameter `<filename>` specifies a file that contains a geometry or a mesh, and an import feature is inserted into the geometry or meshing sequence.

`model.component(<ctag>).geom().remove(<tag>)` deletes the geometry tagged `<tag>`.

General Geometry Settings

`model.geom(<tag>).model(<mtag>)` sets the model component node of the geometry `<tag>` to `<mtag>`.

`String mtag = model.geom(<tag>).model()` returns the model component node tag of the geometry.

`model.component(<ctag>).geom(<tag>).axisymmetric(boolean)` indicates if the geometry is axisymmetric. This is only applicable for 1D and 2D geometries.

`model.component(<ctag>).geom(<tag>).isAxisymmetric()` returns `true` if the geometry is axisymmetric and `false` otherwise.

`model.component(<ctag>).geom(<tag>).lengthUnit(<unit>)` sets the length unit.

`String unit = model.component(<ctag>).geom(<tag>).lengthUnit()` returns the length unit.

`model.component(<ctag>).geom(<tag>).angularUnit(<unit>)` sets the angular unit.

`String unit = model.component(<ctag>).geom(<tag>).angularUnit()` returns the angular unit.

`model.component(<ctag>).geom(<tag>).scaleUnitValue(boolean)` sets the geometry to scale property values when units are changed.

`model.component(<ctag>).geom(<tag>).scaleUnitValue()` returns true if the geometry is set to scale property values when units are changed.

`model.component(<ctag>).geom(<tag>).repairTol(<relTol>)` sets the default relative repair tolerance to use when creating new features.

`double relTol = model.component(<ctag>).geom(<tag>).repairTol()` returns the default relative repair tolerance.

`model.component(<ctag>).geom(<tag>).geomRep(geomrep)` sets the geometry representation to use in a 3D geometry. The *geomrep* string can be `comsol`, meaning the COMSOL kernel or `cadps` (requires the CAD Import Module), meaning the CAD kernel (Parasolid).

`String geomrep = model.component(<ctag>).geom(<tag>).geomRep()` returns the geometry representation.

Creating, Editing, Disabling, and Deleting Features

`model.component(<ctag>).geom(<tag>).create(<ftag>,type)` adds a geometry feature *<ftag>* of type *type* to the geometry *<tag>*, after the current feature.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>)` sets a property in the geometry feature *<ftag>*. All data types listed in Table 2-2 are supported; the applicable data types differ between the properties. String expressions can use parameters from `model.param()`.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).get`*Type*`(property)` returns the value of a property in the geometry feature *<ftag>*.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property).`*selMethod* manages the geometry object selection property *property*. The available selection methods are described in Geometry Object Selection Methods.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).geom().geomMethod` manipulates the 2D geometry sequence corresponding to the work plane feature *<ftag>*. The available methods are the same as for a 2D geometry `model.geom(`*<gtag>*`)`.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).active(false)` disables the feature *<ftag>*.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).active(true)` enables the feature *<ftag>*.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).isActive()` returns `true` if the feature *<ftag>* is enabled, and `false` otherwise.

`model.component(<ctag>).geom(<tag>).feature().remove(<ftag>)` removes the feature *<ftag>*.

`model.component(<ctag>).geom(<tag>).feature().move(<ftag>,<position>)` moves the feature *<ftag>* to the zero indexed position *<position>* in the sequence.

`model.component(<ctag>).geom(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

Building Features

After each build operation, the current feature is set as the last of the active features that were built. The current state contains all objects that are generated by these features.

`model.component(<ctag>).geom(<tag>).run(<ftag>)` builds all features up to (and including) the feature *<ftag>*.

`model.component(<ctag>).geom(<tag>).runPre(<ftag>)` builds all features preceding the feature *<ftag>*; for example, with *<ftag>* being a work plane feature in a 3D geometry, `model.geom(<tag>).runPre(<ftag>)` builds all 3D geometry features preceding the work plane.

`model.component(<ctag>).geom(<tag>).runCurrent()` builds all features up to (and including) the current feature.

`model.component(<ctag>).geom(<tag>).run()` builds all features. The finalized geometry and all selections are also updated.

`model.component(<ctag>).geom().run()` builds the finalized geometry in all geometries.

Getting Build Status

`String fTag = model.component(<ctag>).geom(<tag>).current()` returns the tag of the current feature. If the current state is before the first feature, the empty string `""` is returned.

`String status = model.component(<ctag>).geom(<tag>).feature(<ftag>).status()` returns the status of the feature *<ftag>*. The status is `built`, `warning`, `needs_rebuild`, `edited`, or `error`.

`String msg = model.component(<ctag>).geom(<tag>).feature(<ftag>).message()` returns the warning/error message of the feature *<ftag>*.

Getting Information About Geometry Objects

`String[] n = model.component(<ctag>).geom(<tag>).objectNames()` returns the names of all objects that exist in the current state.

`String[] n = model.component(<ctag>).geom(<tag>).feature(<ftag>).objectNames()` returns the names of the output object generated by the feature *<ftag>*.

`model.component(<ctag>).geom(<tag>).obj(<objname>).geomInfoMethod` returns information about the object *<objname>*. The available methods are described in Geometry Object Information.

`model.component(<ctag>).geom(<tag>).geomInfoMethod` returns information about the finalized geometry of geometry *<tag>*.

Getting Information About Named Selections

`model.component(<ctag>).geom(<tag>).selection(<seltag>).selMethod` returns information about the named selection *<seltag>*. See `Selections of Geometric Entities` and Geometry Object Selection Methods for more information.

Geometric Measurements

Use `model.component(<ctag>).geom(<tag>).measure().selection().selMethod` to specify the domains, boundaries, or edges in geometry objects that you want to measure. You can also specify one vertex or two vertices to get the coordinates of the vertex or the distance between the two vertices, respectively. The available selection methods are described in Geometry Object Selection Methods.

`model.component(<ctag>).geom(<tag>).measure().geomMeasurementMethod` returns the volume, area, length, vertex coordinates, or distance between two vertices according to the selection. The available measurement methods are described in Geometry Object Information.

Use `model.component(<ctag>).geom(<tag>).measureFinal().selection().selMethod` to specify the domains, boundaries, or edges in the finalized geometry that you want to measure. You can also specify one vertex or two vertices to get the coordinates of the vertex or the distance between the two vertices, respectively. The available selection methods are described in `model.selection()`.

`model.component(<ctag>).geom(<tag>).measureFinal().geomMeasurementMethod` returns the volume, area, length, vertex coordinates, or distance between two vertices according to the selection. The available measurement methods are described in Measurements.

Use `model.component(<ctag>).geom(<tag>)).measureFinal().mesh(<mtag>))` to select the mesh with tag *mtag*, when the analyzed geometry is based on an imported mesh, for example, so that measurements are relative to this mesh in its current state. Then, for example, to select domain 1 in a 2D geometry `geom1` and make measurements on the analyzed geometry (for the physics), use the following code:

```
model.component("comp1").geom("geom1").measureFinal().geom(2).set(1);
model.component("comp1").geom("geom1").measureFinal().mesh("");
```

Exporting Geometry Objects

`model.component(<ctag>).geom(<tag>).export().selection().selMethod` can be used to select a number of geometry objects to export to file. The available selection methods are described in Geometry Object Selection Methods.

`model.component(<ctag>).geom(<tag>).export(<filename>)` exports the selected objects to a file.

`model.component(<ctag>).geom(<tag>).exportFinal(<filename>)` exports the finalized geometry to a file.

CAD Defeaturing

If you have a license for the CAD Import Module, or a LiveLink™ product for CAD software, the following functionality is available. For details, see the *CAD Import Module User's Guide*.

`model.component(<ctag>).geom(<tag>).defeaturing(tooltag).defeaturingMethod` uses a defeaturing tool to create a feature that deletes small details. Available tools are listed in the *CAD Import Module User's Guide*.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).find()` searches for small details, for a defeaturing feature *<ftag>*.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).detail().selMethod` manipulates the selection of details to remove, for a defeaturing feature *<ftag>*.

Geometry Object Selection Methods

For a geometry object selection `sel`, the following methods are available:

`sel.init()` sets the selection to be a selection of whole geometry objects. Subsequent calls to `set`, `add`, and `remove` select objects.

`sel.init(dim)` sets the selection property to be a selection of geometric entities of dimension *dim*. Subsequent calls to `all`, `set`, `add`, `remove`, and `clear` select entities.

The following three methods are applicable when the selection consists of whole objects. The argument *<onames>* can be an array of strings, or several string arguments.

`sel.set(<onames>)` sets the selection to be the objects *<onames>*.

`sel.add(<onames>)` adds the objects *<onames>* to the selection.

`sel.remove(<onames>)` removes the objects *<onames>* from the selection.

The following five methods are applicable when the selection consists of geometric entities. The argument *<entities>* can be an array of integers, or several integer arguments.

`sel.all(`*<oname>*`)` sets the selection to be all the entities of object *<oname>*. The selections on other objects are not affected.

`sel.set(`*<oname>*`, `*<entities>*`)` sets the selection on object *<oname>* to be *<entities>*. The selections on other objects are not affected.

`sel.add(`*<oname>*`, `*<entities>*`)` adds the entities *<entities>* to the selection on object *<oname>*. The selections on other objects are not affected.

`sel.remove(`*<oname>*`, `*<entities>*`)` removes the entities *<entities>* from the selection on object *<oname>*. The selections on other objects are not affected.

`sel.clear(`*<oname>*`)` clears the selection on object *<oname>*. The selections on other objects are not affected.

To let the selection be defined by a named selection, use:

`sel.named(`*<seltag>*`)` where *<seltag>* is the trimmed tag of a named selection defined by a preceding feature in the geometry sequence. See `Selections of Geometric Entities` for more information.

To get information about the selection, use:

`String[] onames = sel.objects()` returns the names of the selected objects.

`int dim = sel.dimension()` returns the dimension for the entities in the selection if the selection consists of geometric entities.

`int[] ent = sel.entities(`*<oname>*`, `*dim*`)` returns the entities in the selection on object *<oname>* if the selection consists of geometric entities.

`String[] seltag = sel.named()` returns the trimmed tag of the named selection that this selection refers to, or an empty string if the selection does not refer to a named selection.

If Statements

Use `model.geom(<tag>).create(`*<ftag>*`,`*<type>*`)` to add an If, Else If, Else, or End If feature after the current feature.

Use `model.geom(<tag>).createAfter(`*<ftag>*`,`*<type>*`,`*<postag>*`)` to add an If, Else If, Else, or End If feature after the feature tagged *<postag>*.

Insert Sequence

`model.geom(`*<tag>*`).insertFile(`*<filename>*`,`*<gtag>*`)`; inserts a geometry sequence, with tag *<gtag>*, from another model file , with file name *<filename>*, into the geometry sequence with tag *<tag>*.

`model.geom(`*<tag>*`).insertSequence(`*<mtag>*`,`*<gtag>*`)`; inserts a geometry sequence, with tag *<gtag>*, from another model, with tag *<mtag>*, into the current geometry sequence with tag *<tag>*.

EXAMPLE

Create a 2D geometry model as the union of a circle and rectangle.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g =model.component("comp1").geom().create("geom1",2);
g.create("r1","Rectangle");
g.feature("r1").set("size",new double[]{0.5,1});
g.feature("r1").set("pos",new double[]{-1,0});
g.create("c1","Circle");
```

```
g.feature("c1").set("r",0.5);
g.feature("c1").set("pos",new double[]{0.5,0});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component().create('comp1');
g =model.component('comp1').geom.create('geom1',2);
g.create('r1','Rectangle');
g.feature('r1').set('size',[0.5,1]);
g.feature('r1').set('pos',[-1,0]);
g.create('c1','Circle');
g.feature('c1').set('r',0.5);
g.feature('c1').set('pos',[0.5,0]);
g.run;
```

COMPATIBILITY

From version 5.1, the access method `argument()` is deprecated and replaced with `inputParam()`, and the access method `param()` is deprecated and replaced with `localParam()`. The methods `link(…)`, `linked()`, and `relink()` are deprecated and replaced with `load(…)`, `loaded()`, and `reload()`, respectively.

From version 4.4, the method

```
model.geom(<tag>).runAll();
```

is deprecated. Instead, use

```
model.component(<ctag>).geom(<tag>).run(<ftag>);
```

to specify to which feature node in the geometry sequence you wan to run.

From version 4.3a, the methods

```
model.geom(<tag>).object(<objname>)
String[] onames = sel.object()
```

are deprecated and replaced by the following methods:

```
model.component(<ctag>).geom(<tag>).obj(<objname>)
String[] onames = sel.objects()
```

SEE ALSO

`model.mesh()`

model.group()

Add load groups and constraint groups.

SYNTAX

```
model.group().create(<tag>,type);
model.group(<tag>).identifier(<id>);

model.group(<tag>).type();
model.group(<tag>).identifier();
```

DESCRIPTION

`model.group().create(<tag>,type)` creates a new group of the specified type, which can be either `LoadGroup` or `ConstraintGroup`.

`model.group(<tag>).identifier(<id>)` sets the group identifier, which is used for defining a corresponding parameter, `group.<id>`.

`model.group(<tag>).type()` returns the group type as a string.

`model.group(<tag>).identifier()` returns the group identifier.

model.init()

Creating and defining initial values.

SYNTAX

```
model.init().create(<tag>);
model.init(<tag>).set(<fieldname>,<expr>);
model.init(<tag>).remove(<fieldname>);

model.init(<tag>).varnames();
model.init(<tag>).get(<fieldname>);
```

DESCRIPTION

`model.init().create(<tag>)` creates a new initial value with tag *<tag>*.

`model.init(<tag>).set(<fieldname>,<expr>)` defines the expression *<expr>* as the initial value for the dependent variable (field variable) *<fieldname>*.

`model.init(<tag>).remove(<fieldname>)` removes the field variable *<fieldname>* from the initial value with tag *<tag>*.

`model.init(<tag>).selection().named(<seltag>)` assigns the initial value to the named selection *<seltag>*. `model.init(<tag>).selection().set(...)` defines a local selection that assigns the initial value to geometric entities. For a complete list of methods available under `selection()`, see `Selections`. Only selections at a single geometry level is allowed except for ODE states which require the global selection.

`model.init(<tag>).varnames()` returns the names of the variables for the initial value with tag *<tag>* as a string array.

`model.init(<tag>).get(<fieldname>)` returns the initial value for the field variable *<fieldname>* as a string.

`model.init(<tag>).selection().named()` returns the named selection tag.

`model.init(<tag>).selection().get`*`Type`*`()` returns domain information for the initial value with tag *<tag>*; see `Selections` for available methods.

model.intRule()

Integration rules.

SYNTAX

```
model.intRule().create(<tag>,<ftag>);
model.intRule(<tag>).frame(<ftag>);
model.intRule(<tag>).create(<ftag>);
model.intRule(<tag>).feature(<ftag>).order(gporder);
model.intRule(<tag>).feature(<ftag>).getAllowedPropertyValues(property);
model.intRule(<tag>).frame();
```

DESCRIPTION

`model.intRule().create(<tag>,<ftag>)` creates an integration rule for the frame *<ftag>*.

`model.intRule(<tag>).frame(<ftag>)` sets the frame for the integration rule.

`model.intRule(<tag>).create(<ftag>)` creates an integration rule feature.

`model.intRule(<tag>).feature(<ftag>).order(gporder)` specifies the integration order of the integration rule.

`model.intRule(<tag>).frame()` returns the frame as a string.

`model.intRule(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

EXAMPLE

Specify two integration rules, one with the integration order 2 and one with the integration order 4.

Code for Use with Java

```
model.intRule().create("ir1","f");
model.intRule("ir1").create("ir1").order(2);
model.intRule("ir1").create("ir2").order(4);
```

Code for Use with MATLAB

```
model.intRule.create('ir1','f');
model.intRule('ir1').create('ir1').order(2);
model.intRule('ir1').create('ir2').order(4);
```

SEE ALSO

`model.shape()`

model.massProp()

Compute mass properties and add mass contributions.

SYNTAX

```
model.component(<ctag>).massProp().create(<tag>,"MassProperties");
model.component(<ctag>).massProp(<tag>).selection();
model.component(<ctag>).massProp(<tag>).set(<pname>,<expr>);
model.component(<ctag>).massProp(<tag>).image();

model.component(<ctag>).massProp(<tag>).create(<mctag>, "MassContributions");
model.component(<ctag>).massProp(<tag>).feature(<mctag>).selection()
model.component(<ctag>).massProp(<tag>).feature(<mctag>).set(<pname>,<expr>);
```

DESCRIPTION

Creating Mass Properties and Providing Geometry Source Selections

`model.component(<ctag>).massProp().create(<tag>,“MassProperties”)` creates a mass properties object that computes variables for mass properties such as total mass and the center of mass.

`model.component(<ctag>).massProp(<tag>).selection().set(...)` defines a local selection that assigns the mass properties to geometric entities that act as sources. For a complete list of methods available under `selection()`, see `model.selection()`.

Specifying Density and Mass Properties

You can specify the density to be taken from a physics. For example,

```
model.component(<ctag>).massProp(<tag>).set("densitySource", "fromSpecifiedPhysics")
model.component(<ctag>).massProp(<tag>).feature("mc1").set("physics", "solid");
```

takes the density from the Solid Mechanics interface `solid`.

You can also specify a user-defined density. For example, to specify the density to be 1107 $\mathrm{kg/m^3}$, use

```
model.component(<ctag>).massProp(<tag>).set("densitySource", "userDefined");
model.component(<ctag>).massProp(<tag>).set("expr","1107[kg/m^3]");
```

To create variables for the center of mass and to not create variables for the moment of inertia:

```
model.component(<ctag>).massProp(<tag>).set("createCenterOfMass","on");
model.component(<ctag>).massProp(<tag>).set("createMomentOfInertia","off");
```

Adding a Mass Contribution

You can add mass contributions from other parts of the geometry (an adjacent boundary, for example) by creating a mass contribution:

```
model.component(<ctag>).massProp(<tag>).create("mc1","MassContributions");
model.component(<ctag>).massProp(<tag>).feature("mc1").set("expr", "3");
```

For the mass contributions, you can specify source selections and define the density in the same way as for the mass properties.

Properties and Variables for massProp

The `massProp` feature accepts the following properties:

TABLE 2-81: MASSPROP PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`createCenterOfMass`	`on|off`	`on`	Create center of mass variables.
`createMass`	`on|off`	`on`	Create mass variable.
`createMassContribution`	`on|off`	`on`	Add a mass contribution.
`createMomentOfInertia`	`on|off`	`on`	Create moment of inertia variables.
`createPrincipalInertia`	`on|off`	`on`	Create principal moment of inertia variables.
`createVolume`	`on|off`	`on`	Create volume variable.
`densitySource`	`fromSpecifiedPhysics|userDefined`	`userDefined`	Source for the density values.
`expr`	string		User-defined density expression.
`includeLowerPh`	`on|off`	`on`	Include adjacent entities of lower dimension for density values taken from physics.
`densityFrame`	frame	Material	Integration frame for user-defined density.
`intorder`	4	Positive integer	Integration order.
`outputFrame`	frame	Material	Integration frame for output variables.

The created variables for different mass properties have the following default names:

- `mass1.mass` and `mass1.volume` for the mass and volume, respectively.
- `mass1.CM`*`X`*, and so on, for the coordinates of the center of mass.
- `mass1.I`*`XY`*, and so on, for the components of the moment of inertia.
- `mass1.Ip`*`1`*, and so on, for the moment of inertia principal values.
- `mass1.Ip`*`1X`*, and so on, for the moment of inertia principal directions.

model.material()

Materials and material property groups.

For materials defined on the global level, omit `component(<ctag>).` from the syntax such as `model.component(<ctag>).material().create(<tag>)` in the syntax examples below.

SYNTAX

```
model.component(<ctag>).material().create(<tag>);
model.component(<ctag>).material().create(<tag>,<type>);
model.component(<ctag>).material(<tag>).info(<itag>);
model.component(<ctag>).material(<tag>).info();
model.component(<ctag>).material(<tag>).label(<label>);
model.component(<ctag>).material(<tag>).materialType(<mattype>)
model.component(<ctag>).material(<tag>).propertyGroup(<mtag>);
model.component(<ctag>).material(<tag>).propertyGroup();
model.component(<ctag>).material(<tag>).prefix(<prefix>);
model.component(<ctag>).material(<tag>).prefix();
model.component(<ctag>).material(<tag>).selection();
model.component(<ctag>).material(<tag>).image();
model.component(<ctag>).material(<tag>).set(<pname>,<expr>);
model.component(<ctag>).material().move(<tag>,<position>);

MaterialModel mm = model.component(<ctag>).material(<tag>).propertyGroup().
                   create(<mtag>,<descr>);
mm.addInput(<quantity>);
mm.descr(<pname>,<descr>);
mm.func();
mm.func(<ftag>);
mm.getString(<pname>);
mm.getStringArray(<pname>);
mm.hasParam(<pname>);
mm.info(<itag>);
mm.info();
mm.input();
mm.isOutput(<pname>);
mm.param();
mm.removeInput(<quantity>);
mm.set(<pname>,<expr>);
mm.size(<pname>);
mm.suffix(<suffix>);
mm.suffix();

mm.info().create(<itag>,<descr>);
mm.info(<itag>).title(<title>);
mm.info(<itag>).title();
mm.info(<itag>).body(<body>);
mm.info(<itag>).body();
```

DESCRIPTION

A material is a collection of property groups, where each property group defines a set of material properties, material functions, and model inputs that can be used to define a temperature-dependent material property, for example. A property group usually defines properties used by a particular material model to compute a fundamental quantity. A material property can either be a visible output property or a local parameter. The output property is visible for physics interfaces; local properties are only visible inside the property group. If two property groups define the same output property, the last property group determines the value of the output property. The material function is used by the property group to calculate a property or parameter value as a function of other variables, usually model inputs. The model input is a quantity that the material model recognizes as an input variable (temperature, for

example). The actual variable that represents the model input is not known until the model is solved, and it can also be different between physics interfaces.

There are two types of property groups, user-defined and specialized. When a material is created, there is always one default user-defined property group present. To this property group it is possible to add output properties from a predefined list of quantities. These quantities are recognized by all physics interfaces as material properties — for example, thermal conductivity, electric conductivity, and density. The full list is presented in the physics interface for the default property group. The specialized property groups are built in and usually define few output properties that only some physics interfaces can access. These output properties are not necessarily part of the allowed properties for the default property group. An example of such a specialized group is the refractive index material model, which defines the real and imaginary part of the refractive index as output properties. These properties can only be accessed by the Electromagnetic Waves interface.

`model.component(`*<ctag>*`).material().create(`*<tag>*`)` creates a new material for the model component with the tag *<ctag>*.

`model.component(`*<ctag>*`).material().create(`*<tag>*`,"Common")` also creates a new material for the model component with the tag *<ctag>*.

`model.component(`*<ctag>*`).material().create(`*<tag>*`,"Switch")` creates a material switch for the model component with the tag *<ctag>*. You can add materials to the material switch:

```
model.component(<ctag>).material().create("sw1", "Switch", "");
model.component(<ctag>).material("sw1").feature().create("mat1", "Common", "");
model.component(<ctag>).material("sw1").feature().create("mat2", "Common", "");
```

`model.component(`*<ctag>*`).material().create(`*<tag>*`,"Link")` creates a material link for the model component with the tag *<ctag>*.

`model.component(`*<ctag>*`).material().create(`*<tag>*`,"External")` creates a external material that sets up an interface between a physics feature and functions in an external shared library (a DLL, .so, or .dylib file.). For an external material,
`model.component(`*<ctag>*`).material(`*<tag>*`).set("path",`*<path to external material file>*`)` sets the path to the external shared library. Also, use `model.material(`*<tag>*`).set("threadSafe", "off")`if the DLL is not thread safe (default is, `"on"`; that is, the DLL is thread safe).

`model.material().create(`*<tag>*`,`*<type>*`)` creates a global material, material switch, or material link.

`model.component(`*<ctag>*`).material(`*<tag>*`).info(`*<itag>*`)` returns an information item for a material.

`model.component(`*<ctag>*`).material(`*<tag>*`).input()` returns the list of model inputs.

`model.component(`*<ctag>*`).material(`*<tag>*`).materialType("solid")` or
`model.component(`*<ctag>*`).material(`*<tag>*`).materialType("nonSolid")`sets the material type to a solid or a nonsolid material, respectively.

`model.component(`*<ctag>*`).material(`*<tag>*`).propertyGroup(`*<mtag>*`)` gets the property group named *<mtag>* for the material.

`model.component(`*<ctag>*`).material(`*<tag>*`).selection()` returns the selection of the material. The selection determines which geometry the material belongs to.

`model.component(`*<ctag>*`).material(`*<tag>*`).set("family",`*<appearance>*`)` sets the appearance to a family of materials (as strings; `"water"`, for example): `air`, `aluminum`, `brick`, `concrete`, `copper`, `gold`, `iron`, `lead`,

magnesium, plastic, steel, titanium, water, or custom. With custom, you can set these additional parameters for the appearance:

TABLE 2-82: PROPERTIES FOR CUSTOM APPEARANCE OF MATERIALS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
alpha	double	1	Diffuse and ambient color opacity
ambient	string[] (a color or custom)	custom	Ambient light color
customambient	double[]		RGB values for a custom ambient color
customdiffuse	double[]		RGB values for a custom diffuse color
customspecular	double[]		RGB values for a custom specular color
diffuse	string[] (a color or custom)	custom	Diffuse light color
fresnel	double	0.5	Reflectance at normal incidence for Cook-Torrance
lighting	phong | cooktorrance | simple	phong	Lighting model
noise	on | off	off	Add noise to the appearance
noisefreq	double[]	1	Normal vector noise scale
noisescale	double[]	0	Normal vector noise scale
roughness	double	0.1	Surface roughness for Cook-Torrance lighting model
shininess	double	64	Specular exponent for Blinn-Phong lighting model
specular	string[] (a color or custom)	custom	Specular light color

`model.component(<ctag>).material().move(<tag>,<position>)` moves the material *<tag>* to the zero-indexed position *<position>* in the list.

For a material link, `model.component(<ctag>).material(<tag>).set("link", <linktag>);` creates a material link from a component to the global material with the tag in *<linktag>*. For example,

```
model.component("comp1")).material().create("matlnk1", "Link");
model.material("matlnk1").set("link", "mat1");
```

creates a material link in the component `comp1` and then links it to the global material `mat1`. The material link can also have a selection; for example, `model.material("matlnk1").selection().all();`.

Property Groups

The following syntax examples describe the methods available for property groups added to a material (not available for material switches or material links).

`mm = model.component(<ctag>).material(<tag>).propertyGroup().create(<tag>,<descr>)` creates a new property group and stores it in the variable `mm`.

To define a method to set an output property of a material, use the following syntax (in this example you specify a density for the basic property group `def`):

```
model.compoenent(<ctag>).material("mat1").propertyGroup("def").
set("density", String[] arg);
```

where `arg` is the string value to be defined. For a list of available physical property names (such as `density`), see Table 2-83.

`mm.addInput(<quantity>)` adds a new model input to the property group of the given quantity.

`mm.descr(<pname>,<descr>)` adds the description `<descr>` to the local material property with the name `<pname>`.

`mm.func(<ftag>)` returns the function object named `<ftag>`. For information about how to add and modify functions, see `model.func()`.

`mm.getString(<pname>)` returns the string value of the given parameter. If it is a vector or matrix quantity, the first value is returned.

`mm.getStringArray(<pname>)` returns the string array value of the given parameter. Matrix values are returned in a column-wise order.

`mm.hasParam(<pname>)` returns true if the parameter is defined by the property group.

`mm.info(<itag>)` returns the information object for the property group.

`mm.isOutput(<pname>)` returns true if the given local material parameter is an output property. For user-defined property groups the method returns true for all predefined material properties known to all physics interfaces. For the specialized property groups, it can also return true for other properties.

`mm.param()` returns a list of all parameters stored in the property group.

`mm.removeInput(<quantity>)` removes the given quantity from the list of model inputs.

`mm.set(<pname>,<expr>)` sets the expression for the given property. The expression can use local names for the properties, parameters, and model inputs. For vector and matrix properties, the expression can be string arrays of varying size. Isotropic matrices only require one element or a string, diagonal matrices require three elements, and so forth. Vectors always require three elements.

`mm.size(<pname>)` returns the size of the stored parameter, which usually is 1-by-1, 3-by-1, or 3-by-3, but other sizes are supported.

`model.component(<ctag>).material(<tag>).propertyGroup()` returns a list of all property groups in the material.

`model.component(<ctag>).material(<tag>).propertyGroup(<tag>).info().create(<tag>,<descr>)` creates a new information object that can contain detailed information about this property group. This could, for example, be used by the Material Library to define the Phase/Condition and Orientation/Condition fields.

`mm.info(<itag>).title(<title>)` sets the title of the information object.

`mm.info(<itag>).title()` returns the title.

`mm.info(<itag>).body(<body>)` sets the body text of the information object.

`mm.info(<itag>).body()` returns the body text.

The term *material model* is sometimes used instead of *property group* in some contexts. The graphical user interface uses the term property group.

TABLE 2-83: AVAILABLE PHYSICAL QUANTITIES

PHYSICAL QUANTITY	NAME
Absorbed dose	absorbeddose
Absorption coefficient	absorption
Acceleration	acceleration
Activation energy	activationenergy
Angular acceleration	angularacceleration

TABLE 2-83: AVAILABLE PHYSICAL QUANTITIES

PHYSICAL QUANTITY	NAME
Angular frequency	angularfrequency
Area	area
Bulk viscosity	bulkviscosity
Capacitance	capacitance
Catalytic activity	catalyticactivity
Characteristic acoustic impedance	acousticimpedance
Charge	charge
Coefficient of hygroscopic swelling	hygroscopicswellingcoefficient
Coefficient of thermal expansion	thermalexpansioncoefficient
Collisional power loss	inelasticpowerloss
Compliance	compliance
Compressibility of fluid	compressibility
Concentration	massconcentration
Concentration	concentration
Conductance	conductance
Corrected pressure	correctedpressure
Corrected velocity field	correctedvelocity
Current	current
Current density	currentdensity
Current source	currentsource
Damping constant per unit area	dampingconstantperarea
Damping constant per unit length	dampingconstantperlength
Damping constant per unit volume	dampingconstantpervolume
Density	density
Diffusion coefficient	diffusion
Dimensionless	dimensionless
Dipole moment	dipolemoment
Dispersed phase volume fraction	dispersedphasevolumefraction
Displacement field	displacement
Displacement of shell normals	dimensionless_displacement
Dose equivalent	doseequivalent
Dynamic viscosity	dynamicviscosity
EEDF	eedf
Edge load	edgeload
Effective gas density	effectivegasdensity
Effective plastic strain	effectiveplasticstrain
Elasticity	elasticity
Elastoresistive coupling	couplingelastoresistive
Electric displacement field	displacementfield
Electric field	electricfield
Electric permittivity	permittivity

TABLE 2-83: AVAILABLE PHYSICAL QUANTITIES

PHYSICAL QUANTITY	NAME
Electric potential	electricpotential
Electrical conductivity	electricconductivity
Electrolyte conductivity	electrolyteconductivity
Electrolyte potential	electricpotentialionicphase
Electron density	electrondensity
Electron energy density	electronenergydensity
Electron mobility	electronmobility
Energy	energy
Energy density	energydensity
Entropy	entropydensity
External free energy	externalfreeenergy
Extinction coefficient	extinctioncoefficient
Face load	faceload
Flow rate out from source per unit length	areapertime
Flow resistivity	pressuretimeperarea
Fluid conductance	fluidconductance
Force density	forcedensity
Force load	force
Force potential	forcepotential
Fowler-Nordheim coefficient	fowlernordheimcoefficient
Frequency	frequency
Frequency factor	frequencyfactor
Head	head
Heat capacity at constant pressure (molar)	molarheatcapacity
Heat capacity at constant pressure	heatcapacity
Heat source	powerdensity
Heat transfer coefficient	heattransfercoefficient
Henry's constant	henrysconstant
Hydraulic conductivity	hydraulicconductivity
Inductance	inductance
Initial curvature	planeangleperlength
Initial electron density	initialelectrondensity
Intensity (RMS)	intensity
Inward heat flux	heatflux
Isotropic structural loss factor	lossfactor
Kinematic viscosity	kinematicviscosity
Length	length
Level set variable	levelsetvariable
Line charge	linecharge
Line current source	linecurrentsource
Log mass fraction	logmassfraction

TABLE 2-83: AVAILABLE PHYSICAL QUANTITIES

PHYSICAL QUANTITY	NAME
Log of electron density	logelectrondensity
Log of electron energy density	logelectronenergydensity
Logarithmic ratio	logarithmicratio
Logarithmic ratio per unit length	logarithmicratioperunitlength
Luminous intensity	luminousintensity
Magnetic field	magneticfield
Magnetic flux	magneticflux
Magnetic flux density	magneticfluxdensity
Magnetic permeability	permeability
Magnetic scalar potential	magneticscalarpotential
Magnetic vector potential	magneticvectorpotential
Mass	mass
Mass flow	massflow
Mass flux	massflux
Mass fraction	massfraction
Mass per unit area	massperarea
Mass per unit length	massperlength
Mass source	masssource
Mass transfer coefficient	masstransfercoefficient
Mean electron energy	meanelectronenergy
Mean flow velocity potential	meanflowvelocitypotential
Mean molar mass	molarmass
Molar enthalpy	energyperamount
Molar flux	molarflux
Molar surface flux	molarsurfaceflux
Molar volume	molarvolume
Moment body load	torquepervol
Moment edge load	torqueperlength
Moment face load	torqueperarea
Natural logarithmic ratio	naturallogarithmicratio
Natural logarithmic ratio per unit length	naturallogarithmicratioperunitlength
Normal electron current density	normalelectroncurrentdensity
Normal ion current density	normalioncurrentdensity
Number density	numberdensity
Particle momentum	momentum
Particle position	position
Permeability	hydraulicpermeability
Phase field help variable	phasefieldhelpvariable
Phase field variable	phasefieldvariable
Piezoelectric coupling d (strain-charge)	couplingstraincharge
Piezoelectric coupling e (stress-charge)	couplingstresscharge

TABLE 2-83: AVAILABLE PHYSICAL QUANTITIES

PHYSICAL QUANTITY	NAME
Piezoresistive coupling	couplingpiezoresistive
Plane angle	planeangle
Point current source	pointcurrentsource
Poiseuille coefficient	poiseuillecoefficient
Poisson's ratio	poissonsratio
Porosity	porosity
Power	power
Power flow	powerflow
Power per unit charge	powerpercharge
Power per unit length	powerpermeter
Power per unit mass	powerpermass
Pressure	pressure
Production rate	productionrate
Production/absorption coefficient	heatproduction
Radiative intensity	radiativeintensity
Radioactivity	radioactivity
Ratio of specific heats	ratioofspecificheat
Reaction rate	reactionrate
Reciprocal area	reciprocalarea
Reciprocal initial interface distance	reciprocallength_i
Reciprocal wall distance	reciprocallength
Recombination rate (domain)	recombinationratedomain
Reduced electric field	reducedelectricfield
Reduced electron diffusivity	reduceddiffusivity
Reduced electron mobility	reducedmobility
Relative permeability	relpermeability
Relative permittivity	relpermittivity
Resistance	resistance
Resistivity	resistivity
Scattering coefficient	scattering
Secondary emission energy flux	energyflux
Secondary emission flux	particleflux
Seebeck coefficient	seebeckcoefficient
Solid angle	solidangle
Space charge density	spacechargedensity
Specific dissipation rate	specificdissipationrate
Specific energy	specificenergy
Speed of sound	soundspeed
Spring constant per unit area	springconstantperarea
Spring constant per unit length	springconstantperlength
Spring constant per unit volume	springconstantpervolume

TABLE 2-83: AVAILABLE PHYSICAL QUANTITIES

PHYSICAL QUANTITY	NAME
Squared slip velocity	slipvelocity
Storage	storage
Strain energy per unit area	energydensityperarea
Strain energy per unit length	energydensityperlength
Strain reference temperature	strainreferencetemperature
Stress tensor	stress
Substance	substance
Surface capacitance	surfacecapacitance
Surface charge density	surfacechargedensity
Surface current density	surfacecurrentdensity
Surface electrical conductivity	surfaceconductivity
Surface emissivity	emissivity
Surface energy density	surfaceenergydensity
Surface magnetic current density	surfacemagneticcurrentdensity
Surface resistance	surfaceresistance
Surface site concentration	surfaceconcentration
Surface tension coefficient	surfacetensioncoefficient
Temperature	temperature
Thermal conductivity	thermalconductivity
Time	time
Time change in pressure head	timechangeinpressurehead
Torque	torque
Total damping constant	dampingconstant
Total spring constant	springconstant
Trap density distribution (boundary)	trapdensityboundary
Trap density distribution (domain)	trapdensitydomain
Turbulent dissipation rate	turbulentdissipationrate
Turbulent kinetic energy	turbulentkineticenergy
Undamped turbulent kinematic viscosity	turbulentkinematicviscosity
Velocity field	velocity
Velocity potential	velocitypotential
Volume	volume
Volume fraction	volumefraction
Volume per time	volumepertime
Volumetric heat capacity	volumetricheatcapacity
Wave number	wavenumber
Wavelength	wavelength
Young's modulus	youngsmodulus

SEE ALSO

`model.func()`, `model.physics()`

Meshing sequences.

SYNTAX

```
model.component(<ctag>).mesh().create(<tag>,<gtag>);
model.component(<ctag>).mesh().remove(<tag>);
model.component(<ctag>).mesh(<tag>).create(<ftag>,operation);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag2>,operation);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature().meshMethod
model.component(<ctag>).mesh(<tag>).current(<ftag>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).active(boolean);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).isActive();
model.component(<ctag>).mesh(<tag>).feature().move(<ftag>,<position>);
model.component(<ctag>).mesh(<tag>).feature().remove(<ftag>);
model.component(<ctag>).mesh(<tag>).feature(<fgtag>).getAllowedPropertyValues(property);
model.component(<ctag>).mesh(<tag>).feature().image();
model.component(<ctag>).mesh(<tag>).clearMesh();
model.component(<ctag>).mesh(<tag>).geom();
model.component(<ctag>).mesh(<tag>).image();

model.component(<ctag>).mesh(<tag>).run(<ftag>);
model.component(<ctag>).mesh(<tag>).run();
model.component(<ctag>).mesh().run();

model.component(<ctag>).mesh(<tag>).current();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).status();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).message();

model.component(<ctag>).mesh(<tag>).meshGetMethod
model.component(<ctag>).mesh(<tag>).data().meshModificationMethod
model.component(<ctag>).mesh(<tag>).stat().meshStatisticsMethod

model.component(<ctag>).mesh(<tag>).export(<filename>);
```

DESCRIPTION

Creating and Deleting a Meshing Sequence

`model.component(<ctag>).mesh().create(<tag>,<gtag>)` creates a meshing sequence (or just mesh) for the geometry sequence *<gtag>* and assigns it the tag *<tag>*.

`model.component(<ctag>).mesh().remove(<tag>)` removes the meshing sequence *<tag>*.

Creating, Editing, and Deleting Features

`model.component(<ctag>).mesh(<tag>).create(<ftag>,operation)` adds a feature *<ftag>* of type *operation* to the meshing sequence *<tag>*, after the current feature.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>)` sets the property *property* defined for the feature *<ftag>* to the value *<value>*. All data types listed in Table 2-2 are supported; the applicable data types differ between the properties. String expressions can use parameters from `model.param()`.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property)` returns the value of a property in the feature *<ftag>*.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().selMethod` manages the selection of the feature *<ftag>*. The available selection methods are described in Selection Methods.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection(property).selMethod` manipulates the selection of the property *property*. The available selection methods are described in Selection Methods.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature().meshMethod` manages the entity list for the feature *<ftag>*.

`model.component(<ctag>).mesh(<tag>).current(<ftag>)` sets the current feature to be *<ftag>*.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).active(false)` disables the feature *<ftag>*.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).active(true)` enables the feature *<ftag>*.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>).isActive()` returns `true` if the feature *<ftag>* is enabled, and `false` otherwise.

`model.component(<ctag>).mesh(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

`model.component(<ctag>).mesh(<tag>).feature().move(<ftag>,<position>)` moves the feature *<ftag>* to the zero indexed position *<position>* in the sequence.

`model.component(<ctag>).mesh(<tag>).feature().remove(<ftag>)` removes the feature *<ftag>*.

`model.component(<ctag>).mesh(<tag>).clearMesh()` removes all features from the sequence and clears the mesh.

Building Features

After each build operation, the current feature is set as the last of features that were built. The mesh is updated to be the mesh generated by these features.

`model.component(<ctag>).mesh(<tag>).run(<ftag>)` builds all features up to (and including) the feature *<ftag>*.

`model.component(<ctag>).mesh(<tag>).run()` builds all features.

`model.component(<ctag>).mesh().run()` builds all meshing sequences.

Getting Build Status

`String fTag = model.component(<ctag>).mesh(<tag>).current()` returns the tag of the current feature. If the current state is before the first feature, the empty string `""` is returned.

`String status = model.component(<ctag>).mesh(<tag>).feature(<ftag>).status()` returns the status of the feature *<ftag>*. The status is `built`, `warning`, `needs_rebuild`, `edited`, or `error`.

`String msg = model.component(<ctag>).mesh(<tag>).feature(<ftag>).message()` returns the warning/error message of the feature *<ftag>*.

Getting and Setting Mesh Data

`model.component(<ctag>).mesh(<tag>).meshGetMethod` gets mesh data from the mesh *<tag>*. The available methods are described in Accessing Mesh Data.

`model.component(<ctag>).mesh(<tag>).data().meshModificationMethods` are used to modify mesh data on a low level. You can access and modify individual elements. The available methods are described in Accessing Mesh Data.

`model.component(<ctag>).mesh(<tag>).data().createMesh()` transfers the manipulated data into to the mesh *<tag>*.

Mesh Statistics

`model.component(<ctag>).mesh(<tag>).stat().selection().selMethod` can be used to select a number of geometric entities for which statistics is wanted. The available selection methods are described in Selection Methods.

`model.component(<ctag>).geom(<tag>).stat().meshStatisticsMethod` returns mesh statistics about the selected geometric entities. The available methods are described in Information and Statistics.

Exporting a Mesh to File

`model.component(<ctag>).mesh(<tag>).export(<filename>)` exports the mesh `<tag>` to an `mphbin` or `mphtxt` file.

Plotting a Mesh

Use the `model.component(<ctag>).mesh(<tag>).image()` and `model.component(<ctag>).mesh(<tag>).feature().image()` methods to plotting and exporting mesh images. See Plotting and Exporting Images.

Selection Methods

`selection.allGeom()` sets the selection to be the entire geometry (that is, all geometric entities).

`selection.remaining()` sets the selection to be the geometric entities that remains to be meshed when the feature is about to be built.

selection.geom(`<dim>`)`.all()` sets all geometric entities in dimension `<dim>`.

`selection.geom(<dim>).set(<entities>)` sets the selection to be the geometric entities specified in the integer array `<entities>` in dimension `<dim>`.

`selection.geom(<dim>).add(<entities>)` adds the geometric entities specified in the integer array `<entities>` in dimension `<dim>` to the selection.

`selection.geom(<dim>).remove(<entities>)` removes the geometric entities specified in the integer array `<entities>` in dimension `<dim>` from the selection.

`selection.geom(<dim>).clear()` clears the selection.

To access the selections use:

`int[] dims = selection.dimension()` returns the geometric entity level in `dims[0]` for the entities in the selection. If `dims` is empty the selection defines the entire geometry.

`selection.isRemaining()` returns true if the selection specifies the remaining entities, otherwise false.

`selection.dom(<dim>)` returns the geometric entities in dimension `<dim>` for the selection.

Getting the Geometry Tag

`model.mesh(<tag>).geom()` returns the geometry tag. This can be useful when working with several geometries in the same model.

EXAMPLE

Create a 2D geometry by the union of a circle and square. Build a triangle mesh with `hmax` = 0.1 in domains 1 and 3, and `hmax` = 0.01 in domain 2.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");
```

```
g.create("c1", "Circle");
g.create("sq1", "Square");
g.create("uni1", "Union");
g.feature("uni1").selection("input").set(new String[]{"c1", "sq1"});
m.create("size1", "Size");
m.feature("size1").selection().geom(2).set(new int[]{1, 3});
m.feature("size1").set("hmax", "0.1");
m.create("size2", "Size");
m.feature("size2").selection().geom(2).set(new int[]{2});
m.feature("size2").set("hmax", "0.025");
m.create("ftri1", "FreeTri");
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('c1', 'Circle');
g.create('sq1', 'Square');
g.create('uni1', 'Union');
g.feature('uni1').selection('input').set({'c1', 'sq1'});
m.create('size1', 'Size');
m.feature('size1').selection.geom(2).set([1, 3]);
m.feature('size1').set('hmax', '0.1');
m.create('size2', 'Size');
m.feature('size2').selection.geom(2).set(2);
m.feature('size2').set('hmax', '0.025');
m.create('ftri1', 'FreeTri');
m.run;
```

SEE ALSO

`model.geom()`

model.methodCall()

Calling model methods. You can create and run model methods to extend the functionality of a COMSOL Multiphysics simulation using custom methods. See the *Application Programming Guide* for more information about creating and using methods.

The Model Java-file history for running a method call in the COMSOL Desktop contains the history produced while running the method call and not the method itself.

SYNTAX

`model.methodCall().create(`*<tag>*`,`*<methodname>*`);`
`model.methodCall(`*<tag>*`).run();`
`model.methodCall(`*<tag>*`).inputNames();`
`model.methodCall(`*<tag>*`).methodName();`
`model.methodCall(`*<tag>*`).methods();`
`model.methodCall(`*<tag>*`).set(`*<param>*`,`*<expr>*`);`

DESCRIPTION

`model.methodCall(`*<tag>*`)` represents a method call for a model method.

`model.methodCall().create(`*<tag>*`,`*<methodname>*`)` creates a method call for the model method *<methodname>* with the given tag.

`model.methodCall(<tag>).inputNames();` returns the names of input parameters of a method reference by a given method call.

`model.methodCall(<tag>).methodName` returns the name of the method that the method call runs.

`model.methodCall(<tag>).methods();` returns the names of all methods in the model.

`model.methodCall(<tag>).run()` runs the method call with the tag *<tag>*.

The following examples show how you can specify the names of an input parameter, the value of a 1D double array parameter, and the value of a Boolean parameter:

```
model.methodCall(<tag>).set("paramname","p1");
model.methodCall(<tag>).set("paramvalues",new double[]{2.3 3.7 5.6 7.1 11.3 17.5});
model.methodCall(<tag>).set("sendmail",true);
```

Parameter names are created automatically with the appropriate types according to the inputs that have been specified in the method. This means that you can then use a natural set syntax as shown in the examples above.

ARGUMENTS TO METHOD CALLS

The following table describes the names of arguments that you can use to change the value of inputs to a method call before running it:

TABLE 2-84: ARGUMENT NAMES FOR METHOD CALLS

ARGUMENT NAME	SAMPLE VALUES	DESCRIPTION
`-methodinputnames`	`size, times`	Comma-separated list of names of inputs to change for the method call to run.
`-methodinputvalues`	`0.8,{0.1,0.3,0.8}`	Comma-separated list of the corresponding values. Arrays and 2D arrays are entered using curly braces.
`-methodinputfile`	Path to file	A file to read the inputs to the method call from. This file has the same format as the one used together with `-appargsfile` (see the Application Builder documentation about application arguments),

Specifying method call inputs both from a file and individually on the command line can be combined. If an input is given both in a file and on the command line, the value given on the command line overrides the value given in the file. If a value is given several times in the file or on the command line, the last given value overrides any previous given value.

USING METHOD CALLS FROM A MODEL JAVA-FILE

You can use the model method in a method call from a Model Java-file if the file starts by loading an MPH-file (including its model method) and then calls a run of a method call. However, in this context, model methods do not support user interface commands or file schema. The table below table lists user interface commands that are not supported:

TABLE 2-85: UNSUPPORTED USER INTERFACE COMMANDS IN MODEL JAVA-FILES

COMMAND	RESULT
Alert	Command is ignored
Confirm	Command causes an exception
DebugLog	Command is ignored
FileOpen	Command causes an exception
FileSaveAs	Command causes an exception
ImportFile	Command causes an exception
Message	Command is ignored
OpenURL	Command is ignored

TABLE 2-85: UNSUPPORTED USER INTERFACE COMMANDS IN MODEL JAVA-FILES

COMMAND	RESULT
Request	Command causes an exception
SelectNode	Command is ignored
SetProgress	Command is ignored
SetProgressInterval	Command is ignored
ZoomExtents	Command is ignored

SEE ALSO

`model.form()`

model.modelNode()

Model nodes (component nodes).

This syntax is used when you turn off the component syntax (clear the **Use component syntax** check box on the **Methods** page in the **Preferences** dialog box). Otherwise, the code that COMSOL Multiphysics creates uses `model.component().create(<tag>)` instead of `model.modelNode().create(<tag>)`, and so on. See `model.component()`.

A model node has one of three types:

- Component: Component nodes in the model builder tree have this type.
- ExtraDim: Extra dimension nodes under global definitions have this type.
- MeshComponent: Mesh parts nodes under global definitions have this type.

All three types are included in the list returned by `model.modelNode()`.

SYNTAX

```
model.modelNode().create(<tag>);
model.modelNode().create(<tag>, <basetag>);
model.modelNode().create(<tag>, <type>);

model.modelNode(<tag>).scope();
model.modelNode(<tag>).baseSystem();
model.modelNode(<tag>).baseSystem(<system>);
model.modelNode(<tag>).sorder();
model.modelNode(<tag>).sorder(<stype>);
model.modelNode(<tag>).defineLocalCoord();
model.modelNode(<tag>).defineLocalCoord(boolean);
```

DESCRIPTION

`model.modelNode(<tag>)` represents a model node (component node) in the model tree.

`model.modelNode().create(<tag>)` creates a model node (component node) with the given tag.

`model.modelNode().create(<tag>, <basetag>)` creates an extra dimension model node with the tag *<tag>* associated to the base model node *<basetag>*.

`model.modelNode().create(<tag>, <type>)` creates a model component node with the tag *<tag>* of one of the following types, set as the string *<type>*: `Component`, for a normal geometry component; `ExtraDim`, for an extra dimension; or `MeshComponent`, for a mesh component. For example, to create a mesh component:

```
model.modelNode().create("mcomp1", "MeshComponent");
model.geom().create("mgeom1", 3);
```

```
model.mesh().create("mpart1", "mgeom1");
```

`model.modelNode(<tag>).scope()` returns the fully qualified scope name.

`model.modelNode(<tag>).baseSystem(<system>)` use the given base system as unit system for the model node. This overrides the global unit system specified for the entire model object. To use global system again, set the base system of the model node to `null`.

`model.modelNode(<tag>).sorder()` returns the geometry shape order used for the model node and its descendants.

`model.modelNode(<tag>).sorder(<stype>)` Sets the geometry shape order. Allowed values are automatic, linear, quadratic, cubic, quartic, and quintic, and the default is automatic. With automatic shape order, the physics interfaces under the model node decide the most optimum shape order. The shape order set here is also used for the discretization of the mesh displacement when using ALE functionality.

`model.modelNode(<tag>).defineLocalCoord()` returns true if local coordinate variables exist. By default, this is the case, except for model components created before version 5.0.

`model.modelNode(<tag>)).defineLocalCoord(boolean)` sets a flag that determines whether local coordinate variables exist.

NOTE

You assign a model node to a physics interface, a geometry, and so forth using the methods

```
model.geom(<tag>).model(<mtag>);
model.physics(<tag>).model(<mtag>);
```

The methods

```
model.geom(<tag>).model();
model.physics(<tag>).model();
```

return the tag of the current model node.

The last created model node is the default model node for any geometry or physics interface that you create. If no model node exists when you create a geometry or a physics interface, a default model node with tag `mod1` is automatically created for you.

EXAMPLE

Create a model node and assign it to a geometry and an analytic function.

Code for Use with Java

```
model.modelNode().create("mod1");

model.geom().create("geom1", 3);
model.geom("geom1").model("mod1");

model.func().create("an1", "Analytic");
model.func("an1").model("mod1");
```

Code for Use with MATLAB

```
model.modelNode.create('mod1');

model.geom.create('geom1', 3);
model.geom('geom1').model('mod1');

model.func.create('an1', 'Analytic');
model.func('an1').model('mod1');
```

COMPATIBILITY

The `model.modelNode().createExtraDim(<tag>)` method has been deprecated in version 5.2. Use `model.modelNode().create(<tag>), "ExtraDim");` instead.

model.multiphysics()

Add multiphysics features to this feature container.

SYNTAX

```
model.multiphysics().create(<tag>,...);
model.multiphysics().image()
```

DESCRIPTION

`model.multiphysics().create(<tag>,<coupling>,<geom>,<sdim>);` adds a multiphysics coupling with the tag and the name to a geometry and a space dimension. Use `-1` as the space dimension to indicate a coupling valid in the entire model.

EXAMPLE

In a model with a Solid Mechanics interface and a Heat Transfer in Solids interface, add a Thermal Expansion multiphysics coupling on the domain level and a Temperature Coupling on a model-wide level in a geometry `geom1`:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
model.component("comp1").geom.create("geom1", 3);
model.multiphysics().create("te1","ThermalExpansion","geom1",3);
model.multiphysics().create("tc1","TemperatureCoupling","geom1",-1);
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
model.component('comp1').geom.create('geom1', 3);
model.multiphysics.create('te1','ThermalExpansion','geom1',3);
model.multiphysics.create('tc1','TemperatureCoupling','geom1',-1);
```

model.nodeGroup()

Node groups.

You can create node groups to structure the nodes in the model tree. It can be useful in this context when editing a Model Java-file created in the COMSOL Desktop and then opens it in the COMSOL Desktop again. It can also be useful in model methods.

SYNTAX

```
model.nodeGroup().create(<tag>,<type>);
model.nodeGroup().create(<tag>,<type>,<context>);

model.nodeGroup(<tag>).add(<nodetag>);
model.nodeGroup(<tag>).add(<parenttag>,<nodetag>);

model.nodeGroup().ungroup(<tag>);
```

There is also a component list `model.component("comp1").nodeGroup()` with the groups belonging to a component.

DESCRIPTION

`model.nodeGroup(<tag>)` represents a node group in the model tree.

`model.nodeGroup().create(<tag>,<type>)` creates a node group of the specified type. For example,

```
model.nodeGroup().create("grp1", "GlobalDefinitions");
```

creates a node group with the tag `"grp1"` under the **Global Definitions** node in the model tree.

`model.nodeGroup().create(<tag>,<type>,<context>)` creates a group of the specified type in the specified context. For example,

```
model.nodeGroup().create("g", "Geometry", "geom1")
```

creates a group in a geometry sequence.

Use `model.nodeGroup().ungroup(<tag>)` to ungroup (remove) a group. Removing the group does not remove its members form the model.

For a node group, the following methods are available:

- Use `nodeGroup.add(<type>,<tag>)` to add a node with the tag `<tag>` of the type `<type>` to the group. For example `group.add("func", "an1")` adds `model.func("an1")` to the group.
- Use `nodeGroup.remove(<type>,<tag>)` to remove a node with the tag `<tag>` of the type `<type>` from the group.

EXAMPLE

The following example creates a node group under Definitions in a Component, adds two Model Input features to it, and then removes it by the `ungroup` method (the creation of the Component and Model Input is not included in the code below):

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.nodeGroup().create("grp1", "Definitions", "comp1");
model.nodeGroup("grp1").set("type", "commondef");
model.nodeGroup("grp1").add("common", "minpt1");
model.nodeGroup("grp1").add("common", "minpt2");
model.nodeGroup().ungroup("grp1");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.nodeGroup.create('grp1', 'Definitions', 'comp1');
model.nodeGroup('grp1').set('type', 'commondef');
model.nodeGroup('grp1').add('common', 'minpt1');
model.nodeGroup("grp1").add('common', 'minpt2');
model.nodeGroup.ungroup('grp1');
```

model.ode()

Create global equations (ODEs and DAEs).

SYNTAX

```
model.ode().create(<tag>);
model.ode(<tag>).state(<statelist>);
model.ode(<tag>).state(<pos>,<state>);
model.ode(<tag>).ode(<state>,<equation>);
model.ode(<tag>).descr(<state>,<descr>);
model.ode(<tag>).weak(<wlist>);
model.ode(<tag>).weak(<pos>,<wexpr>);
model.ode(<tag>).discrete(<boolean>);
model.ode(<tag>).valueType(prop);

model.ode(<tag>).state();
model.ode(<tag>).ode(<state>);
model.ode(<tag>).descr(<state>);
model.ode(<tag>).weak();
model.ode(<tag>).discrete();
model.ode(<tag>).valueType();
```

DESCRIPTION

`model.ode(<tag>)` returns a global equation (or an ODE or a DAE) with tag *<tag>*.

`model.ode().create(<tag>)` creates an global equation with tag *<tag>*.

`model.ode(<tag>).state(<statelist>)` sets the states of the global equation tagged *<tag>* according to the list *<statelist>*.

`model.ode(<tag>).state(<pos>,<state>)` edits the state at position *<pos>* in the state vector for the global equation *<tag>*.

`model.ode(<tag>).ode(<state>,<equation>)` sets the equation for the state *<state>*. If the state variable has not previously been added using `model.ode(<tag>).state(<statelist>)` then *<state>* is appended to the list of state variables.

`model.ode(<tag>).descr(<state>,<descr>)` sets the description for the state *<state>*.

`model.ode(<tag>).weak(<wlist>)` set weak equations. *<wlist>* is a list of weak expressions.

`model.ode(<tag>).weak(<pos>,<wexpr>)` sets the weak expression at position *<pos>* in the list of weak expressions.

`model.ode(<tag>).state()` returns the state variables as a string array.

`model.ode(<tag>).ode(<state>)` returns the global equation for the state variable *<state>* as a string.

`model.ode(<tag>).descr(<state>)` returns the description of the state variable *<state>* as a string.

`model.ode(<tag>).weak()` returns the weak equations as a string vector of weak expressions.

`model.ode(<tag>).discrete(true)` specifies that the global equation contains event states.

`model.ode(<tag>).valueType(prop)` specifies value type as `real` or `complex` when splitting of complex variables in real and imaginary parts has been turned on.

`model.ode(<tag>).valueType()` returns the value type.

EXAMPLE

Define a global equations with the variables u and w, the ODEs $u_t+1 = 0$ and $v_t+1 = 0$, where the subscript t indicates the derivative with respect to time. Also define a weak expression $\text{test}(u)\cdot v$.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.ode().create("ode1");
```

```
model.ode("ode1").ode("u","ut+1");
model.ode("ode1").ode("v","vt-1");
model.ode("ode1").weak(new String[]{"test(u)*v"});
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.ode.create('ode1');
model.ode('ode1').ode('u','ut+1');
model.ode('ode1').ode('v','vt-1');
model.ode('ode1').weak({'test(u)*v'});
```

SEE ALSO

`model.init()`, `model.solverEvent()`

model.opt()

Optimization interface.

SYNTAX

```
model.opt().objective().create(<tag>,type)
model.opt().objective(<tag>).set(property,<value>)

model.opt().constr().create(<tag>)
model.opt().constr(<tag>).etc

model.opt().gconstr().create(<tag>)
model.opt().gconstr(<tag>).constr(<constrExpr>)
model.opt().gconstr(<tag>).lbound(<lboundExpr>)
model.opt().gconstr(<tag>).ubound(<uboundExpr>)
```

DESCRIPTION

The purpose of `model.opt` is to manage information relating to optimization and sensitivity analysis. Most of the fields under `model.opt` are read and interpreted directly by the optimization and sensitivity solvers. They never affect the result of other solvers.

`model.opt().objective().create(<tag>,type)` adds an objective function of the specified type. The supported types are `Global` and `LeastSquares`.

`model.opt().objective(<tag>).set(property,<value>)` sets an objective function property. Objective functions of type `Global` support the single property `expr`, which takes a globally defined expression as value. Allowed properties for objectives of type `LeastSquares` are described below.

`model.opt().objective(<tag>).selection().named(<seltag>)` assigns the objective function to the named selection `<seltag>`.
`model.opt().objective(<tag>).selection().set(...)` defines a local selection that assigns the objective function to geometric entities. For a complete list of methods available under `selection()`, see `model.selection()`. Only objective functions of type `LeastSquares` require a selection. See further below.

`model.opt().constr().create(<tag>)` adds a pointwise (mesh-based) constraint on the control variables. The syntax is shared with `model.constr()` with the exception that the `ctype` parameter expects values `constr`, `lbound`, and `ubound` for constraint, lower bound, and upper bound, respectively.

`model.opt().gconstr().create(<tag>)` registers a global constraint with the optimization solvers. Such constraints consist of a globally available expression, which can depend both on optimization variables and on the forward PDE solution, together with likewise global expressions for lower and upper bound.

`model.opt().gconstr(<tag>).constr(<constrExpr>)` specifies a global constraint expression.

`model.opt().gconstr(<tag>).lbound(<lboundExpr>)` sets lower bound for the constraint.

`model.opt().gconstr(<tag>).ubound(<lboundExpr>)` sets upper bound for the constraint.

Least-Squares Objective Functions

Least-squares objective functions are specified in terms of measured values, stored on file, together with information about how corresponding expressions can be evaluated for the current control variable values. An overview of the allowed properties is given in the table below.

TABLE 2-86: PROPERTIES FOR OBJECTIVE FUNCTION TYPE LEASTSQUARES

PROPERTY	VALUE	DESCRIPTION
`filename`	string	Full path of the measurement data file.
`paramnames`	string[]	Parameters used in the experiment.
`paramexprs`	string[]	Values of the given parameters.
`columntypes`	string[]	List of column type indicators.
`columnexprsweights`	string[]	Column contribution weights.
`columnexprs`	string[]	Measurement expressions.

In principle, you must specify the following for each measured value:

- To which experiment the value belongs and parameters for that experiment
- Which expression to evaluate
- Where the expression must be evaluated
- For which time or parameter value the evaluation must be performed

Each *experiment* corresponds to a solution of the forward problem with a given set of parameter values. In practice, measurements for each experiment must be stored in a separate file, and specified as a separate `LeastSquares` objective feature where you give the full path of the measurement data file in the `filename` property. Parameters specified in the `paramnames` property are given the values specified using `paramexprs` property during the forward solution. One forward solution is performed for each unique set of parameter names and values.

The required measurement data file format is row- and column-oriented. Entries on each row must be separated by commas or semicolons, while rows are separated by line feeds. Use the `columtypes` property to specify the content of each column, in the order that they appear in the data file, according to the following table:

TABLE 2-87: ALLOWED COLUMN TYPES

TYPE	COLUMN CONTENTS
time	Actual measurement times
param	Actual parameter values
coord	Actual measurement coordinates
value	Measured values
none	Ignored column

Columns of type `time` are only allowed for transient problems. The measurements on the same row are assumed to be made at the specified time. Forward model values are interpolated to the given times. There must only be one column of type `time`, and it requires no further parameters.

Columns of type `param` contain parameter values for which the measurements on the same row have been made, and for which the forward problem must be solved. A data file can contain multiple parameter columns. Corresponding parameter names must be given in the `columnnames` property.

Columns of type `coord` contain global coordinates where the measurements on the same row have been made. The coordinate columns must be coupled to a coordinate variable by specifying the coordinate variable name in the `columnnames` property for the given column and the frame tag `spatial`, `material`, `mesh` or `geometry` in the `columnexprs` property. For example, in a 3D model, you need three columns of type `coord` with `columnnames` entries `x`, `y`, and `z`, respectively.

A `value` column contains measured data. For each `value` column, a corresponding expression to be evaluated must be specified in the `columnexprs` property. Entries in `value` columns are interpreted as real numbers when possible. Anything else, including for example hash marks (`#`) and the literal strings `nan`, `Nan`, `NaN` and `NAN` is interpreted as an illegal value which is excluded from the least squares objective function evaluation. A weight for the objective contribution from a column, multiplying the squared difference between the measured value and the expression, can be specified as a positive globally expression that can be evaluated using the `columnexprsweights` property. To exclude a measurement from a comma-separated file, you can also simply leave a value column empty.

Columns of type `none` can be used to exclude columns from the data file.

Coordinates are interpreted as global in the context of the objective feature's selection. This means that the value column expressions are evaluated at the points within the selection that best match the given coordinates. If the interpolation fails for some point because its coordinates lie too far outside the selection, the corresponding value is ignored.

model.pair()

Create and define identity pairs and contact pairs.

SYNTAX

```
model.component(<ctag>).pair().create(<tag>,type,<gtag>);
model.component(<ctag>).pair(<tag>).type(type);
model.component(<ctag>).pair(<tag>).type();
model.component(<ctag>).pair(<tag>).pairName(<pname>);
model.component(<ctag>).pair(<tag>).pairName();
model.component(<ctag>).pair(<tag>).source().selMethod;
model.component(<ctag>).pair(<tag>).source().named(<seltag>);
model.component(<ctag>).pair(<tag>).source().named();
model.component(<ctag>).pair(<tag>).destination().selMethod;
model.component(<ctag>).pair(<tag>).destination().named(<seltag>);
model.component(<ctag>).pair(<tag>).destination().named();
model.component(<ctag>).pair(<tag>).swap();
model.component(<ctag>).pair(<tag>).srcFrame(<frame>);
model.component(<ctag>).pair(<tag>).srcFrame();
model.component(<ctag>).pair(<tag>).dstFrame(<frame>);
model.component(<ctag>).pair(<tag>).dstFrame();
model.component(<ctag>).pair(<tag>).hasAutoSelection();
model.component(<ctag>).pair(<tag>).manualSelection(manual);
model.component(<ctag>).pair(<tag>).manualSelection();
model.component(<ctag>).pair(<tag>).searchMethod(method);
model.component(<ctag>).pair(<tag>).searchMethod();
model.component(<ctag>).pair(<tag>).manualDist(manual);
model.component(<ctag>).pair(<tag>).manualDist();
model.component(<ctag>).pair(<tag>).searchDist(<dist>);
model.component(<ctag>).pair(<tag>).searchDist();
model.component(<ctag>).pair(<tag>).opName(src2dst);
model.component(<ctag>).pair(<tag>).mphOpName(src2dst);
model.component(<ctag>).pair(<tag>).gapName(src2dst);
model.component(<ctag>).pair(<tag>).active(boolean);
model.component(<ctag>).pair(<tag>).isActive();
model.component(<ctag>).pair().remove(<tag>);
```

DESCRIPTION

`model.component(<ctag>).pair().create(<tag>,type,<gtag>)` creates a pair with tag *<tag>* in the geometry with tag *<gtag>* in the component with tag *<ctag>*. The type *type* is either `Contact` or `Identity`.
`model.component(<ctag>).pair(<tag>).type()` returns the pair type as a string.
`model.component(<ctag>).pair(<tag>).type(type)` changes the pair type.

`model.component(<ctag>).pair(<tag>).pairName(<pname>)` sets the pair name, which is used as a suffix in operator names and variable names. By default, the pair name is the same as the tag.
`model.component(<ctag>).pair(<tag>).pairName()` returns the pair name.

`model.component(<ctag>).pair(<tag>).source().named(<seltag>)` assigns the source boundaries to the named selection *<seltag>*.
`model.component(<ctag>).pair(<tag>).source().set(...)` defines a local selection that assigns the source boundaries to geometric entities. For a complete list of methods available under `model.component(<ctag>).pair(<tag>).source()`, see `model.selection()`.

`model.component(<ctag>).pair(<tag>).destination().named(<seltag>)` assigns the destination boundaries to the named selection *<seltag>*.
`model.component(<ctag>).pair(<tag>).destination().set(...)` defines a local selection that assigns the destination boundaries to geometric entities. For a complete list of methods available under `model.component(<ctag>).pair(<tag>).destination()`, see `model.selection()`.

`model.component(<ctag>).pair(<tag>).swap()` swaps the source and destination selections.

`model.component(<ctag>).pair(<tag>).srcFrame(<frame>)` and `model.pair(<tag>).dstFrame(<frame>)` sets the source and destination frames for the identity mapping. The argument *<frame>* can have the values `spatial`, `material`, or `mesh`. The default is `spatial`. These frames are only used for identity pairs. `model.component(<ctag>).pair(<tag>).srcFrame()` and `model.component(<ctag>).pair(<tag>).dstFrame()` returns the frame tags.

`model.component(<ctag>).pair(<tag>).hasAutoSelection()` returns true if the contact pair was created automatically, using the create pairs check box in the finalize geometry node.

`model.component(<ctag>).pair(<tag>).manualSelection(manual)` enables or disables manual control of the selections for a pair that was created automatically.
`model.component(<ctag>).pair(<tag>).manualSelection()` returns `true` if manual control of selections is enabled, and `false` otherwise.

`model.component(<ctag>).pair(<tag>).searchMethod(method)` sets the search method for a contact pair. The argument *method* can be `fast` or `direct`. The default is `fast`.
`model.component(<ctag>).pair(<tag>).searchMethod()` returns the search method

`model.component(<ctag>).pair(<tag>).manualDist(manual)` enables or disables manual control of the search distance for a contact pair. The argument *manual* is Boolean. The default value `false` means that the search distance is automatically computed based on the size of the geometry.
`model.component(<ctag>).pair(<tag>).manualDist()` returns `true` if manual control of search distance is enabled, and `false` otherwise.

`model.component(<ctag>).pair(<tag>).searchDist(<dist>)` sets the search distance for a contact pair, when manual control of the search distance is enabled. The argument *<dist>* is a string whose default unit is the geometry's length unit. The default is `1e-2`. `model.component(<ctag>).pair(<tag>).searchDist()` returns the search distance as a string.

`model.component(<ctag>).pair(<tag>).opName(src2dst)` returns the name of the operator transferring an expression from source to destination (if *src2dst*=`true`) or from destination to source (if *src2dst*=`false`).

`model.component(<ctag>).pair(<tag>).mphOpName(src2dst)` returns the name of the multiphysics operator transferring an expression from source to destination (if `src2dst=true`) or from destination to source (if `src2dst=false`). When the test operator is applied on this operator, it does not give any contribution (reaction force) for the structural mechanics interfaces' degrees of freedom due to the variable point mapping. These operators are available only for contact pairs.

`model.component(<ctag>).pair(<tag>).gapName(src2dst)` returns the name of the geometric gap variable seen from the destination (if `src2dst=true`) or seen from the source (if `src2dst=false`). These variables are available only for contact pairs.

`model.component(<ctag>).pair(<tag>).active(boolean)` enables or disables the pair.

`boolean enabled = model.component(<ctag>).pair(<tag>).isActive()` returns `true` if the pair is enabled, and `false` otherwise.

`model.component(<ctag>).pair().remove(<tag>)` deletes the pair.

EXAMPLE

Create a contact pair in the geometry `geom1` with source boundaries 4 and 6 and destination boundaries 10 and 12.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("blk1", "Block");
g.create("blk2", "Block");
g.feature("blk2").set("pos", new String[]{"0.5", "0.5", "1"});
g.feature("fin").name("Form Assembly");
g.feature("fin").set("action", "assembly");
g.feature("fin").set("imprint", true);
g.feature("fin").set("createpairs", false);
g.run();

model.component("comp1").pair().create("p1", "Contact", "geom1");
model.component("comp1").pair("p1").source().set(new int[]{4, 6});
model.component("comp1").pair("p1").destination().set(new int[]{10, 12});
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom().create('geom1', 3);
g.create('blk1', 'Block');
g.create('blk2', 'Block');
g.feature('blk2').set('pos', {'0.5', '0.5', '1'});
g.feature('fin').name('Form Assembly');
g.feature('fin').set('action', 'assembly');
g.feature('fin').set('imprint', true);
g.feature('fin').set('createpairs', false);
g.run;

model.component('comp1').pair.create('p1', 'Contact', 'geom1');
model.component('comp1').pair('p1').source().set([4, 6]);
model.component('comp1').pair('p1').destination.set([10, 12]);
```

model.param() and model.result().param()

Add, define, and remove global parameters. For parameters in results and postprocessing, `model.result().param()` works in the same way as `model.param()`.

SYNTAX

```
model.param().set(<param>,<expr>);
model.param().set(<param>,<expr>,<descr>);
model.param().descr(<param>,<descr>);
model.param().remove(<param>);
model.param().clear();

model.param().varnames();
model.param().get(<param>);
model.param().descr(<param>);
model.param().evaluate(<param>);
model.param().evaluateComplex(<param>);
model.param().evaluateUnit(<param>);
model.param().loadFile(tempFile, ...);
model.param().saveFile(tempFile, ...);

model.param(<ptag>).setShowInParamSel(true|false);
model.param(<ptag>).paramCase().create(<pctag>);
model.param(<ptag>).paramCase(<pctag>).set(<param>,<expr>);
model.param(<ptag>).setFromCase(<param>,<pctag>);
```

The last four syntaxes above are only applicable for global parameters and not for parameters in the results.

DESCRIPTION

`model.param()` is a collection of global model parameters. Likewise, `model.result().param()` is a collection of model parameters for results and postprocessing.

`model.param().set(`*<param>*`,`*<expr>*`)` defines the parameter *<param>* as *<expr>*.

`model.param().set(`*<param>*`,`*<expr>*`,`*<descr>*`)` defines the parameter *<param>* as *<expr>* and assigns it the description *<descr>*.

`model.param().descr(`*<param>*`,`*<descr>*`)` sets the description for the parameter *<param>*.

`model.param().remove(`*<param>*`)` removes the parameter *<param>*. `model.param().clear()` removes all parameters.

`model.param().varnames()` returns the names of all parameters as a string array.

`model.param().get(`*<param>*`)` returns the parameter value as a string.

`model.param().descr(`*<param>*`)` returns the parameter description as a string.

`model.param().evaluate(`*<param>*`)` evaluates the value of the parameter *<param>* as a double real-valued floating-point value. For complex-valued parameters, use the `evaluateComplex` method instead.

`model.param().evaluateComplex(`*<param>*`)` evaluates the value of the parameter *<param>* as a double floating-point array with the real and imaginary part of a complex-valued parameter.

`model.param().evaluateUnit(`*<param>*`)` returns the unit of the parameter *<param>* if defined. It returns `null` if the parameter has no unit defined, or if the model does not use any unit system.

For `model.param().loadFile()` and `model.param().saveFile()`, see The loadFile and saveFile Methods.

Use `model.param(`*<ptag>*`).setShowInParamSel(false);` to exclude the parameters in the global parameter set in *<ptag>* in parameter selections. The default is that `setShowInParamSel` is `true`; that is, all the parameters are included in parameter selections.

`model.param(`*<ptag>*`).paramCase().create(`*<pctag>*`)` creates a parameter case for a set of global parameters *<ptag>*. You can create several parameter cases, where you can use the `.set(`*<param>*`,`*<expr>*`);` syntax to specify another expression for any existing parameter <param>. Then use

`model.param(<ptag>).setFromCase(<param>,<pctag>);` to specify the parameter case `<pctag>` as the source for the value of the parameter **<*param*>**.

EXAMPLE

Define the parameter `c` in terms of another parameter `a` and then remove `c`.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.param().set("c","1+a");
model.param().remove("c");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.param.set('c','1+a');
model.param.remove('c');
```

SEE ALSO

`model.variable()`

model.physics()

Create and define properties for a physics interface.

SYNTAX

```
model.component(<ctag>).physics().create(<tag>,physint);
model.component(<ctag>).physics().create(<tag>,physint,<geomtag>);
model.component(<ctag>).physics().create(<tag>,physint,<geomtag>,<varnames>);
model.component(<ctag>).physics(<tag>).model(<mtag>);
model.component(<ctag>).physics(<tag>).field(fieldname).fieldname(<namelist>);
model.component(<ctag>).physics(<tag>).field(fieldname).fieldname(<pos>,<name>);
model.component(<ctag>).physics(<tag>).prop(propname).set(property,<value>);
model.component(<ctag>).physics(<tag>).create(<ftag>,feature);
model.component(<ctag>).physics(<tag>).create(<ftag>,feature,<dim>);
model.component(<ctag>).physics(<tag>).feature(<ftag>).create(<ftag2>,feature);
model.component(<ctag>).physics(<tag>).feature(<ftag>).create(<ftag2>,feature,<dim>);
model.component(<ctag>).physics(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).physics(<tag>).feature().move(<ftag>,<position>);

model.component(<ctag>).physics(<tag>).feature(<ftag>).feature();
model.component(<ctag>).physics(<tag>).feature(<ftag>).feature(<ftag2>);
model.component(<ctag>).physics(<tag>).feature(<ftag>).featureInfo();
model.component(<ctag>).physics(<tag>).feature(<ftag>).featureInfo("info");
feature = model.component(<ctag>).physics(<tag>).feature(<ftag>);
feature.featureInfo("info").set(variable,<value>);
feature.featureInfo("info").getInfoTable(id);

model.component(<ctag>).physics(<tag>).model();
model.component(<ctag>).physics(<tag>).field(fieldname).fieldname();
model.component(<ctag>).physics(<tag>).scope();
model.component(<ctag>).physics(<tag>).geom();
model.component(<ctag>).physics(<tag>).image();
model.component(<ctag>).physics(<tag>).prop(propname).getType(<pname>);
model.component(<ctag>).physics(<tag>).prop(propname).param();
model.component(<ctag>).physics(<tag>).prop(propname).getAllowedPropertyValues(property);
model.component(<ctag>).physics(<tag>).feature(<ftag>).getAllowedPropertyValues(property);
model.component(<ctag>).physics(<tag>).feature(<ftag>).getType(<pname>);
model.component(<ctag>).physics(<tag>).feature(<ftag>).param();
model.component(<ctag>).physics(<tag>).diagram(<dtag>).getAllowedPropertyValues(property);

model.component(<ctag>).physics(<tag>).feature(<tag>).set(String pname, int value);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      set(String pname, int pos, int value);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      set(String pname, int pos, int[] value);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      set(String pname, int pos1, int pos2, int value);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, String value, int index);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, String value, int firstIndex, int secondIndex);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, String[] value, int index);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, double value, int index);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, double value, int firstIndex, int secondIndex);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, double[] value, int index);
model.component(<ctag>).physics(<tag>).feature(<tag>).setIndex(String name, int value, int
  index);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, String value, int index);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, String value, int index);
model.component(<ctag>).physics(<tag>).feature(<tag>).
      setIndex(String name, int value, int firstIndex, int secondIndex);
model.component(<ctag>).physics(<tag>).feature(<tag>).
```

```
      setIndex(String name, int[] value, int index);
model.component(<ctag>).physics(<tag>).feature(<tag>).importData();
model.component(<ctag>).physics(<tag>).feature(<tag>).discardData();
model.component(<ctag>).physics(<tag>).feature(<tag>).image();

model.component(<ctag>).physics(<tag>).prop(<tag>).set(String pname, int value);
model.component(<ctag>).physics(<tag>).prop(<tag>).set(String pname, int pos, int value);
model.component(<ctag>).physics(<tag>).prop(<tag>).set(String pname, int pos, int[] value);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      set(String pname, int pos1, int pos2, int value);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, String value, int index);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, String value, int firstIndex, int secondIndex);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, String[] value, int index);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, double value, int index);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, double value, int firstIndex, int secondIndex);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, double[] value, int index);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, int value, int index);
model.physics(<tag>).prop(<tag>).setIndex(String name, String value, int index);
model.physics(<tag>).prop(<tag>).setIndex(String name, String value, int index);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, int value, int firstIndex, int secondIndex);
model.component(<ctag>).physics(<tag>).prop(<tag>).
      setIndex(String name, int[] value, int index);
```

The `set()` methods index/position arguments are 1-based. The `setIndex()` methods index/position arguments are 0-based.

DESCRIPTION

`model.component(<ctag>).physics().create(<tag>,physint)` creates and returns a physics interface.

`model.component(<ctag>).physics().create(<tag>,physint)` or `model.component(<ctag>).physics().create(<tag>,physint,<geomtag>)` adds a physics interface to the model and initializes it with defaults. The *physint* argument specifies which physics interface to create. There can be several different values of *physint* which create the same internal physics interface class, but which set different defaults. The constructor without the *<geomtag>* argument can only be used (and should be used) by 0D (space-independent) interfaces.

`model.component(<ctag>).physics().create(<tag>,physint,<geomtag>,<varnames>)` adds an interface with the field variable names *<varnames>*. Only interfaces supporting a varying number of field variables considers this argument. Providing the variable names in the `create` method rather than changes them afterward using `model.component(<ctag>).physics(<tag>).field(fieldname).fieldname(<namelist>)` ensures that the default features are correct.

`model.component(<ctag>).physics(<tag>).field(fieldname).fieldname(<namelist>)` sets a name of a dependent variable. The entity *fieldname* (which could be, for example, `temperature`, `x-velocity`, `electric field`) specifies which dependent variable to set the name for. The available fields are provided by the physics interface. The argument *<namelist>* can be a list of names for physics interfaces supporting an arbitrary number of dependent variables. The physics interfaces provide default names for the dependent variables.

`model.component(<ctag>).physics(<tag>).field(fieldname).fieldname(<pos>,<name>)` changes the name at position *<pos>* in the list of field names.

`model.component(<ctag>).physics(<tag>).selection().named(<seltag>)` specifies that the physics interface is active on the named selection `<seltag>`.
`model.component(<ctag>).physics(<tag>).selection().set(...)` defines a local selection that makes the physics interface active on the selection's geometric entities. For a complete list of methods available under `selection()`, see `Selections`.The selection must apply to the physics interface's maximum geometry level. The `create()` method makes the physics interface active in all domains. 0D interfaces are always active globally and do not support these methods.

`model.component(<ctag>).physics(<tag>).prop(propname).set(pname,<value>)` sets the value of some property parameter. All string types listed in Table 2-2 are supported.

`model.component(<ctag>).physics(<tag>).create(<ftag>,feature)` adds a new feature instance to the physics interface and initializes the feature with defaults. The available features are given by the physics interface.

`model.component(<ctag>).physics(<tag>).create(<ftag>,feature,<dim>)` adds a new feature instance to the physics interface and initializes the feature with defaults. The feature is assigned to the domain level `<dim>`. Use this constructor for features which can be applied to more than one domain level. The constructor without the `<dim>` argument assigns the feature to the highest domain level, which the feature supports.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).set(pname,<value>)` sets a parameter value. All string types listed in the section Table 2-2 are supported.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).selection().named(<seltag>)` assigns the physics feature to the named selection `<seltag>`.
`model.component(<ctag>).physics(<tag>).selection().set(...)` defines a local selection that assigns the physics feature to geometric entities. For a complete list of methods available under `selection()`, see `Selections`. 0D features need no domain selection.

`model.component(<ctag>).physics(<tag>).feature().move(<ftag>,<position>)` moves the feature `<ftag>` to the zero indexed position `<position>` in the list. A feature cannot be moved before a default feature and the default features cannot be moved.

`model.component(<ctag>).physics(<tag>).create(<itag>,"init")` creates an initial value feature, using the reserved feature ID `init`.

`model.component(<ctag>).physics(<tag>).feature(<itag>).set(varname,<value>)` specifies an initial value. The variable names are the field variables. For wave problems, the time derivatives of the field variables are also included in the list of variables.

`model.component(<ctag>).physics(<tag>).model()` returns the model component node tag of the interface.

`model.component(<ctag>).physics(<tag>).field(fieldname).fieldname()` returns the field names as a string array.

`model.component(<ctag>).physics(<tag>).scope()` returns the fully qualified scope name.

`model.component(<ctag>).physics(<tag>).geom()` returns the geometry tag as a string.

`model.component(<ctag>).physics(<tag>).selection().named()` returns the selection tag as a string.

`model.component(<ctag>).physics(<tag>).selection().get`*`Type`*`()` returns domain information. See `Selections` for available methods.

`model.component(<ctag>).physics(<tag>).prop(propname).get`*`Type`*`(pname)` returns the parameter value. See `get* and Selection Access Methods` for available methods.

`model.component(<ctag>).physics(<tag>).prop(propname).param()` returns the parameter names as a string array.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).get<Type>(<pname>)` returns the parameter value. See `get* and Selection Access Methods` for available methods.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).param()` returns the parameter names as a string array.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).selection().named()` returns the selection tag as a string array.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).feature()` returns the list of feature attributes. This list supports the same methods as `model.component(<ctag>).physics(<tag>).feature()`.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).feature(<ftag2>)` returns the feature attribute *<ftag2>*. The feature attributes support the same methods as `model.component(<ctag>).physics(<tag>).feature(<ftag>)`.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).featureInfo()` returns a list of info objects.

`model.physics(<tag>).feature(<ftag>).featureInfo("info")` returns the info object that contains information about the variables, weak expressions, and constraints that a feature generates. The `model.component(<ctag>).physics(<tag>)` and `model.coordSystem(<tag>)` objects also have this list that you access with `model.component(<ctag>).physics(<tag>).featureInfo("info")`. These objects do not support the `set` method, which only works for the object `model.component(<ctag>).physics(<tag>).feature(<ftag>)`.

`model.component(<ctag>).physics(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)`, `model.component(<ctag>).physics(<tag>).prop(propname).getAllowedPropertyValues(property)`, and `model.component(<ctag>).physics(<tag>).diagram(<dtag>).getAllowedPropertyValues(property)` return the set of allowed values for a property if the set is a finite set of strings; otherwise, they return null.

`feature.featureInfo("info").set(variable,<value>)` locks the named variable to the given expression. The expression must be given as a string array.

`feature.featureInfo("info").getInfoTable(id)` returns a table that lists all information about a certain table id. The supported IDs are `Expression`, `Shape`, `Weak`, and `Constraint`.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).importData()` imports the file that the physics feature references into the model. This is only allowed for specific physics features that allow external files to be used, such as the Release from Data File feature for the particle tracing interfaces.

`model.component(<ctag>).physics(<tag>).feature(<ftag>).discardData()` Discards the external file imported by the `importData()` command. This only has an effect if `importData()` has been called previously for the physics feature. This is only allowed for specific physics features that allow external files to be used, such as the Release from Data File feature for the particle tracing interfaces.

EXAMPLE

This example creates an Electrostatics interface. It sets boundaries 3 and 8 to the ground potential and assigns the electric potential of 1 V at boundary 4.

When the physics interface is created a couple of default features are automatically added. One of them is the Charge Conservation feature, which has the tag `ccn1`. The relative permittivity is this feature is set to 1.

Code for Use with Java

```
model.component("comp1").physics().create("es","Electrostatics","geom1");
model.component("comp1").physics("es").create("gnd1", "Ground", 2);
model.component("comp1").physics("es").feature("gnd1").selection().set(new int[]{3, 8});
```

```
model.component("comp1").physics("es").create("pot1", "ElectricPotential", 2);
model.component("comp1").physics("es").feature("pot1").selection().set(new int[]{4});
model.component("comp1").physics("es").feature("pot1").set("V0", "1");
model.component("comp1").physics("es").feature("ccn1").set("epsilonr_mat", "userdef");
model.component("comp1").physics("es").feature("ccn1").set("epsilonr", "1");
```

Code for Use with MATLAB

```
model.component('comp1').physics.create('es','Electrostatics','geom1');
model.component('comp1').physics('es').create('gnd1', 'Ground', 2);
model.component('comp1').physics('es').feature('gnd1').selection().set([3, 8]);
model.component('comp1').physics('es').create('pot1', 'ElectricPotential', 2);
model.component('comp1').physics('es').feature('pot1').selection.set(4);
model.component('comp1').physics('es').feature('pot1').set('V0', '1');
model.component('comp1').physics('es').feature('ccn1').set('epsilonr_mat', 'userdef');
model.component('comp1').physics('es').feature('ccn1').set('epsilonr', '1');
```

COMPATIBILITY

From version 4.3 the methods

```
model.physics(<tag>).feature(<ftag>).params();
model.physics(<tag>).prop(propname).params();
```

are deprecated and replaced by the methods

```
model.physics(<tag>).feature(<ftag>).param();
model.physics(<tag>).prop(propname).param();
```

SEE ALSO

`model.material()`, `model.study()`

model.probe()

Create and defined properties for probes, which you can add to a model to monitor some quantity (real or complex-valued number) during a time-dependent, frequency-domain, or parametric simulation.

SYNTAX

```
model.probe().create(<tag>, type);
model.probe(<tag>).model(<mtag>);
model.probe(<tag>).set(property,<value>);
model.probe(<tag>).create(<etag>, etype);
model.probe(<tag>).feature(<etag>).set(eproperty,<evalue>);
model.probe(<tag>).feature(<etag>).getAllowedPropertyValues(property);
model.probe(<tag>).genResult(String sol)
model.probe(<tag>).image()
```

DESCRIPTION

`model.probe().create(<tag>, type)` creates a probe of type *type* with tag *<tag>*.

`model.probe(<tag>).model(<mtag>)` sets the model component node to `<mtag>`.

`model.probe(<tag>).set(property,<value>)` set *property* to *<value>*.

`model.probe(<tag>).selection(...)` sets the selection for the probe. This is possible for the probes of the types `Domain`, `Boundary`, and `Edge`.

`model.probe(<tag>).create(<etag>, etype)` creates a point probe expression of type *etype* and tag *<tag>*.

`model.probe(<tag>).feature(<etag>).set(eproperty,<evalue>)` sets the property *eproperty* on the point probe expression *<etag>*.

`model.probe(<tag>).feature(<etag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

`model.probe(<tag>).genResult(String sol)` where *sol* is a solver sequence tag. This function prepares for using a probe while solving or during postprocessing. The command is invoked automatically when a solver or study is run from the COMSOL Desktop for all active probes but needs to be invoked explicitly when run through the API. The function `genResult(String sol)` sets up result features for evaluating the corresponding probe using the solver sequence *sol*. If `null` is used, the default solver sequence for a solution data set is used. When *sol* is `none` then the corresponding probe solution data set does not refer to any solver sequence. This means, for example, that the current model is used for selections used for this probe. When a solver sequence is run, then solution to use for the probes is always reset to use the current solver.

Use the `model.probe(<tag>).image()` methods for plotting and exporting probe plot images. See Plotting and Exporting Images.

Boundary Probes, Domain Probes, Edge Probes, Global Variable Probes, and Probe Point Expressions

Probes can be of the following types:.

TABLE 2-88: PROBE TYPES

TYPE	DESCRIPTION
`Boundary`	Probe that defines a value as an integral, maximum, minimum, or average over boundaries.
`Domain`	Probe that defines a value as an integral, maximum, minimum, or average over domains.
`Edge`	Probe that defines a value as an integral, maximum, minimum, or average over edges (in 3D).
`GlobalVariable`	Probe that defines a value using a global variable.
`PointExpr`	Probe that defines a value by interpolation of an expression in a probe point. The probe point is defined by the parent, a DomainPoint or a BoundaryPoint.

Boundary Point Probes and Domain Point Probes

Probe points can be of the following types:

TABLE 2-89: PROBE POINT TYPES

TYPE	DESCRIPTION
`BoundaryPoint`	Defines a probe coordinate on a boundary in 3D.
`DomainPoint`	Defines a probe coordinate in a domain.

Probes take the following properties:

TABLE 2-90: PROBE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`descr`	string		Description of the probe. Used for model.result().
`descractive`	`on` | `off`	`off`	Manual control of description.
`expr`	string		The expression defining the probe.
`frame`	string	spatial frame	Frame used for defining the probe.
`intorder`	Integer	4	Integration order (DomainProbe and BoundaryProbe).
`intsurface`	Boolean	false	Compute surface integral for1D axisymmetric DomainProbe and 2D axisymmetric BoundaryProbe average and integral probe types.
`intvolume`	Boolean	false	Compute volume integral for 2D axisymmetric DomainProbe average and integral probe types.

TABLE 2-90: PROBE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
method	integration | summation	integration	Method used (DomainProbe and BoundaryProbe).
probename	string	probe tag	Probe variable name.
table	string	default	Table to use for probe evaluation.
type	average | maximum | minimum | integral	average	Type of probe (DomainProbe and BoundaryProbe).
unit	string	unit of expr	Unit for the probe. Used for model.result().
window	string	default	The plot window to use for the probe.

A probe point of the type DomainPoint takes the following properties:

TABLE 2-91: PROBE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
bndsnap1	on|off	off	Snap to nearest point (1D).
bndsnap2	on|off	off	Snap to nearest boundary point (2D).
bndsnap3	on|off	off	Snap to nearest boundary point (3D).
coords	Matrix of doubles		Probe coordinates.
depthpointnormal	double	0	Depth along line defined by the pointnormal method.
depthpointdirection	double	0	Depth along line defined by the pointdirection method.
depthtwopoints	double	0	Depth along line defined by the twopoints method.
dimension	1 | 2 | 3	3	The spatial dimension in which the point resides.
first	Double array		The coordinates of the first point on the probe line.
method	pointnormal | pointdirection | twopoints | none	pointnormal	Line entry method.
second	Double array		The coordinates of the second point (for method=twopoints)
twopointscurrent	first | second	first	Point selector (for method=twopoints)

A probe point of BoundaryPoint types take the following properties:

TABLE 2-92: PROBE PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
coords	Double array	0,0,0	Probe coordinates.
rawcoords	Double array	0,0,0	Full precision probe coordinates.
snapcoords	Double array	0,0,0	The boundary-snapped coordinates.

model.reduced()

Reduced-order modeling.

SYNTAX

```
model.reduced()
model.reduced().create('rom1');
model.reduced().create('rom1',filepath);

model.reduced().getControls()
model.reduced().getDescriptions(String[])
model.reduced().getM(String)
model.reduced().getMatrices()
model.reduced().getN(String)
model.reduced().getNnz(String)
model.reduced().getOutputs()
model.reduced().getParameters()
model.reduced().getSparseMatrixCol(String)
model.reduced().getSparseMatrixRow(String)
model.reduced().getSparseMatrixVal(String)
model.reduced().getSparseMatrixValImag(String)
model.reduced().getString(String)
model.reduced().getValues(String[])
model.reduced().getVector(String)
model.reduced().getVectorImag(String)
model.reduced().getVectors()
model.reduced().isReal(String)
model.reduced().renameControl(String, String)
model.reduced().renameOutput(String, String)
model.reduced().set(String, String)
model.reduced().setControl(String, String)
model.reduced().setParameter(String, String)
```

DESCRIPTION

`model.reduced().create('rom1')` creates a reduced model container with the tag `rom1`.

`model.reduced().create('rom1',`*`filepath`*`)` imports a reduced model from a COMSOL MPHROM reduced-order model file in *`filepath`*.

`getOutputs()` returns a list of the names of output variables of the model.

`renameOutput(`*`oldName`*`,`*`newName`*`)` gives the output variable a new name.

`getParameters()` returns a list of the names of parameters of the reduced model.

`setParameters(`*`name`*`,`*`expr`*`)` sets the expression for the parameter value in *`name`* to *`expr`*.

`getControls()` returns a list of the names of model control inputs of the reduced model.

`setControl(`*`name`*`,`*`expr`*`)` sets the expression for the control value.

`renameControl(`*`oldName`*`,`*`newName`*`)` gives the model control variable a new name.

`getDescriptions(String[] `*`names`*`)` returns a list of descriptions for the corresponding names of parameters, controls, properties, outputs, vectors, and matrices.

`getValues(String[] `*`names`*`)` returns a list of expressions for the corresponding names of parameters, controls, properties, or outputs.

String properties are used for reduced model settings:

- `set(`*`name`*`,`*`value`*`)`: Set the value of the property.
- `getString(`*`name`*`)`: Get the string value of the property.

Depending on the type of model, the following properties are available:.

TABLE 2-93: PROPERTIES FOR MODEL.REDUCED

NAME	VALUE	DEFAULT	DESCRIPTION
depvars	on | off	off	Control if models with output variables also should define degrees of freedom.
reconstruction	on | off	off	Control if reduced models with reconstruction capability should have reconstruction enabled or not.
rtol	String		Relative tolerance for time dependent modal models.

`getVectors()` and `getMatrices()` return lists of names of vectors and matrices that can be retrieved from a reduced model.

For information about the `getM`, `getN`, `getNnz`, `isReal`, and the `getSparseMatrix` and `getVector` methods, see the matrix data tables Table 6-6 and Table 6-7 in the *Solvers and Study Steps* chapter.

model.result()

Postprocessing and results interface.

SYNTAX

```
model.result();
model.result().create(<pgtag>,dim);
model.result().create(<pgtag>,ftype);
model.result().autoplot();
model.result().autoplot(<value>);
model.result(<pgtag>).set(property,<value>);
model.result(<pgtag>).run();

model.result(<pgtag>).create(<ftag>,ftype);
model.result(<pgtag>).feature(<ftag>).getPlotGroup();
model.result(<pgtag>).feature(<ftag>).getType();
model.result(<pgtag>).feature(<ftag>).getSDim();
model.result(<pgtag>).feature(<ftag>).isPlotGroup();
model.result(<pgtag>).feature(<ftag>).prepareView(<value>);
model.result(<pgtag>).feature(<ftag>).selection(...);
model.result(<pgtag>).feature(<ftag>).set(property,<value>);
model.result(<pgtag>).feature(<ftag>).run();
model.result(<tag>).feature(<ftag>).getAllowedPropertyValues(property);

model.result(<pgtag>).feature(<ftag>).create(<attrtag>, attrtype);
model.result(<pgtag>).feature(<ftag>).feature(<attrtag>).set(property,<value>);

model.result().dataset().create(<dtag>,dtype);
model.result().dataset(<dtag>).create(<dtag2>,dtype);
model.result().dataset(<dtag>).selection(...);
model.result().dataset(<dtag>).set(property,<value>);
model.result().dataset(<dtag>).getAllowedPropertyValues(property);

model.result().export().create(<etag>,<pgtag>,ctype);
model.result().export(<etag>).create(<e2tag>,ctype);
model.result().export(<etag>).set(property,<value>);
model.result().export(<etag>).run();
model.result().export(<etag>).getAllowedPropertyValues(property);

model.result().numerical().create(<ntag>,ntype);
model.result().numerical(<ntag>).selection(...);
model.result().numerical(<ntag>).set(property,<value>);
model.result().numerical(<ntag>).run();
```

```
model.result().table().create(<ftag>,ntype);
model.result().table(<ftag>).setColumnHeaders(<headers>);
model.result().table(<ftag>).setTableData(<realData>,<imagData>);
model.result().table(<ftag>).getColumnHeaders();
model.result().table(<ftag>).getReal();
model.result().table(<ftag>).getImag();
model.result().table(<ftag>).isComplex();
model.result().table(<ftag>).clearTableData();
model.result().table(<ftag>).save(<filename>);

model.result().report().create(<rtag>);
odel.result().report(<rtag>).getAllowedPropertyValues(property);
model.result().report(<rtag>).set(rprop,<value>);
model.result().report(<rtag>).set("template", <value>);
model.result().report(<rtag>).generate();
mmodel.result().report(<rtag>).create(<r2tag>,frtype);
model.result().report(<rtag>).feature(<r2tag>).set(rprop,<value>);
model.result().report(<rtag>).feature(<r2tag>).create(<r3tag>,frtype);
model.result().report(<rtag>).feature(<r2tag>).feature(<r3tag>).set(rprop,<value>);
model.result().report(<rtag>).run();
```

DESCRIPTION

`model.result(<pgtag>)` returns a plot group with tag *<pgtag>*.

`model.result().create(<pgtag>,dim)` creates a plot group with the tag *<pgtag>*, of dimension *dim*, where *dim* can be 1, 2, or 3.

`model.result().create(<pgtag>,ftype)` creates a plot group of type *ftype*.

`model.result().autoplot()` returns true if plot features are plotted automatically when selected. `model.result().autoplot(true)` and `model.result().autoplot(false)` enable and disable automatic plotting, respectively.

`model.result(<pgtag>).create(<ftag>,ftype)` creates a plot feature of type *ftype* tagged *<ftag>* belonging to the plot group *<pgtag>*.

`model.result(<pgtag>).feature(<ftag>).getType()` returns the type of the feature *<ftag>*. This is the same string *ftype* that was used to create the feature.

`model.result(<pgtag>).feature(<ftag>).getSDim()` returns the spatial dimension of the plot group.

`model.result(<pgtag>).feature(<ftag>).isPlotGroup()` return `true` if the feature is a plot group. This method is also available on the child features.

`model.result(<pgtag>).feature(<ftag>).getPlotGroup()` returns the plot group the feature belongs to. This method is also available on the child features.

`model.result(<pgtag>).feature(<ftag>).create(<attrtag>, attrtype)` creates an attribute feature with the tag *<attrtag>* of type *attrtype*, belonging to the feature *<ftag>*.

`model.result(<pgtag>).run()` plots the plot group.

`model.result(<pgtag>).feature(<ftag>).prepareView(<value>)` returns the view to use when plotting the plot group to which the feature belongs. The argument is a Boolean, and if `true`, the view is created if needed.

`model.result().dataset().create(<dtag>,dtype)` creates a data set feature with the tag *<dtag>* and the type *dtype*.

`model.result().export().create(<etag>,<pgtag>,etype)` creates an export feature with the tag *<etag>*, belonging to plot group *<pgtag>* and of export type *etype*.

`model.result().numerical().create(<ntag>, ntype)` creates a numerical results feature with the tag `<ntag>` of the numerical feature type `ntype`.

`model.result().numerical(<ntag>).run()` evaluates the numerical results feature.

`model.result(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)`, `model.result().dataset(<dtag>).getAllowedPropertyValues(property)`, `model.result().export(<etag>).getAllowedPropertyValues(property)`, and `model.result().report(<rtag>).getAllowedPropertyValues(property)` return the set of allowed values for a property if the set is a finite set of strings; otherwise, they return null.

`model.result().dataset(<dtag>).refresh()` updates Grid data set using data from functions that read files (Elevation, Image, and Interpolation).

`model.result().table().create(<ftag>,ntype)` creates a table feature with the tag `<ftag>`. The set and get methods used to manipulate tables are described in Table.

The data extraction methods used to retrieve plot or numerical data are described in Results.

`model.result().report().create(<rtag>,"Report")` creates a report with tag `<rtag>`.

`model.result().report().create(<ttag>,"Template")` creates a report template with tag `<ttag>`. Such report templates are customized alternatives to the built-in templates: brief, intermediate, and complete. A complete report template contains a single instance of each of the regular model-contents report features. When a model-contents report feature occurs in a template, the available properties match those of the corresponding regular report feature. However, some regular report-feature properties, such as the `noderef` property for referencing the model feature to report on, are not applicable and therefore not available.

To set up a template `template`, you can build it feature by feature or use one of the built-in templates as the starting point and then generate it before customizing the settings:

```
template.set("level", lvalue);
template.set("absentnodes",state);
template.generate();
```

The allowed values for the `level` property are `"brief"`, `"intermediate"` (default), and `"complete"`. The value of this property is also used to define the initial settings when building the template manually. The `absentnodes` property can take two values:

- `"exclude"` (default) — template nodes that are absent from or disabled in the template are *excluded* when generating a report using the template;
- `"include"` — conversely, template nodes that are absent from or disabled in the template are *included* when generating a report using the template.

Having created the report `report`, specify which template to use and then generate contents:

```
report.set("template", value);
report.generate();
```

The allowed values for the `template` property depends on the availability of custom templates in the model, the installation, and the user's report templates directory:

- The built-in templates, `"brief"`, `"intermediate"` (default), and `"complete"`, are always available.
- If the model contains report templates with tags `tmpl1`, …, `tmpln`, these can be chosen as templates for `report` by setting the `template` property to any of the values `"model.tmpl1"`, …, `"model.tmpln"`, with `model` being a fixed namespace prefix.

- If the directory `data/reporttemplates` under the COMSOL Multiphysics installation root directory contains MPH-files with report templates, these can be chosen by setting template to `"installation.`*`<TemplateFilename>`*`.`*`<ttag>`*`"`. Here `installation` is a fixed namespace prefix, *`<TemplateFilename>`*`.mph` is the name of the MPH-file, and *`<ttag>`* is a report template tag.
- Finally, if the `reporttemplates` directory under the user settings directory `.comsol/v54` under your local home directory contains MPH-files with report templates, these are chosen using the same pattern as for installation templates with the difference that the namespace prefix is `user`.

Note that if `report` already has child nodes when `report.generate()` is called, these nodes will be removed before the generation of new contents.

`report.create(`*`<tptag>`*`,"TitlePage")` adds a title page to the report `report`. Only one title-page feature can be added.

`report.feature(`*`<tptag>`*`).set(`*`prop,value`*`)` sets the title-page property *`prop`* to the value *`value`*.

`report().create(`*`<toctag>`*`,"TableOfContents")` adds a table of contents to the report `report`. Only one table-of-contents feature can be added.

`report.create(`*`<stag>`*`,"Section")` adds an additional section level to a report.

`report.feature(`*`<stag>`*`).set(`*`prop,value`*`)`

`report.feature(`*`<stag>`*`).create(`*`<ftag>`*`),`*`feature`*`)`

`report.feature(`*`<stag>`*`).feature(`*`<ftag>`*`).set(`*`prop,value`*`)`

To add a report contents feature — that is, a feature corresponding to content in the report — to a report section feature `section`, type, `section.create(`*`<frtag>`*`,`*`frtype`*`,…)`. Depending on the report feature type *`frtype`*, the create operation includes zero, one or two tags that refer to the model feature to report about. The tags must refer to an existing feature of the correct type. The report feature types are available for reporting on the model contents are listed in Table 2-94. For details on their usage, see the section Model Contents — Report Components in the *COMSOL Multiphysics User's Guide*.

TABLE 2-94: MODEL-CONTENTS REPORT FEATURES

REPORT FEATURE	DESCRIPTION
`Model`	Prints information about the model root, such as model file.
`ModelNode`	Prints information about a model component.
`Parameter`	Reports on a global parameters feature.
`Variables`	Reports on a variables feature.
`Functions`	Reports on a function feature.
`ThermoPackage`	Reports on a thermodynamics property-package feature (requires a Chemical Reaction Engineering Module license).
`MethodCall`	Report on a method-call feature.
`Group`	Report on a constraint- or load-group feature.
`ReducedModel`	Report on a reduced-model feature.
`GeometryPart`	Report on a geometry part.
`MeshPart`	Report on a mesh part.
`ExtraDim`	Prints information about an extra-dimension model component.
`MatrixVariable`	Report on a matrix-variable feature.
`ParticipationFactors`	Report on a participation-factors feature.
`ResponseSpectrum`	Report on a response-spectrum feature.

TABLE 2-94: MODEL-CONTENTS REPORT FEATURES

REPORT FEATURE	DESCRIPTION
MassProperties	Reports on a mass-properties feature.
Probe	Reports on a probe feature.
ComponentCoupling	Reports on a component-coupling feature.
Selection	Reports on a selection feature.
Pair	Reports on a pair feature.
CoordinateSystem	Reports on a coordinate system feature.
MovingMesh	Report on a moving-mesh feature.
AbsorbingLayer	Reports on an absorbing-layer feature.
PML	Reports on a perfectly-matched-layer feature.
InfiniteElements	Reports on an infinite-element-domain feature.
MultiphysicsProp	Reports on a Multiphysics-properties feature.
Geometry	Reports on a geometry.
Material	Reports on a material feature.
Physics	Reports on a physics interface and its features.
Multiphysics	Reports on a multiphysics coupling and its features.
Mesh	Reports on a mesh.
Study	Reports on a study.
Solver	Reports on a solver.
ResultParameter	Reports on a result-parameters feature.
DataSet	Reports on a data-set feature.
DerivedValues	Reports on a derived-values feature.
Table	Includes a results table in the report.
PlotGroup	Includes a plot group in the report.
EvaluationGroup	Reports on an evaluation-group feature.
Export	Includes an export feature in the report.

In addition, the custom report feature types listed in Table 2-95 are also available for building reports. Their usage is described in the section Custom Report Components in the *COMSOL Multiphysics User's Guide*.

TABLE 2-95: CUSTOM-CONTENTS REPORT FEATURES

REPORT FEATURE	DESCRIPTION
Equation	Adds an equation to the report.
Heading	Adds a heading to the report.
Image	Adds an image to the report.
List	Adds a list to the report.
ListItem	Adds an item to a list.
Tbl	Adds a custom table to the report.
TblHRow	Adds a heading row to a custom table.
TblRow	Adds a body row to a custom table.
Text	Adds a text paragraph to the report.
Code	Adds a text paragraph with code formatting.

Finally, a number of report feature types are provided for creating reports for applications created in the Application Builder. These are listed in Table 2-96. For further details, see the sections Arrays and Scalars and Declaration Components in the *COMSOL Multiphysics User's Guide* and references therein.

TABLE 2-96: ARRAYS, SCALARS, AND DECLARATION-CONTENTS REPORT FEATURES

REPORT FEATURE	DESCRIPTION
`Arrays`	Adds a customized table for Array 1D and Array 2D declaration nodes defined under the Declarations branch in the Application Builder.
`Scalars`	Adds a table where the columns to include and the table data rows can be customized.
`ChoiceList`	Reports on a choice list.
`UnitSet`	Reports on a unit set.
`StringDataField`, `BooleanDataField`, `IntegerDataField`, `DoubleDataField`	Reports on scalar data declarations.
`StringArrayDataField`, `BooleanArrayDataField`, `IntegerArrayDataField`, `DoubleArrayDataField`	Reports on 1D array data declarations.
`StringMatrixDataField`, `BooleanMatrixDataField`, `IntegerMatrixDataField`, `DoubleMatrixDataField`	Reports on 2D array data declarations.

To point a report feature `rFeature` to another feature with tag *<ftag>* in the tree, use the method `rFeature.set("noderef",`*<ftag>*`)` method. A report contents feature must point to a feature of the type it is designed to report on; see the table above. Instead of a feature tag, set `"noderef"` to `"none"` to clear a reference.

`model.result().report(`*<rtag>*`).feature(`*<stag>*`).feature(`*<frtag>*`).set(`*frprop*`, `*<value>*`)`

to set a property in a report feature.

EXAMPLES

Create a data set and set it to point to the tagged solution `sol1` from a solver sequence:

Code for Use with Java

```
model.result().dataset().create("dset", "Solution");
model.result().dataset("dset").set("solution", "Sol1");
```

Code for Use with MATLAB

```
model.result.dataset.create('dset', 'Solution');
model.result.dataset('dset').set('solution', 'Sol1');
```

Create a 3D plot group containing a streamline plot and a plane with a contour plot on:

Code for Use with Java

```
result().create("pg1",3);
result("pg1").set("data","dset");
result("pg1").create("stream","Streamline");
model.result("pg1").feature("stream").set("expr", new String[]{"2-x", "0", "z"});
model.result("pg1").feature("stream").selection().set(new int[]{2});
result().dataset().create("cutp1","CutPlane");

result("pg1").create("cont1","Contour");
result("pg1").feature("cont1").set("data","cutp1");
result("pg1").run();
```

Code for Use with MATLAB

```
result.create('pg1',3);
```

```
result('pg1').set('data','dset');
result('pg1').create('stream','Streamline');
model.result('pg1').feature('stream').set('expr', {'2-x', '0', 'z'});
model.result('pg1').feature('stream').selection.set(2);
result.dataset.create('cutp1','CutPlane');

result('pg1').create('cont1','Contour');
result('pg1').feature('cont1').set('data','cutp1');
result('pg1').run;
```

model.savePoint()

Manage selections and hide features used by result features.

SYNTAX

```
model.savePoint(<tag>).geom(<gtag>)
model.savePoint(<tag>).geom(<gtag>).selection(<stag>)
model.savePoint(<tag>).geom(<gtag>).view(<vtag>)
```

DESCRIPTION

`model.savePoint(<tag>)` is a container of selections and hide features used by result features. When solving, a copy of the model is made — a save point model — which is used in results and analysis. The selections and hide features contained in `model.savePoint(<tag>)` refer to the geometry in this copy.

Editing the data in `model.savePoint(<tag>)` can only be done in the following circumstances.

- The geometry on which the analysis is done has been modified after solving. In this case the selections and hide feature can be edited but not created or removed.
- The geometry on which the analysis is done has been removed. In this case the selections and hide features can be both edited, created, and deleted.

In all other circumstances, edit the selections in `model.component(<ctag>).selection()`, and the hide features in `model.component(<ctag>).view()`. Changes there are synchronized with the data in `model.savePoint()`.

`model.savePoint(<tag>).geom(<gtag>)` returns a container with selections and views with hide features for a geometry in the save point model.

`model.savePoint(<tag>).geom(<gtag>).selection(<stag>)` returns a selection.

`model.savePoint(<tag>).geom(<gtag>).view(<vtag>)` returns a view. Contrary to the views in `model.component(<ctag>).view()`, only the hide features in `view.hideEntities()` can be edited.

SEE ALSO

`model.selection()`, `model.weak()`

model.selection()

Named selections.

SYNTAX

```
model.selection().create(<tag>);
model.selection().create(<tag>,<type>);
model.selection(<tag>).model(<mtag>);
model.selection(<tag>).set(property,<value>);
model.selection(<tag>).geom(<gtag>,dim);
model.selection(<tag>).geom(<gtag>,highdim,lowdim,typelist);
model.selection(<tag>).geom(dim);
model.selection(<tag>).all();
model.selection(<tag>).set(<entlist>);
model.selection(<tag>).add(<entlist>);
model.selection(<tag>).remove(<entlist>);
model.selection(<tag>).inherit(bool);

model.selection(<tag>).model();
model.selection(<tag>).isGeom();
model.selection(<tag>).geom();
model.selection(<tag>).dimension();
model.selection(<tag>).entities(dim);
model.selection(<tag>).interiorEntities(dim);
model.selection(<tag>).isInheriting();
model.selection(<tag>).inputDimension();
model.selection(<tag>).inputEntities();
model.selection(<tag>).image();
```

DESCRIPTION

`model.component(<ctag>).selection(<tag>)` returns a named selection. Anywhere where you define a selection, you can point to a named selection by using its tag, for example, *`selection`*`.named(<tag>.`

`model.component(<ctag>).selection().create(<tag>)` creates a named selection of type Explicit.

`model.component(<ctag>).selection().create(<tag>,<type>)` creates a named selection of type *`<type>`*. The following types are available: `"Explicit"`, `"Union"`, `"Intersection"`, `"Difference"`, `"Complement"`, `"Adjacent"`, `"Ball"`, `"Box"`, `"Cylinder"`, and `"Disk"`.

`model.selection(<tag>).model(<mtag>)` sets the model component node of the selection.

`model.selection(<tag>).model()` returns the model component node tag of the selection.

`model.component(<ctag>).selection(<tag>).set(`*`property`*`,<value>)` sets a property value for the selection. Which properties are available for the different selection types are listed on the following pages. All other assignment methods are only supported by the `Explicit` selection type.

Use the `model.selection(<tag>).image()` methods for plotting and exporting selection images. See Plotting and Exporting Images.

All other methods are explained in the section `Selections`.

Other entities can use any of the selections in `model.component(<ctag>).selection()` when defining its selection. For example, create a selection `sel1`:

```
model.component("comp1").selection().create("sel1");
```

Then, for example, a variable entities can use this selection:

```
model.component("comp1").variable().create("var1”);
model.component("comp1").variable("var1").model("mod1");
model.component("comp1").variable("var1").selection().named("sel1");
```

What properties are available depends on the type of selection. The following selection types are available:

Explicit

Selection defined by an explicit set of geometric entities such as domains or boundaries.

TABLE 2-97: EXPLICIT SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`angletol`	double	`5`	Angle tolerance for continuity evaluation
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`groupcontang`	`on` | `off`	`off`	Continuous tangent mode

When `groupcontang` is set to `on`, the `set`, `add`, and `remove` methods operate on groups of adjacent entities that have continuous tangents at their junctions.

The `angletol` property defines the tolerance for the continuity evaluation.

Ball

Selection of entities that are inside or intersect a ball.

TABLE 2-98: BALL SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`entitydim`	`0` | `1` | `2` | `3`	`sdim`	Dimension of entities to select
`angletol`	double	`5`	Angle tolerance for continuity evaluation
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`groupcontang`	`on` | `off`	`off`	Continuous tangent mode
`groupcontang`	`on`|`off`	`off`	Continuous tangent mode
`inputent`	`all` | `selections`	`all`	Use all entities or entities defined by input property
`input`	string[]	`{}`	Input selections
`condition`	`intersects` | `inside` | `somevertex` | `allvertices`	`intersects`	Condition for inclusion of an entity
`posx`	double	0	Center of ball, first coordinate
`posy`	double	0	Center of ball, second coordinate
`posz`	double	0	Center of ball, third coordinate
`r`	double	0	Radius

The `posx`, `posy`, and `posz` properties define the center of the ball, and `r` defines the radius. These properties take their units from the corresponding geometry sequence.

When `condition` is `intersects`, all entities that intersect the ball are included in the selection. The rendering mesh is used for the calculation. You can set the accuracy of the rendering mesh using

```
ModelUtil.setPreference("graphics.rendering.detail",<detail>);
```

where *<detail>* is `coarse`, `normal`, `fine`, or `wireframe`.

When `condition` is `inside`, all entities that are completely inside the ball are included in the selection. The rendering mesh is used for the calculation.

When `condition` is `somevertex`, all entities that have at least one adjacent vertex inside the ball are included in the selection.

When `condition` is `allvertices`, all entities that have all adjacent vertices inside the ball are included in the selection.

When `inputent` is `selections`, the selection is restricted to the entities in the selections defined by the input property. When `inputent` is `all`, all entities in the geometry are considered.

When `groupcontang` is set to `on`, the selection operates on groups of entities that have continuous tangents at their junctions.

The `angletol` property defines the tolerance for the continuity evaluation.

Box

Selection of entities that are inside or intersect a box.

TABLE 2-99: BOX SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`entitydim`	0 | 1 | 2 | 3	`sdim`	Dimension of entities to select
`angletol`	double	5	Angle tolerance for continuity evaluation
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`groupcontang`	`on` | `off`	`off`	Continuous tangent mode
`groupcontang`	`on`|`off`	`off`	Continuous tangent mode
`inputent`	`all` | `selections`	`all`	Use all entities or entities defined by input property
`input`	string[]	{}	Input selections
`condition`	`intersects` | `inside` | `somevertex` | `allvertices`	`intersects`	Condition for inclusion of an entity
`xmax`	double	`inf`	Maximum x-coordinate of box
`xmin`	double	`-inf`	Minimum x-coordinate of box
`ymax`	double	`inf`	Maximum y-coordinate of box
`ymin`	double	`-inf`	Minimum y-coordinate of box
`zmax`	double	`inf`	Maximum z-coordinate of box
`zmin`	double	`-inf`	Minimum z-coordinate of box

The `xmax`, `xmin`, `ymax`, `ymin`, `zmax`, and `zmin` properties define the box. These properties take their units from the corresponding geometry sequence.

When `condition` is `intersects`, all entities that intersect the box are included in the selection. The rendering mesh is used for the calculation. You can set the accuracy of the rendering mesh using

```
ModelUtil.setPreference("graphics.rendering.detail",<detail>);
```

where *<detail>* is `coarse`, `normal`, `fine`, or `wireframe`.

When `condition` is `inside`, all entities that are completely inside the box are included in the selection. The rendering mesh is used for the calculation.

When `condition` is `somevertex`, all entities that have at least one adjacent vertex inside the box are included in the selection.

When `condition` is `allvertices`, all entities that have all adjacent vertices inside the box are included in the selection.

When `inputent` is `selections`, the selection is restricted to the entities in the selections defined by the input property. When `inputent` is `all`, all entities in the geometry are considered.

When `groupcontang` is set to `on`, the selection operates on groups of entities that have continuous tangents at their junctions.

The `angletol` property defines the tolerance for the continuity evaluation.

Cylinder

Selection of entities that are inside or intersect a cylinder in 3D.

TABLE 2-100: CYLINDER SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`angle1`	double	0	Start angle
`angle2`	double	360	End angle (default: 360 degrees; that is, a full cylinder)
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`groupcontang`	`on` | `off`	`off`	Continuous tangent mode
`entitydim`	`0` | `1` | `2` | `3`	3	Dimension of entities to select
`angletol`	double	5	Angle tolerance for continuity evaluation
`groupcontang`	`on`|`off`	`off`	Continuous tangent mode
`inputent`	`all`|`selections`	`all`	Use all entities or entities defined by input property
`input`	string[]	{}	Input selections
`condition`	`intersects` | `inside` | `somevertex` | `allvertices`	`intersects`	Condition for inclusion of an entity
`pos`	double[]	{0,0,0}	Cylinder base point
`axis`	double[]	{0,0,1}	Direction of the cylinder axis. Vector has length 3 if `axistype` is `cartesian` and length 2 if `axistype` is `spherical`. Not used if `axistype` is x, y, or z.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`top`	double	`inf`	Coordinate of upper face in local coordinate system
`bottom`	double	`-inf`	Coordinate of lower face in local coordinate system

TABLE 2-100: CYLINDER SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
r	double (nonnegative)	0	Outer radius
rin	double (nonnegative)	0	Inner radius

The pos property defines the center of the cylinder and the axis property defines the cylinder axis. The top, bottom, r, and rin properties define the size of the cylinder. Setting rin equal to r corresponds to a cylindrical surface. These properties take their units from the corresponding geometry sequence. Using the angle1 and angle2 properties, you can create a cylinder segment.

When condition is intersects, all entities that intersect the cylinder are included in the selection. The rendering mesh is used for the calculation. You can set the accuracy of the rendering mesh using

```
ModelUtil.setPreference("graphics.rendering.detail",<detail>);
```

where *<detail>* is coarse, normal, fine, or wireframe.

When condition is inside, all entities that are completely inside the cylinder are included in the selection. The rendering mesh is used for the calculation.

When condition is somevertex, all entities that have at least one adjacent vertex inside the cylinder are included in the selection.

When condition is allvertices, all entities that have all adjacent vertices inside the cylinder are included in the selection.

When inputent is selections, the selection is restricted to the entities in the selections defined by the input property. When inputent is all, all entities in the geometry are considered.

When groupcontang is set to on, the selection operates on groups of entities that have continuous tangents at their junctions.

The angletol property defines the tolerance for the continuity evaluation.

Disk

Selection of entities that are inside or intersect a disk.

TABLE 2-101: DISK SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
angle1	double	0	Start angle
angle2	double	360	End angle (default: 360 degrees; that is, a full disk)
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
groupcontang	on | off	off	Continuous tangent mode
entitydim	0 | 1 | 2	sdim	Dimension of entities to select
angletol	double	5	Angle tolerance for continuity evaluation
groupcontang	on|off	off	Continuous tangent mode
inputent	all | selections	all	Use all entities or entities defined by input property
input	string[]	{}	Input selections

TABLE 2-101: DISK SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
condition	intersects | inside | somevertex | allvertices	intersects	Condition for inclusion of an entity
posx	double	0	Center of disk, first coordinate
posy	double	0	Center of disk, second coordinate
r	double (nonnegative)	0	Outer radius
rin	double (nonnegative)	0	Inner radius

The posx and posy properties define the center of the disk, and r and rin define the outer and inner radius, respectively. These properties take their units from the corresponding geometry sequence. Using the angle1 and angle2 properties, you can create a disk segment.

When condition is intersects, all entities that intersect the disk are included in the selection. The rendering mesh is used for the calculation. You can set the accuracy of the rendering mesh using

```
ModelUtil.setPreference("graphics.rendering.detail",<detail>);
```

where *<detail>* is coarse, normal, fine, or wireframe.

When condition is inside, all entities that are completely inside the disk are included in the selection. The rendering mesh is used for the calculation.

When condition is somevertex, all entities that have at least one adjacent vertex inside the disk are included in the selection.

When condition is allvertices, all entities that have all adjacent vertices inside the disk are included in the selection.

When inputent is selections, the selection is restricted to the entities in the selections defined by the input property. When inputent is all, all entities in the geometry are considered.

When groupcontang is set to on, the selection operates on groups of entities that have continuous tangents at their junctions.

The angletol property defines the tolerance for the continuity evaluation.

Union

Selection defined by the union of a set of selections.

TABLE 2-102: UNION SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
entitydim	0 | 1 | 2 | 3	sdim	Dimension of entities to select
input	string[]	{}	Selections to add

Intersection

Selection defined by the intersection of a set of selections.

TABLE 2-103: INTERSECTION SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.

TABLE 2-103: INTERSECTION SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
groupcontang	on | off	off	Continuous tangent mode
entitydim	0 | 1 | 2 | 3	sdim	Dimension of entities to select
input	string[]	{}	Selections to intersect

Difference

Selection defined by the difference between two sets of selections.

TABLE 2-104: DIFFERENCE SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
groupcontang	on | off	off	Continuous tangent mode
entitydim	0 | 1 | 2 | 3	sdim	Dimension of entities to select
add	string[]	{}	Selections to add
subtract	string[]	{}	Selections to subtract

Complement

Selection defined by the complement of a set of selections.

TABLE 2-105: COMPLEMENT SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
groupcontang	on | off	off	Continuous tangent mode
entitydim	0 | 1 | 2 | 3	sdim	Dimension of entities to select
input	string[]	{}	Selections to invert

Adjacent

Selection of entities that are adjacent to entities in another selection.

TABLE 2-106: ADJACENT SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
groupcontang	on | off	off	Continuous tangent mode
entitydim	0 | 1 | 2 | 3	sdim	Dimension of entities to select
input	String[]	{}	Input selections

TABLE 2-106: ADJACENT SELECTION PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
outputdim	0 | 1 | 2 | 3	sdim-1	Dimension of output entities
exterior	on|off	on	Include exterior boundaries/edges
interior	on|off	off	Include interior boundaries/edges.

EXAMPLES

Define the selection `equ1` as the domain of a rectangle and the selection `bnd1` as the boundary of the rectangle.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
model.component("comp1").geom().create("geom1",2);
model.component("comp1").geom("geom1").create("f1","Rectangle");
model.component("comp1").geom("geom1").run("f1");
model.component("comp1").selection().create("equ1").geom(2);
model.component("comp1").selection("equ1").all();
model.component("comp1").selection().create("bnd1").geom(1);
model.component("comp1").selection("bnd1").all();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
model.component('comp1').geom.create('geom1',2);
model.component('comp1').geom('geom1').create('f1','Rectangle');
model.component('comp1').geom('geom1').run('f1');
model.component('comp1').selection.create('equ1').geom(2);
model.component('comp1').selection('equ1').all;
model.component('comp1').selection.create('bnd1').geom(1);
model.component('comp1').selection('bnd1').all;
```

The (outer) boundaries for the model can be set with the following selection:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
model.component("comp1").geom().create("geom1",2);
model.component("comp1").geom("geom1").create("r1","Rectangle");
model.component("comp1").selection().create("outer").
      geom("geom1",2,1,new String[]{"exterior"});
model.component("comp1").selection("outer").all();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
model.component('comp1').geom.create('geom1',2);
model.component('comp1').geom('geom1').create('r1','Rectangle');
model.component('comp1').selection.create('outer').geom('geom1',2,1,{'exterior'});
model.component('comp1').selection('outer').all;
```

Create a selection for all boundaries of a block intersecting a ball with radius 0.5 and center (1,1,1):

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
model.component("comp1").geom().create("g1",3).create("blk1","Block");
model.component("comp1").geom("g1").run();
model.component("comp1").selection().create("ball1", "Ball");
model.component("comp1").selection("ball1").set("entitydim", "2");
model.component("comp1").selection("ball1").set("posx", "1");
model.component("comp1").selection("ball1").set("posy", "1");
model.component("comp1").selection("ball1").set("posz", "1");
```

```
model.component("comp1").selection("ball1").set("r", "0.5");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
model.component('comp1').geom.create('g1',3).create('blk1','Block');
model.component('comp1').geom('g1').run;
model.component('comp1').selection.create('ball1', 'Ball');
model.component('comp1').selection('ball1').set('entitydim', '2');
model.component('comp1').selection('ball1').set('posx', '1');
model.component('comp1').selection('ball1').set('posy', '1');
model.component('comp1').selection('ball1').set('posz', '1');
model.component('comp1').selection('ball1').set('r', '0.5');
```

Create a selection of all edges adjacent to the boundaries in the ball selection:

Code for Use with Java

```
model.component("comp1").selection().create("adj1", "Adjacent");
model.component("comp1").selection("adj1").set("entitydim", "2");
model.component("comp1").selection("adj1").set("outputdim", "1");
model.component("comp1").selection("adj1").set("input", new String[]{"ball1"});
```

Code for Use with MATLAB

```
model.component('comp1').selection.create('adj1', 'Adjacent');
model.component('comp1').selection('adj1').set('entitydim', '2');
model.component('comp1').selection('adj1').set('outputdim', '1');
model.component('comp1').selection('adj1').set('input', {'ball1'});
```

SEE ALSO

Selections

model.shape()

Create and define shape functions for the field variables' elements.

SYNTAX

```
model.shape().create(<tag>,<frame>);
model.shape(<tag>).elementSet(<condition>);
model.shape(<tag>).frame(<ftag>);
model.shape(<tag>).create(<ftag>,<func>);
model.shape(<tag>).feature(<ftag>).set(property,<value>);
model.shape(<tag>).slits().named(<seltag>);
model.shape(<tag>).slits().set(...);
model.shape(<tag>).upFlux(<varName>);
model.shape(<tag>).downFlux(<varName>);
model.shape(<tag>).domainFlux(<expressions>,<frame>);

model.shape(<tag>).elementSet();
model.shape(<tag>).frame();
model.shape(<tag>).feature(<ftag>).shape();
model.shape(<tag>).feature(<ftag>).getType(<property>);
model.shape(<tag>).feature(<ftag>).properties;
model.shape(<tag>).fieldVariable();
model.shape(<tag>).slits().named();
model.shape(<tag>).slits().getType();
model.shape(<tag>).upFlux();
model.shape(<tag>).downFlux();
```

DESCRIPTION

`model.shape(<tag>)` returns a shape function.

`model.shape().create(<tag>,<frame>)` creates a shape function with tag *<tag>* and assigns the frame *<frame>* to it.

`model.shape(<tag>).frame(<ftag>)` assigns frame *<ftag>* to the shape function. See `model.frame()` for a discussion on the default frame.

`model.shape(<tag>).create(<ftag>,<func>)` creates a shape feature with the shape function expression `func`. `func` can be a shape function name (`shlag`, for example) or a shape function with arguments (`shlag(2,u)`, for example). The latter is interpreted as an assignment of some property values.

`model.shape(<tag>).feature(<ftag>).set(property,<value>)` sets a property for the shape function. Of the data types listed in Table 2-2, the ones supported are those for integers, strings, and string arrays. Which ones are applicable differs for each property.

`model.shape(<tag>).selection().named(<seltag>)` assigns the shape function to the named selection *<seltag>*.
`model.shape(<tag>).selection().set(...)` defines a local selection that assigns the shape function to geometric entities. For a complete list of methods available under `selection()`, see `Selections`.

`model.shape(<tag>).upFlux(<varName>)` and `model.shape(<tag>).downFlux(<varName>)` set the names of the up and down boundary flux variables. `model.shape(<tag>).domainFlux(<expressions>,<frame>)` sets expressions for the domain flux in a given frame. This is required to make the boundary flux variables produce accurate results. Only Lagrange shape functions support boundary flux variables.

`model.shape(<tag>).frame()` returns the frame tag as a string.

`model.shape(<tag>).feature(<ftag>).shape()` returns the shape function expression as a string.

`model.shape(<tag>).feature(<ftag>).get`*`Type`*`(property)` returns a property value. For available data types, see `get* and Selection Access Methods`.

`model.shape(<tag>).feature(<ftag>).properties()` returns the names of the properties as a string array.

`model.shape(<tag>).fieldVariable()` returns the field variables which the shape functions define.

`model.shape(<tag>).selection().named()` returns the selection tag as a string.

`model.shape(<tag>).elementSet(<condition>)` sets the element set condition to the given string. The condition should be an expression containing *element set variables* (defined in `model.elementSet()`) and the logical operators `&&`, `||`, and `!`. The shape function is defined only on the mesh elements for which the condition is true (nonzero).

`model.shape(<tag>).elementSet()` returns the element set condition. An empty string means no condition.

`model.shape(<tag>).selection().get`*`Type`*`()` returns domain information. For available methods, see `model.selection()`.

`model.shape(<tag>).slits()` returns a selection used to generate a slit on the shape. Works exactly as selections.

`model.shape(<tag>).upFlux()` and `model.shape(<tag>).downFlux()` return the names of the up and down flux variables (an empty string if the variable names have not been set.)

EXAMPLE

Define the shape function `shlag(2,"u")`:

Code for Use with Java

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shlag");
model.shape("shu").feature("f1").set("order",2);
model.shape("shu").feature("f1").set("basename","u");
```

```
model.shape("shu").selection().named("equ1");
```

Code for Use with MATLAB

```
model.shape.create('shu','f');
model.shape('shu').create('f1','shlag');
model.shape('shu').feature('f1').set('order',2);
model.shape('shu').feature('f1').set('basename','u');
model.shape('shu').selection.named('equ1');
```

See also Shape Functions and Element Types for information and syntax examples for all shape functions (element types).

SEE ALSO

`model.coeff()`, `model.intRule()`, `model.weak()` and the Elements and Shape Function Programming chapter.

model.sol()

Solver sequences.

SYNTAX

```
model.sol().create(<tag>)
model.sol().create(<tag>,<studytag>)
model.sol().create(<tag>,<studytag>,<varstag>)
model.sol().remove(<tag>)

model.sol(<tag>).create(<ftag>,<oper>)
model.sol(<tag>).feature().remove(<ftag>)
model.sol(<tag>).feature(<ftag>).create(<f2tag>,<oper>)
model.sol(<tag>).feature(<ftag>).set(property,<value>)
model.sol(<tag>).feature(<ftag>).getAllowedPropertyValues(property);
model.sol(<tag>).attach(<stag>)
model.sol(<tag>).clearSolutionData()
model.sol(<tag>).copySolution(<ctag>)
model.sol(<tag>).createAutoSequence(<stag>)
model.sol(<tag>).createSolution()
model.sol(<tag>).updateSolution()
model.sol(<tag>).isEmpty()
model.sol(<tag>).isInitialized()
model.sol(<tag>).run(<ftag>)
model.sol(<tag>).runFrom(<ftag>)
model.sol(<tag>).runFromTo(<ftagstart>,<ftagstop>)
model.sol(<tag>).runAll()
model.sol(<tag>).run()
model.sol(<tag>).continueRun()
```

DESCRIPTION

`model.sol().create(<tag>)` adds a solver sequence to the model.

`model.sol().create(<tag>,<studytag>)` adds a solver sequence to the model. The constructor adds one feature of the type `StudyStep` to the solver sequence with the tag *<studytag>*. This `StudyStep` feature is connected to a study step (see `model.study()`).

`model.sol().create(<tag>,<studytag>,<varstag>)` adds a solver sequence to the model. The constructor adds one feature of the type `StudyStep` with the tag *<studytag>* and one feature of the type `Variables` with the tag *<varstag>* to the solver sequence.

`model.sol().remove(<tag>)` removes a solver sequence from the model.

`model.sol(<tag>).create(<ftag>,<oper>)` creates a solver feature. Each solver feature is a solver operation.

`model.sol(<tag>).feature().remove(<ftag>)` removes the solver feature *<ftag>*.

`model.sol(<tag>).feature(<ftag>).set(property,<value>)` sets the property *property* for the feature *<ftag>*.

`model.sol(<tag>).feature(<ftag>)).getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

`model.sol(<tag>).attach(<stag>)` attaches a solver sequence with tag *<tag>* to a study with tag *<stag>*, which makes it visible under that study.

`model.sol(<tag>).clearSolutionData()` clears computed solution data associated with the solver sequence *<tag>*. Solution selection settings and settings in results features associated with the solution are not modified.

`model.sol(<tag>).setClusterStorage(<value>)` sets the solution storage format used on clusters. Use the *<value>* `"all"` to store the solution on all cluster nodes and the *<value>* `"single"` to store the solution only on a single cluster node.

`model.sol(<tag>).getClusterStorage()` returns `"all"` if the solution is stored on all cluster nodes and `"single"` if the solution is only stored a single cluster node.

`model.sol(<tag>).copySolution(<ctag>)` copies the solution data associated with the solver sequence *<tag>* to a new solver sequence *<ctag>*. The features are not copied.

`model.sol(<tag>).createAutoSequence(<stag>)` creates a solver sequence of features automatically from the study *<stag>*. The sequence of study steps are used as input to the sequence generation algorithm but also the physics used in the study steps are used to automatically adopt the solver settings.

`model.sol(<tag>).createSolution()` creates a solution object from one or more set operations (`setU(..)`, ...), see Solution Creation for details.

`model.sol(<tag>).updateSolution()` updates a solution data associated with the solver sequence to make it consistent with the current model.

`model.sol(<tag>).isEmpty()` is true if there is no solution data or if all solution data has been cleared.

`model.sol(<tag>).isInitialized()` is true if the solution is a valid (initialized) object. Even if the solution has been cleared, `isInitialized` is true (use `isEmpty` to check for cleared solution data).

`model.sol(<tag>).run(<ftag>)` runs the features for a solver sequence up to and including the feature *<ftag>*.

`model.sol(<tag>).runFrom(<ftag>)` runs the features for a solver sequence from and including the feature *<ftag>*.

`model.sol(<tag>).runFromTo(<ftagstart>,<ftagstop>)` runs the features for a solver sequence from and including the feature *<ftagstart>* to and including the feature *<ftagstop>*.

`model.sol(<tag>).runAll()` and `model.sol(<tag>).run()` run all the features for a solver sequence.

`model.sol(<tag>).continueRun()` continues to run a solver sequence.

EXAMPLES

Assume that a study `st1` represents one stationary study step with the tag `stat1` for some equations.

Code for Use with Java

```
model.sol().create("s","step1","vars1");
model.sol("s").feature("step1").set("study","st1");
model.sol("s").feature("step1").set("studystep","stat1");
model.sol("s").create("solver1","Stationary");
```

Code for Use with MATLAB

```
model.sol.create('s','step1','vars1');
```

```
model.sol('s').feature('step1').set('study','st1');
model.sol('s').feature('step1').set('studystep','stat1');
model.sol('s').create('solver1','Stationary');
```

Assume that a second study step with frequency response is added to the study with tag `freq1` and that you want to make a frequency sweep from 10 to 1000 using the parametric solver and the solution above as the linearization point (bias solution).

Code for Use with Java

```
model.sol("s").create("step2","StudyStep");
model.sol("s").feature("step2").set("study","st1");
model.sol("s").feature("step2").set("studystep","freq1");
model.sol("s").create("vars2","Variables");
SolverFeature s2 = (SolverFeature) model.sol("s").create("solver2","Stationary");
s2.set("nonlin","linper");   //(*)
s2.set("linpmethod","sol");
s2.set("linpsol", "s");
s2.set("storelinpoint", "on");
s2.create("par","Parametric");
s2.feature("par").set("pname","freq");
s2.feature("par").set("plist",new double[]{10,1000});
s2.runAll();
```

Code for Use with MATLAB

```
model.sol('s').create('step2','StudyStep');
model.sol('s').feature('step2').set('study','st1');
model.sol('s').feature('step2').set('studystep','freq1');
model.sol('s').create('vars2','Variables');
s2 = model.sol('s').create('solver2','Stationary');
s2.set('nonlin','linper');   //(*)
s2.set('linpmethod','sol');
s2.set('linpsol', 's');
s2.set('storelinpoint', 'on');
s2.create('par','Parametric');
s2.feature('par').set('pname','freq');
s2.feature('par').set('plist',[10,1000]);
s2.runAll;
```

At this point the solution `s` is associated to the study step `freq1` (but it depends indirectly on the bias study step `stat1` as well).

(*) Uses the small-signal study functionality, which makes it possible to access also the linearization point for postprocessing together with the small-signal solution. Here it is assumed that the bias problem and the small-signal problem can be set up independently for the two study steps.

COMPATIBILITY

From version 5.3a, the method

```
model.sol(<tag>).clearSolution()
```

is deprecated and replaced by the method

```
model.sol(<tag>).clearSolutionData()
```

since `clearSolutionData` generally works as expected, while `clearSolution` clears settings unexpectedly.

SEE ALSO

`model.study()`

model.solverEvent()

Create and define events for the solver.

SYNTAX

```
model.solverEvent().create(<tag>,evtype);
model.solverEvent(<tag>).start(expr);
model.solverEvent(<tag>).start();
model.solverEvent(<tag>).period(expr);
model.solverEvent(<tag>).period();
model.solverEvent(<tag>).condition(expr);
model.solverEvent(<tag>).condition();
model.solverEvent(<tag>).reinit();
model.solverEvent(<tag>).reinit().create(<tag>);
model.solverEvent(<tag>).reinit(<tag>).set(<var>,expr);
```

DESCRIPTION

Create events and control event settings. There are two types of events; `Explicit` and `Implicit`.

`model.solverEvent().create(`*<tag>*`,`*evtype*`)` creates a new event of type *evtype*, either `Explicit` and `Implicit`.

Explicit Events

Explicit events triggers on a predefined timing.

`model.solverEvent(`*<tag>*`).start(expr)` sets the start time for an explicit event.

`model.solverEvent(`*<tag>*`).period(expr)` sets the period for an explicit event. After the start time, the event then triggers after each period.

Implicit Events

Implicit events trigger when a condition goes from false to true.

`model.solverEvent(`*<tag>*`).condition(expr)` sets the condition for an implicit event.

Re-Initialization

When an event is triggered, any degree of freedom can be re-initialized. This typically means that they get a new value. You specify these values with a re-initialization method, `reinit(...)`, which has the same syntax as `model.init(...)` .

`model.solverEvent(`*<tag>*`).reinit().create(`*<tag>*) adds a new reinit feature to the event. In most cases you only need one, but you need more when you have reinitialization conditions on several geometric entity levels, for example on a global selection and a domain selection.

Event State Variables

An event needs state variables in most cases. There are discrete states and indicator states. Discrete states are just ODE states that only change during re-initialization, and can only have a zero-valued equation (or no equation). The indicator states are needed for implicit events and are ODE states with nonzero equations.

`model.ode().create(`*<tag>*`).type(`*<ode type>*) creates a new global equation that contains event state variables if you set the ode type to `discrete` for discrete states and `quadrature` for indicator states.

`model.ode(`*<tag>*`).state(`*<states>*) adds a new discrete states to the global equation.

`model.ode(`*<tag>*`).ode(`*<state>*`,"sin(2*pi*t)")` adds a new indicator state and its right-hand side to the global equation. The left-hand side of the equation is the state variable, so the full equation for the indicator state becomes `nojac(sin(2*pi*t))-`*<state>*.

EXAMPLE

Example of an idealized bouncing ball using implicit events.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
```

```
model.study().create("std1");
model.study("std1").create("time1", "Transient");
model.study("std1").feature("time1").set("tlist", "0 10");
model.study("std1").feature("time1").set("rtol", 1e-6);// Nondiscrete states
model.ode().create("ode1");
model.ode("ode1").ode("y", "-2*y-ytt");
model.init().create("ode1");
model.init("ode1").selection().global();
model.init("ode1").set("y", "1");
// Discrete states
model.ode().create("ode2").type("quadrature");
model.ode("ode2").ode("z1", "y");
// Implicit event
model.solverEvent().create("impl1", "Implicit");
model.solverEvent("impl1").condition("!(z1>=0)");
model.solverEvent("impl1").reinit().create("reinit");
model.solverEvent("impl1").reinit("reinit").selection().global();
model.solverEvent("impl1").reinit("reinit").set("y", "y");
// Bounce reverts velocity
model.solverEvent("impl1").reinit("reinit").set("yt", "-yt");
model.sol().create("sol1");
model.sol("sol1").createAutoSequence("std1");
// Special solver settings for events
model.sol("sol1").feature("t1").set("tout", "tsteps");
model.sol("sol1").feature("t1").set("atolglobal", "1e-6");
model.sol("sol1").feature("t1").set("initialstepbdfactive", "on");
model.sol("sol1").feature("t1").set("initialstepbdf", "1e-6");
model.sol("sol1").feature("t1").set("eventtol", "2e-6");
model.sol("sol1").feature("t1").set("ewtrescale", "off");
model.sol("sol1").runAll();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.study.create('std1');
model.study('std1').create('time1', 'Transient');
model.study('std1').feature('time1').set('tlist', '0 10');
model.study('std1').feature('time1').set('rtol', 1e-6);
% Nondiscrete states
model.ode.create('ode1');
model.ode('ode1').ode('y', '-2*y-ytt');
model.init.create('ode1');
model.init('ode1').selection().global();
model.init('ode1').set('y', '1');
% Discrete states
model.ode.create('ode2').type('quadrature');
model.ode('ode2').ode('z1', 'y');
% Implicit event
model.solverEvent.create('impl1', 'Implicit');
model.solverEvent('impl1').condition('!(z1>=0)');
model.solverEvent('impl1').reinit().create('reinit');
model.solverEvent('impl1').reinit('reinit').selection().global();
model.solverEvent('impl1').reinit('reinit').set('y', 'y');
% Bounce reverts velocity
model.solverEvent('impl1').reinit('reinit').set('yt', '-yt');
model.sol().create('sol1');
model.sol('sol1').createAutoSequence('std1');
% Special solver settings for events
model.sol('sol1').feature('t1').set('tout', 'tsteps');
model.sol('sol1').feature('t1').set('atolglobal', '1e-6');
model.sol('sol1').feature('t1').set('initialstepbdfactive', 'on');
model.sol('sol1').feature('t1').set('initialstepbdf', '1e-6');
model.sol('sol1').feature('t1').set('eventtol', '2e-6');
model.sol('sol1').feature('t1').set('ewtrescale', 'off');
model.sol('sol1').runAll;
```

SEE ALSO

`model.ode()`, `model.init()`

model.study()

Create and define studies.

SYNTAX

```
model.study().create(<tag>);
model.study(<tag>).create(<ftag>,type);
model.study(<tag>).feature().move(<ftag>,position);

model.study(<tag>).run()
model.study(<tag>).runNoGen()
model.study(<tag>).createAutoSequences(type)
model.study(<tag>).showAutoSequences(type)
model.study(<tag>).getSolverSequences(type)
model.study(<tag>).setStoreSolution(boolean)
model.study(<tag>).isStoreSolution()
model.study(<tag>).feature(<ftag>).getAllowedPropertyValues(property);

step = model.study(<tag>).feature(<ftag>);

step.mesh(<geom>,<mesh>);
step.activate(<physpath>,<bool>);
step.discretization(<physpath>,<discr>);
step.mglevel.create(<mglevel>);
step.mglevel(<mglevel>).mesh(<geom>,<mesh>);
step.mglevel(<mglevel>).discretization(<physpath>,<discr>);

step.type();
step.activate(<physpath>);
step.discretization(<physpath>);
step.mesh(<geom>);
step.mglevel(<mglevel>).mesh(<geom>);
step.mglevel(<mglevel>).discretization(<physpath>);
```

DESCRIPTION

`model.study` stores a list of studies, each of which consists of a number of study steps. Each study step, in turn, defines a solver-ready problem. This means that a study step can be turned into an extended mesh, and a basic solver (Stationary, Time, Eigenvalue, Modal, AWE, Optimization) can be applied, resulting in a solution object.

The central property of a study step is its *study type*, which on one hand controls the equations generated by physics interfaces, and on the other hand triggers automatic selection of a suitable solver. Another important property of a study step is which mesh to use (for each geometry in the model). Other fundamental simulation parameters can also be found among the study step settings, like the time span for a Time Dependent study type and frequency range for a Frequency Domain study type.

Under a study step, you can add *multigrid levels*. The parent node still defines the problem to be solved (for example, the study type and the mesh). Therefore, the added multigrid levels must necessarily be coarser than the parent study step.

Most physics features and also some other parts of the model object (for example expression features) must support a `step` member, which (in analogy to the spatial `selection`) controls for which study steps the feature is active. In many ways, the study selection can be seen as a fourth, discrete, dimension.

`model.study().create(<tag>)` creates a new study sequence.

`model.study(<tag>).run()` computes the study.

`model.study(<tag>).runNoGen()` runs the attached solver sequence without regenerating it.

`model.study(<tag>).createAutoSequences(type)` creates an attached solver sequence or job using default solver settings if the solver sequence has not been edited. This command is similar to **Compute** in the COMSOL Desktop. The argument *type* is one of `all`, `jobs`, or `sol`, corresponding to creating both jobs and solver sequences or one of them.

`model.study(<tag>).showAutoSequences(type)` generates a new attached solver sequence or job using default solver settings. This command is similar to **Show Default Solver** in the COMSOL Desktop; that is, it always creates unedited solver sequences. See `createAutoSequences` above for information about the *type* argument.

`model.study(<tag>).getSolverSequences(type)` returns a list of tags for solver sequences (see `model.sol()`) connected to this study. The *type* argument is one of `SolverSequence`, `CopySolution`, `ParametricStore`, `Stored`, `Parametric`, `None`, or `All`.

`model.study(<tag>).setStoreSolution(boolean)` inserts a Solution Store node between each study step in a multistep study if set to `true`. If set to `false`, Solution Store nodes are only inserted in certain cases. Use `model.study(<tag>).isStoreSolution()` to check if a Solution Store node is inserted between each study step (it then returns `true`).

`model.study(<tag>).create(<ftag>,type)` creates a new study step of the given type within the specified sequence. The set of allowed values should be limited to study types supported by at least one physics interface present in the model (Stationary, Time, Frequency, and Eigenvalue should always be allowed).

`model.study(<tag>).feature().move(<ftag>,position)` moves the feature *<ftag>* to the zero indexed position *<position>* in the list.

`step = model.study(<tag>).feature(<ftag>)` obtains a reference to a specified study step.

`model.study(<tag>).feature(<ftag>)).`
`getAllowedPropertyValues(property)` returns the set of allowed values for a property if the set is a finite set of strings; otherwise, it returns null.

`step.mesh(<geom>,<mesh>)` specifies which mesh to use for geometry *<geom>* in the model.

`step.activate(<physpath>,<bool>)` activates or deactivates a physics interface or a physics feature. The string *<physpath>* is a path to a node in a physics interface. Currently only the tag of the physics interface tag itself is supported.

`step.discretization(<physpath>,<discr>)` assigns discretization for a physics interface. The string *<physpath>* is the path of a physics interface. The string *<discr>* is a tag of a discretization feature under a physics mode. The default *<discr>* the physics interface tag. It can be changed to the tag of a discretization node under a physics interface.

`step.mglevel.create(<mglevel>)` adds a (coarser) multigrid level to a study.

`step.mglevel(<mglevel>).mesh(<geom>,<mesh>)` specifies a mesh for the multigrid level. The set of allowed values must, in addition to the actual meshes, include an option “from parent”. This should be the default choice and indicates that the multigrid level uses the same mesh as the parent study.

`step.mglevel(<mglevel>).discretization(<physpath>,<discr>)` assigns discretization for a multigrid level. The string *<physpath>* is the path of a physics interface. The string *<discr>* is a tag of a discretization feature under a physics mode. The default *<discr>* the physics interface tag. It can be changed to the tag of a discretization node under a physics interface.

`step.type()` returns the study type.

`step.mesh(<geom>)` returns the mesh selected for the given geometry.

`step.activate(<physpath>)` returns activation status of a physics interface or a physics interface feature. Currently only the tag of the physics interface tag itself is supported.

`step.mglevel(<mglevel>).mesh(<geom>)` returns the mesh for the selected multigrid level and geometry.

`step.mglevel(<mglevel>).discretization(<discpath>)` returns activation status of a discretization feature.

EXAMPLE

The following code sets up a study sequence to analyze the influence of structural deformation on a waveguide with a numerical port boundary condition. It consists of three steps: stationary structural mechanics followed by an eigenvalue study for the port and finally a wave propagation problem solved with manual multigrid levels (to get nested meshes).

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
model.component("comp1").geom().create("geom1", 3);
model.component("comp1").geom("geom1").create("blk1", "Block");
model.component("comp1").geom().run();
model.component("comp1").mesh().create("mesh1", "geom1");
model.component("comp1").mesh().create("mesh2", "geom1");
model.component("comp1").mesh().create("mesh3", "geom1");

model.physics().create("rfw1", "ElectromagneticWaves", "geom1");
model.study().create("seq1");
Study s1 = model.study("seq1");
s1.create("struct","Stationary");
s1.feature("struct").mesh("geom1","mesh1");
s1.create("port","BoundaryModeAnalysis");
s1.feature("port").set("PortName","port1");
s1.feature("port").mesh("geom1","mesh2");
s1.create("wave","Frequency");
s1.feature("wave").mesh("geom1","mesh2");
s1.feature("wave").mglevel().create("mgl1");
s1.feature("wave").mglevel().create("mgl2");
s1.feature("wave").mglevel("mgl2").mesh("geom1","mesh3");
model.physics("rfw1").create("mgl1","Discretization");
model.physics("rfw1").feature("mgl1").set("order","1");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
model.component('comp1').geom.create('geom1', 3);
model.component('comp1').geom('geom1').create('blk1', 'Block');
model.component('comp1').geom.run;
model.component('comp1').mesh.create('mesh1', 'geom1');
model.component('comp1').mesh.create('mesh2', 'geom1');
model.component('comp1').mesh.create('mesh3', 'geom1');

model.physics.create('rfw1', 'ElectromagneticWaves', 'geom1');
model.study.create('seq1');
s1 = model.study('seq1');
s1.create('struct','Stationary');
s1.feature('struct').mesh('geom1','mesh1');
s1.create('port','BoundaryModeAnalysis');
s1.feature('port').set('PortName','port1');
s1.feature('port').mesh('geom1','mesh2');
s1.create('wave','Frequency');
s1.feature('wave').mesh('geom1','mesh2');
s1.feature('wave').mglevel.create('mgl1');
s1.feature('wave').mglevel.create('mgl2');
s1.feature('wave').mglevel('mgl2').mesh('geom1','mesh3');
model.physics('rfw1').create('mgl1','Discretization');
```

```
model.physics('rfw1').feature('mgl1').set('order','1');
```

In this case, the only settings that must be applied in the study members of other features are the ones relating to multigrid levels. The physics interfaces' equation form is by default set to `automatic`, which means that they respond suitably to the study type each time an extended mesh (xmesh) is created.

SEE ALSO

`model.batch()`, `model.physics()`, `model.sol()`

model.unitSystem()

Unit systems.

SYNTAX

```
UnitSystem us = model.unitSystem().create(<tag>);
us.baseUnit().create(<tag>,<symbol>,<quantity>)
us.derivedUnit().create(<tag>,<units>,<powers>);
us.additionalUnit().create(<tag>,<dim>);
model.unitSystem().builtInTags();

us.baseUnit(<tag>);
us.derivedUnit(<tag>);
us.additionalUnit(<tag>)
us.derivedUnit(<tag>).aliases();
us.baseUnit(<tag>).dimension();
us.derivedUnit(<tag>).quantity();
us.derivedUnit(<tag>).offset();
us.derivedUnit(<tag>).scale();
us.derivedUnit(<tag>).symbol();
us.derivedUnit(<tag>).definition(<units>,<powers>);
us.additionalUnit(<tag>).aliases(<aliases>);
us.additionalUnit(<tag>).quantity(<quantity>);
us.additionalUnit(<tag>).offset(<offset>);
us.additionalUnit(<tag>).scale(<scale>);
us.additionalUnit(<tag>).offset(<offset>);
us.additionalUnit(<tag>).symbol(<symbol>);
```

DESCRIPTION

`model.unitSystem().create(`*<uname>*`)` creates a unit system *<uname>*.

`us.baseUnit().create(`*<tag>*`,`*<symbol>*`,`*<quantity>*`)` creates a base unit for the quantity *<quantity>*, tagged *<tag>* with the symbol *<symbol>*. The quantity is any of the seven base dimensions (`length`, `mass`, `time`, `current`, `temperature`, `substance`, and `intensity`).

`us.derivedUnit().create(`*<tag>*`,`*<units>*`,`*<powers>*`)` creates a new derived unit tagged *<tag>* and derived from the units in *<units>* each to the power of the powers in *<powers>*.

`us.derivedUnit(`*<tag>*`).definition(`*<units>*`,`*<powers>*`)` sets the definition of a derived unit in powers of other units. The resulting dimension must agree with any previously specified dimension for this unit. Use the `create` method to define a dimension from the derived units.

`us.additionalUnit().create(`*<tag>*`,`*<dim>*`)` creates a new additional unit.

All methods below are valid for all units, no matter what unit list they belong to. Furthermore, only the set methods are described here, but there is also a corresponding get method.

`model.unitSystem().builtInTags()` returns the tags of the built-in unit systems. The method `model.unitSystem().tags()` returns the tags of the user-defined unit systems. Both sets of tags can be used to retrieve the unit system using `model.unitSystem(`*<tag>*`)`.

`us.additionalUnit(<tag>).aliases(<aliases>)` sets alternative names for the unit that can be used in unit expressions.

`us.additionalUnit(<tag>).quantity(<quantity>)` assigns a physical quantity to the given unit.

`us.additionalUnit(<tag>).scale(<scale>)` sets the scale of the additional unit.

`us.derivedUnit(<tag>).symbol(<symbol>)` sets the symbol of the derived unit.

`us.derivedUnit(<tag>).offset(<offset>)` sets the offset of the derived unit.

NOTES

You can set the base unit system for the entire model using `model.baseSystem(<utag>)` or separately for each component node using `model.component(<tag>).baseSystem(<utag>)`.

The SI system is read only and always created by default.

EXAMPLE

Create a `cgs2` unit system with the base unit for length set to centimeter (cm). Also add meter/second (m/s) as a derived unit for speed and degrees Celsius as an additional unit for temperature:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
UnitSystem us = model.unitSystem().create("cgs2");
model.baseSystem("cgs2");
us.baseUnit().create("centimeter","cm","length");
us.derivedUnit().create("meter_per_second",new int[]{1,0,-1,0,0,0,0,0});
Unit du = us.derivedUnit("meter_per_second");
du.definition(new String[]{"meter","second"},new int[]{1,-1,0,0,0,0,0,0});
Unit au = us.additionalUnit().create("celsius",new int[]{0,0,0,0,1,0,0,0});
au.offset(273.15);
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
us = model.unitSystem.create('cgs2');
model.baseSystem('cgs2');
us.baseUnit.create('centimeter','cm','length');
us.derivedUnit.create('meter_per_second',[1,0,-1,0,0,0,0,0]);
du = us.derivedUnit('meter_per_second');
du.definition({'meter','second'},[1,-1,0,0,0,0,0,0]);
au = us.additionalUnit.create('celsius',[0,0,0,0,1,0,0,0]);
au.offset(273.15);
```

SEE ALSO

`model.physics()`

model.variable()

Create, define, and remove variables.

SYNTAX

```
model.variable().create(<tag>);
model.variable(<tag>).set(<var>,<expr>);
model.variable(<tag>).set(<var>,<expr>,<descr>);
model.variable(<tag>).descr(<var>,<descr>);
model.variable(<tag>).remove(<var>);
model.variable(<tag>).clear();
model.variable(<tag>).model(<mtag>);

model.variable(<tag>).varnames();
model.variable(<tag>).get(<var>);
model.variable(<tag>).descr(<var>);
model.variable(<tag>).model();
model.variable(<tag>).scope();
model.variable(<tag>).loadFile(tempFile, ...);
model.variable(<tag>).saveFile(tempFile, ...);.
```

For variables on the component level, use `model.component(<ctag>).variable().create(<tag>)`, and so on, instead of the syntax above for global variables.

DESCRIPTION

`model.variable(<tag>)` returns a variable collection. Each variable collection can contain several variables, but only one selection.

`model.variable()`.create(`<tag>`) creates a variables node with tag `<tag>`.

`model.variable(<tag>).set(<var>,<expr>)` defines the variable `<var>` by the expression `<expr>`.

`model.variable(<tag>).set(<var>,<expr>,<descr>)` defines a variable and gives it a description.

`model.variable(<tag>).descr(<var>,<descr>)` defines a description for the variable `<var>`.

`model.variable(<tag>).model(<mtag>)` sets the model component node.

`model.variable(<tag>).selection().named(<seltag>)` assigns the variable node to the named selection `<seltag>`.

`model.shape(<tag>).selection().set(...)` defines a local selection that assigns the variable collection to geometric entities. Before assigning a selection, the variable's model must be set using `model.variable(<tag>).model(<mtag>)`. Only the global selection and selections on a geometry in the model can be used. For a complete list of methods available under `selection()`, see Selections.

`model.variable(<tag>).remove(<var>)` removes a variable from the variable collection.

`model.variable(<tag>).clear()` removes all variables from the variable collection.

`model.variable(<tag>).varnames()` returns the names of all expressions as a string array.

`model.variable(<tag>).get(<var>)` returns the variable value as a string.

`model.variable(<tag>).descr(<var>)` returns the variable description as a string.

`model.variable(<tag>).model()` returns the model component node tag.

`model.variable(<tag>).scope()` returns the fully qualified scope name.

`model.variable(<tag>).selection().named()` returns the selection tag as a string.

`model.variable(<tag>).selection().get`*`Type`*`()` returns domain information. For available methods, see `model.selection()`.

For `model.param().loadFile()` and `model.param().saveFile()`, see The loadFile and saveFile Methods.

EXAMPLES

Define the expression `e` as `x+1` in Domains 1 and 2 and as `x-1` in Domain 3.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
model.component("comp1").geom().create("geom1",3);
model.component("comp1").geom("geom1").create("blk1", "Block");
model.component("comp1").geom("geom1").run();
model.component("comp1").variable().create("e1").set("e","x+1");
model.component("comp1").variable("e1").selection().geom("geom1",2);
model.component("comp1").variable("e1").selection().set(new int[]{1,2});
model.component("comp1").variable().create("e2").set("e","x-1");
model.component("comp1").variable("e2").selection().geom("geom1",2);
model.component("comp1").variable("e2").selection().set(3);
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
model.component.geom.create('geom1',3);
model.component.geom('geom1').create('blk1', 'Block');
model.component.geom('geom1').run;
model.component.variable.create('e1').set('e','x+1');
model.component.variable('e1').selection.geom('geom1',2);
model.component.variable('e1').selection.set([1,2]);
model.component.variable.create('e2').set('e','x-1');
model.component.variable('e2').model('mod1');
model.component.variable('e2').selection().geom('geom1',2);
model.component.variable('e2').selection().set(3);
```

SEE ALSO

`model.selection()`

model.view()

Create and manage views.

For views defined on the global level, under Results, omit `component(<ctag>).` from the syntax such as `model.component(<ctag>).view().create(<vtag>,<gtag>)` in the syntax examples below.

SYNTAX

```
model.component(<ctag>).view().create(<vtag>,<gtag>)
model.component(<ctag>).view().create(<vtag>,<viewdim>)
model.component(<ctag>).view().create(<vtag>,<gtag>,<workplane>)
model.component(<ctag>).view(<vtag>).set(<pname>,<pvalue>)
model.component(<ctag>).view(<vtag>).get<Type>(<pname>)

model.component(<ctag>).view(<vtag>).axis().set(<pname>, <pvalue>)
model.component(<ctag>).view(<vtag>).axis().get<Type>(<pname>)
model.component(<ctag>).view(<vtag>).camera().set(<pname>, <pvalue>)
model.component(<ctag>).view(<vtag>).camera().get<Type>(<pname>)
model.component(<ctag>).view(<vtag>).copyToGeometry()
model.component(<ctag>).view(<vtag>).copyToWorkPlane()
model.component(<ctag>).view(<vtag>).geom()
model.component(<ctag>).view(<vtag>).getHiddenEntities()
model.component(<ctag>).view(<vtag>).getHiddenEntities(<mesh>)
model.component(<ctag>).view(<vtag>).getSDim()
model.component(<ctag>).view(<vtag>).isCurrent()
model.component(<ctag>).view(<vtag>).light().create(<ltag>, <ltype>)
model.component(<ctag>).view(<vtag>).light(<ltag>).set(<pname>, <pvalue>)
model.component(<ctag>).view(<vtag>).light(<ltag>).get<Type>(<pname>)
model.component(<ctag>).view(<vtag>).hideObjects().create(<htag>)
model.component(<ctag>).view(<vtag>).hideObjects(<htag>).set(<pname>, <pvalue>)
model.component(<ctag>).view(<vtag>).hideObjects(<htag>).get<Type>(<pname>)
model.component(<ctag>).view(<vtag>).hideEntities().create(<htag>)
model.component(<ctag>).view(<vtag>).hideEntities(<htag>).set(<pname>, <pvalue>)
model.component(<ctag>).view(<vtag>).hideEntities(<htag>).get<Type>(<pname>)
model.component(<ctag>).view(<vtag>).hideEntities(<htag>).image()
model.component(<ctag>).view(<vtag>).hideMesh().create(<htag>)
model.component(<ctag>).view(<vtag>).hideMesh(<htag>).set(<pname>, <pvalue>)
model.component(<ctag>).view(<vtag>).hideMesh(<htag>).get<Type>(<pname>)
model.component(<ctag>).view(<vtag>).hideMesh(<htag>).image()
```

DESCRIPTION

View Settings

`model.component(<ctag>).view()` returns a list of view that can be used when viewing geometry/mesh and plot groups. Each view has an axis and some properties on the top level. In 3D, a view also has a camera and a list of lights. All views also have a list of hide features.

`model.component(<ctag>).view().create(<vtag>,<gtag>)` creates a view tied to the geometry with the given tag. The dimension of the view is the same as the dimension for the geometry.

`model.component(<ctag>).view().create(<vtag>,<viewdim>)` creates a view with the given tag for the given dimension (1, 2, or 3). These views are not tied to any geometry and show up under the Views node under Results in the COMSOL Desktop.

`model.component(<ctag>).view().create(<vtag>,<gtag>,<workplane>)` creates a view tied to the work plane with the given tag in the geometry sequence with the given tag. The dimension of the view is 2.

`model.component(<ctag>).view(<vtag>).set(<pname>,<pvalue>)` sets the given property to the given value.

`model.component(<ctag>).view(<vtag>).geom()` returns the geometry sequence (or null for the views not associated with a geometry).

`model.component(<ctag>).view(<vtag>).getSDim()` returns the view's space dimension.

`model.component(<ctag>).view(<vtag>).get`*`Type`*`(<pname>)` returns the property with the given name of type *`Type`*.

TABLE 2-107: VIEW PROPERTIES

NAME	VALUE	DIMENSIONS	DESCRIPTION
`default`	`true` | `false`	1, 2, 3	If this is the default view to use when viewing the geometry and mesh.
`headlight`	`true` | `false`	3	If the light in the camera should be turned on.
`locked`	`true` | `false`	1, 2, 3	If the settings should be updated from interactive changes or not.
`rendermesh`	`true` | `false`	2, 3	If mesh rendering should be used (default: `on`).
`scenelight`	`true` | `false`	3	If the background lights as specified by the added lights should be turned on.
`showmaterial`	`true` | `false`	2, 3	If the material color and texture should appear or not.
`showselection`	`true` | `false`	2, 3	If the selection colors should appear or not.
`showunits`	`true` | `false`	1, 2, 3	If the axis units should appear or not.
`viewscaletype`	`none`|`automatic`|`manual`	2, 3	Control the view scale to achieve a suitable axis scaling (default: None).
`wireframe`	`true` | `false`	3	If wireframe rendering should be used.
`xscale`	double	2, 3	Scaling factor for x-axis when using a manual view scale.
`yscale`	double	2, 3	Scaling factor for y-axis when using a manual view scale.
`zscale`	double	3	Scaling factor for z-axis when using a manual view scale.

Axis Settings

The axis settings apply to 2D views with an *x*- and a *y*-axis.

`model.component(<ctag>).view(<vtag>).axis().set(<pname>, <pvalue>)` sets the given axis property to the given value. Which axis properties that are available in the different dimensions are given in the table below.

`model.component(<ctag>).view(<vtag>).axis().get`*`Type`*`(<pname>)` returns the axis property with the given name.

TABLE 2-108: AXIS PROPERTIES

NAME	VALUE	DIMENSIONS	DESCRIPTION
`auto`	`on`|`off`	1, 2, 3	Set if axis settings should be automatically stored and updated from interactive changes using mouse and toolbar buttons.
`equal`	`on`|`off`	2, 3	Should the same scaling be used for all directions.
`logx`	`on`|`off`	1	Should log scale be used for the x-axis.
`logy`	`on`|`off`	1	Should log scale be used for the y-axis.
`manualspacing`	`on`|`off`	2	Should manual spacing be used for x and y grid lines.
`manuallimits`	`on`|`off`	1, 2, 3	Should manual axis limits be used. If not a zoom extents is performed each time something is plotted into the axis.
`xextra`	double array	2	An array with extra x grid lines.
`xmax`	double	1, 2, 3	The maximum *x*-coordinate.
`xspacing`	double	2	Manual spacing for x grid lines.
`yextra`	double array	2	An array with extra y grid lines.
`ymin`	double	2, 3	The minimum *y*-coordinate.
`ymax`	double	2, 3	The maximum *y*-coordinate.
`yspacing`	double	2	Manual spacing for y grid lines.

TABLE 2-108: AXIS PROPERTIES

NAME	VALUE	DIMENSIONS	DESCRIPTION
zmin	double	3	The minimum *z*-coordinate.
zmax	double	3	The maximum *z*-coordinate.

Camera Settings

These settings apply to the camera for 3D views.

`model.component(`*`<ctag>`*`).view`*`(<vtag>)`*`.camera().set(`*`<pname>, <pvalue>`*`)` sets the given camera property to the given value.

`model.component(`*`<ctag>`*`).view`*`(<vtag>)`*`.camera().get`*`Type`*`(`*`<pname>`*`)` returns the camera property with the given name.

TABLE 2-109: CAMERA PROPERTIES

NAME	VALUE	DESCRIPTION
autocontext	isotropic | anisotropic	Use an isotropic automatic cube scaling or an anisotropic automatic block scaling with x, y, and z direction relative scales.
autoupdate	true | false	Use automatic update of the view when viewscaletype is automatic.
projection	perspective| orthographic	Use perspective or orthographic projection.
manualspacing	on|off	Should manual spacing be used for grid lines.
position	double array	The position of the camera.
target	double array	The point the camera looks at.
up	double array	The up direction.
rotationpoint	double array	The center of rotation.
viewscaletype		
xextra	double array	An array with extra x grid lines.
xspacing	double	Manual spacing for x grid lines.
xweight	double	Relative weight in the x-direction for anisotropic automatic view scale.
yextra	double array	An array with extra y grid lines.
yspacing	double	Manual spacing for y grid lines.
yweight	double	Relative weight in the y-direction for anisotropic automatic view scale.
zextra	double array	An array with extra z grid lines.
zspacing	double	Manual spacing for z grid lines.
zoomanglefull	double	The full field of view angle in degrees.
zweight	double	Relative weight in the z-direction for anisotropic automatic view scale.

Light Settings

These settings control the different types of lighting — direction light, spotlight, head light, and point light — that you can add to a 3D view.

`model.component(`*`<ctag>`*`).view`*`(<vtag>)`*`.light().create(`*`<ltag>,<ltype>`*`)` creates a light with the given tag and type. *`<ltype>`* can be any of `'DirectionalLight'`, `'PointLight'`, `'SpotLight'`, and `'HeadLight'`.

`model.component(`*`<ctag>`*`).view`*`(<vtag>)`*`.light(`*`<ltag>`*`).set(`*`<pname>,<pvalue>`*`)` sets the given light property to the given value. Different properties are available for the different types of lights according to the table below.

`model.component(<ctag>).view(<vtag>).light(<ltag>).get<Type>(<pname>)` returns the light property with the given name.

TABLE 2-110: LIGHT PROPERTIES

NAME	VALUE	LIGHT TYPES	DESCRIPTION
`color`	string or RGB triplet	all	The color of the light.
`cameracoord`	`on|off`	all	If the light should be defined in the camera coordinate system or the world coordinate system.
`direction`	double array	`DirectionalLight`, `SpotLight`	The direction from which the light shines or is directed at.
`position`	double array	`PointLight`, `SpotLight`	The position from which the light shines.
`spreadangle`	double	`SpotLight`	The spread angle for the light.

Hiding Geometry Objects, Geometric Entities, and Imported Meshes

`model.component(<ctag>).view(<vtag>).hideObjects().create(<htag>)` creates a hide feature of geometric objects in the geometry sequence. The API for controlling it is similar to the API for selection in the geometry sequence; see Geometry Object Selection Methods under model.geom().

`model.component(<ctag>).view(<vtag>).hideEntities().create(<htag>)` creates a hide feature of geometric entities in the analyzed geometry used, for example, for the physics. The API for controlling it is similar to the API for selections on the finalized geometry; see `model.selection()`.

`model.component(<ctag>).view(<vtag>).hideMesh().create(<htag>)` creates a hide feature of geometric entities in the analyzed geometry from an imported mesh used, for example, for the physics. The API for controlling it is similar to the API for selections on the finalized geometry; see `model.selection()`. For example, the following code hides boundary 4 in the geometry based on the mesh in `mesh1`:

```
// Create mesh hide object in view 1
model.component("comp1").view("view1").hideMesh().create("hide1");
// Select mesh1
model.component("comp1").view("view1").hideMesh("hide1").mesh("mesh1");
// Hide boundary 4 (3D is assumed)
model.component("comp1").view("view1").hideMesh("hide1").geom(2).set(4);
```

`model.component(<ctag>).view(<vtag>).getHiddenEntities()` returns an integer array of hidden entities in each dimension. The entity numbers refer to the entities of the finalized geometry.

`model.component(<ctag>).view(<vtag>).getHiddenEntities(<mesh>)` returns an integer array of hidden entities in each dimension. The entity numbers refer to the entities of specified meshing sequence with the tag `<mesh>` in its current state.

For plotting or exporting images of views with hidden objects, use the `model.component(<ctag>).view(<vtag>).hideEntities(<htag>).image()` and `model.component(<ctag>).view(<vtag>).hideMesh(<htag>).image()` methods. See Plotting and Exporting Images.

Copying Views

To copy a view to a geometry or work plane, you can use the `copyToGeometry` and `copyToWorkPlane` methods. For example,

```
model.component("comp1").view("view1").copyToWorkPlane();
```

copies the view `view1` to a work plane.

SEE ALSO

`model.result()`

model.weak()

Weak form equations.

SYNTAX

```
model.weak().create(<tag>);
model.weak(<tag>).weak(<wlist>);
model.weak(<tag>).weak(<pos>,<wepxr>);
model.weak(<tag>).intRule(<irlist>);
model.weak(<tag>).intRule(<pos>,<irule>);
model.weak(<tag>).condition(<condition>);

model.weak(<tag>).weak();
model.weak(<tag>).intRule();
model.weak(<tag>).condition();
```

DESCRIPTION

`model.weak(<tag>)` returns the weak form equations with tag *<tag>*.

`model.weak().create(<tag>)` creates weak form equations with tag *<tag>*.

`model.weak(<tag>).weak(<wlist>)` sets the equations. You can supply a single weak expression or a list of weak expressions. *<wlist>* is a string or a string array.

`model.weak(<tag>).weak(<pos>,<wexpr>)` sets the equations at position *<pos>* in the list.

`model.weak(<tag>).intRule(<irlist>)` assigns the integration rules to the weak form equations. The list of integration rules must have the same length as the list of equations, or be of length 1. In the latter case all weak expressions use the same integration rule.

`model.weak(<tag>).intRule(<pos>,<irule>)` sets the integration rule at position *<pos>* in the integration rule list.

`model.weak(<tag>).condition(<condition>)` introduces conditional assembly. The feature is assembled if *<condition>* is true.

`model.weak(<tag>).selection().named(<seltag>)` assigns the weak equations to the named selection *<seltag>*.

`model.weak(<tag>).selection().named(<seltag>)` defines a local selection that assigns the weak equations to geometric entities. Before assigning a selection, the variable's model must be set using `model.variable(<tag>).model(<mtag>)`. Only the global selection and selections on a geometry in the model can be used. For a complete list of methods available under `selection()`, see Selections.

EXAMPLE

Define the weak expressions `u*test(u)` and `v*test(v)` on the selection `dom1`, using the integration rule `gp1` and the frame `ref`.

Code for Use with Java

```
model.weak().create("w1").selection().named("dom1");
model.weak("w1").intRule("gp1");
model.weak("w1").weak(new String[]{"u*test(u)","v*test(v)"});
```

Code for Use with MATLAB

```
model.weak.create('w1').selection.named('dom1');
model.weak('w1').intRule('gp1');
model.weak('w1').weak({'u*test(u)','v*test(v)'});
```

SEE ALSO

`model.coeff()`, `model.shape()`

Plotting and Exporting Images

For a number of model entities, two methods for plotting and exporting images are available:

- `image().plot()` plots the model entity in a window. The plotting is available when running a graphics server. The `plot()` method does nothing when run from a model method.
- `image().export()` exports an image of the model entity to file.

To set properties related to the plotting or export of images, use the standard `set` method on the `image()` object.

The following examples show the basic usage of these methods.

This example plots a geometry sequence in a window:

```
model.geom("geom1").image().plot();
```

This example exports a physics interface to a PNG file.

```
model.physics("es").image().set("pngfilename", "C:\physics.png");
model.physics("es").image().export();
```

The `image()` method is available for many objects in, for example, the lists `model.common()`, `model.cpl()`, `model.coordSys()`, `model.func()`, `model.geom()`, `model.material()`, `model.mesh()`, `model.multiphysics()`, `model.pair()`, `model.physics()`, `model.physics(<tag>).feature()`, `model.probe()`, and `model.selection()`.

PROPERTIES FOR THE IMAGE() OBJECTS

The following properties are available for the export of images:

TABLE 2-111: EXPORT PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`antialias`	`on` | `off`	`on`*	Enable or disable antialiasing.
`axes`	`on` | `off`	`on`*	If `options` is `on`: enable or disable display of the coordinate axes. Used for 1D and 2D plots.
`axisorientation`	`on` | `off`	`on`*	If `options` is `on`: enable or disable display of the axis orientation indicator. Used for 3D plots.
`background`	`current` | `color` | `transparent`	`color`*	The background color.
`bmpfilename`	String		The name of the output file if `imagetype` is `bmp`.
`customcolor`	double array	`{1, 1, 1}`*	If `background` is `color`: the red, green, and blue components of the background color.
`epsfilename`	String		The name of the output file if `imagetype` is `eps`.
`fontsize`	integer	9*	The font size.
`giffilename`	String		The name of the output file if `imagetype` is `gif`.
`grid`	`on` | `off`	`on`*	If `options` is `on`: enable or disable display of the coordinate grid. Used for 3D plots.
`height`	integer	480 px*	The height of the image.
`lockratio`	`on` | `off`	`off`*	If `on`, the aspect ratio of the image is preserved when the width or the height is changed.
`imagetype`	`bmp` | `eps` | `jpeg` | `png` | `tiff` | `gif`	`png`*	The type of image to export. `eps` can only be used for 1D plots.

TABLE 2-111: EXPORT PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
jpegfilename	String		The name of the output file if imagetype is jpeg.
logo	on | off	on*	If options is on: enable or disable display of the logotype.
options	on | off	off*	Enable or disable optional components of the image.
pngfilename	String		The name of the output file if imagetype is png.
resolution	integer	480 px*	Tthe image resolution in dots per inch.
size	current | web print | presentation | custom | any custom size settings	current*	How to specify the size and resolution of the image. The value current gives a 800x600 image with the resolution 96 dots per inch. The values manualweb and manualprint let you give a size and resolution suitable for the web or printing, respectively, but also let you specify the size and resolution manually.
tifffilename	String		The name of the output file if imagetype is tiff.
title	on | off	on*	If options is on: enable or disable display of the title.
unit	px | mm | in	px*	The unit for the dimensions of the image.
width	integer	480 px*	The width of the image when size is manualweb.

* When making an image export, the value of the image feature doing the export will be stored and used as the default value when creating a new image feature. The image feature is created the first time the image() method is called.

The following properties are related to plotting of images:

TABLE 2-112: PROPERTIES FOR PLOTTING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
window	new | window tag	new	The window to plot in. The window tags must be of the form window*N*, where *N* is an integer (for example, window3).
windowtitle	String	Plot *N*	The window's title. The default is Plot *N*, where *N* is taken from the window tag.

The following properties are used for both export and plotting of images:

TABLE 2-113: PROPERTIES FOR EXPORT AND PLOTTING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
renderwireframe	on | off | fromview	on	Whether to use wireframe rendering for the geometry. The value fromview specifies that the view controls the rendering. The other values override the view setting. This property is only available in 3D and only for the features that plot a selection. This excludes geometries, meshes, and functions.
view	auto | view tag	auto	The view settings to use when displaying this image. auto indicates that the view is selected automatically and will be the current view for the geometry being displayed.
zoomextents	on | off	on	Whether to zoom the image to its extents. This property is only available for image objects displaying a geometry or mesh.

TABLE 2-113: PROPERTIES FOR EXPORT AND PLOTTING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
zooming	nozooming | zoomextents | zoomtoselection	px*	How to zoom the image. This property is available for all image objects except for those displaying a geometry, mesh, or function.
zoomlevel	integer (in the range from -15 to 15)	0	The number of zoom-in (if positive) or zoom-out (if negative) action steps to perform after zooming or zoomextents has been applied.

The tables below contain properties that are available for `image()` objects attached to a certain parent type.

The following property is used when attached to a geometry object:

TABLE 2-114: GEOMETRY PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
showmaterial	on | off | fromview	fromview	Enable or disable material color and texture.
showselection	on | off | fromview	fromview	Enable or disable material color and texture.

The only difference for the `showmaterial` and `showselection` properties for the geometry is that the values are taken from the view by default- They are `off` by default for all other features (such as probes and physics features).

The following property is used when attached to a pair object:

TABLE 2-115: PAIR PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selection	srcanddst | source | destination	srcanddst	Whether to display the source and destination selection, only the source selection, or only the destination selection.

The following property is used when attached to a physics feature or multiphysics coupling object:

TABLE 2-116: PHYSICS FEATURE OR MULTIPHYSICS COUPLING PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selection	main | selection name	main	Which selection to display. Some physics features and multiphysics couplings have multiple selections. The value main corresponds to the selection retrieved by calling selection() on the physics feature or coupling, and the other values are the names to obtain a selection using selection(*<name>*).

The following property is used when attached to a component coupling object:

TABLE 2-117: PAIR PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selection	srcanddst | source | destination	srcanddst	A property with these values is available for the Boundary Similarity, Edge Map, and Point Map component coupling features. Whether to display the source and destination selection, only the source selection, or only the destination selection.
selection	source | srcvertices | dstvertices	source	A property with these values is available for the Linear Extrusion and Linear Projection component coupling features. Whether to display the source selection, the source vertices selection, or the destination vertices selection.

Errors and Warnings

Introduction

For errors and warnings in the mesh and solver sequences, the following methods are available to retrieve an error message or warning message:

```
String warning = model.sol(<stag>).getWarningMessage();
```

returns the warning message as a string, and

```
String error = model.sol(<stag>).getErrorMessage();
```

returns the error message as a string. Here, *<stag>* is a solver sequence tag.

In addition, which the following section shows examples of, the following methods area available in the meshing sequences and solver sequences:

- `hasProblems()`, a Boolean method that is true if problems exist.
- `problems()`, a String[ ] array with names of features with problems (that is, the union of warnings and errors)
- `errors()` and `warnings()`, String[ ] arrays with information about error and warning, respectively.

Retrieving Problem Information

Problems here means the union of warnings and errors.

EXAMPLE OF RETRIEVING PROBLEM INFORMATION IN A MESH

The following example shows how to retrieve information about a problem in the mesh (the same syntax also works for problems in the geometry):

1 Build a geometry:

```
Model mdl = ModelUtil.create("Model");
mdl.component().create("comp1");
mdl.component("comp1").geom().create("g",3);
mdl.component("comp1").geom("g").create("cyl1","Cylinder").set("h",3.0);
mdl.component("comp1").geom("g").create("cyl2","Cylinder").set("h",3.0).set("r",0.95);
mdl.component("comp1").geom("g").create("co1","Difference");
mdl.component("comp1").geom("g").feature("co1").selection("input").set("cyl1");
mdl.component("comp1").geom("g").feature("co1").selection("input2").set("cyl2");
```

2 Build a mesh:

```
MeshSequence ms = mdl.component("comp1").mesh().create("m", "g");
ms.feature("size").set("hauto", 9);
ms.create("ftri1","FreeTri");
ms.feature("ftri1").selection().geom(2).set(1, 2, 7, 10);
ms.create("ftet1","FreeTet");
ms.feature("ftet1").create("ms1","Size");
ms.run();
```

3 Check if the mesh was built with problems:

```
boolean problem = ms.hasProblems();
```

4 Get the names of the features with problems. In this case, the feature `ftet1`:

```
String[] problemFeatures = ms.feature().problems();
MeshFeature problematicFeature = ms.feature(problemFeatures[0]);
```

5 Get error information:

```
String[] errors = problematicFeature.errors();
```

```
for (String tag : errors) {
  analyzeProblems(problematicFeature.problem(tag));
}
```

Where `analyzeProblems` is the following method to recursively retrieve error information:

```
private static void analyzeProblems(MeshProblemFeature problem) {
  String errorMessage = problem.message();
  System.out.println(errorMessage);

  if (problem.hasSelection()) {
    MeshSelection sel = problem.selection();
    System.out.println("Selection: " + sel);
  }
  String[] problemDetails = problem.problems();
  for (String tag : problemDetails) {
    MeshProblemFeature detail = problem.problem(tag);

    // Recursively analyze subproblems
    analyzeProblems(detail);
  }
}
```

6 Get warning information:

```
String[] warnings = problematicFeature.warnings();
  for (String tag : warnings) {
    analyzeProblems(problematicFeature.problem(tag));

}
```

where `analyzeProblems` is the same method as described in the previous step.

EXAMPLE OF RETRIEVING PROBLEM AND WARNING INFORMATION IN A SOLVER

The same technique is also available for retrieving information about problems and warnings in a solvers sequence:

1 For a solver sequence `ss1`, check if there are any problems:

```
SolverSequence ss1
boolean problem = ss1.hasProblems();
```

2 Get the names of the features with problems:

```
String[] problemNames = ss1.feature().problemNames();
```

3 Get error information:

```
String[] errorNames = ss1.feature(problemNames[0]).problem().errorNames();
SolverFeature errorFeature = ss1.feature(problemNames[0]).problem(errorNames[0]);
String errorMessage = errorFeature.getString("message");
```

4 Get warning information:

```
String[] warningNames = ss1.feature(problemNames[0]).problem().warningNames();
SolverFeature warningFeature = ss1.feature(problemNames[0]).problem(warningNames[0]);
String warningMessage = warningFeature.getString("message");
```

3

Geometry

This chapter includes reference information about the geometry commands and how to work with a geometry sequence and the geometry objects to create the model geometry. In this chapter:

About Geometry Commands

- Features for Creating Geometric Primitives
- Features for Geometric Operations
- Features for Virtual Operations
- Features for Mesh Control
- Geometry Object Information Methods

For documentation of additional geometry commands available in the Design Module, CAD Import Module, ECAD Import Module, and LiveLink™ for CAD products, see the documentation for each of those products.

Features for Creating Geometric Primitives

Table 3-1 is an overview of the features for creating 3D geometric primitives:

TABLE 3-1: 3D GEOMETRIC PRIMITIVES

NAME	DESCRIPTION
`BezierPolygon`	Chain of connected line segments, quadratic or cubic curves
`Block`	Right-angled parallelepiped (box)
`Cone`	Right circular cone or cone frustum
`Cylinder`	Right circular cylinder
`ECone`	Oblique cone or cone frustum with elliptic base
`Ellipsoid`	Ellipsoid
`Helix`	Helix solid, surface, or curve
`Hexahedron`	Hexahedron bounded by bilinear faces
`LineSegment`	Line segment between two vertices or points
`ParametricCurve`	Curve defined by coordinate expressions
`ParametricSurface`	Surface defined by coordinate expressions
`Point`	One or several points
`Polygon`	Chain of connected line segments
`Pyramid`	Rectangular pyramid
`Sphere`	Sphere or ball
`Tetrahedron`	Tetrahedron
`Torus`	Torus

Table 3-2 is an overview of the features for creating 2D geometric primitives:

TABLE 3-2: 2D GEOMETRIC PRIMITIVES

NAME	DESCRIPTION
`BezierPolygon`	Chain of connected line segments, quadratic or cubic curves
`Circle`	Circle or disc
`Ellipse`	Ellipse
`LineSegment`	Line segment between two vertices or points
`ParametricCurve`	Curve defined by coordinate expressions

TABLE 3-2: 2D GEOMETRIC PRIMITIVES

NAME	DESCRIPTION
`Point`	One or several points
`Polygon`	Chain of connected line segments
`Rectangle`	Rectangle
`Square`	Square

Table 3-3 is an overview of the features for creating 1D geometric primitives:

TABLE 3-3: 1D GEOMETRIC PRIMITIVES

NAME	DESCRIPTION
`Interval`	One interval, or a chain of connected intervals
`Point`	One or several points

Features for Geometric Operations

The `Import` feature imports geometry objects from a file or from another geometry. The `FromMesh` feature constructs a geometry object from a (deformed) mesh.

Table 3-4 through Table 3-8 list the features that create new geometric objects from existing ones, Table 3-9 lists programming features for construction of geometry parts with conditionally active geometry features, for example.

TABLE 3-4: WORK-PLANE RELATED FEATURES (ONLY 3D, EXCEPT FOR CROSSSECTION)

NAME	DESCRIPTION
`WorkPlane`	Create a work plane for drawing 2D objects that are embedded into 3D
`Extrude`	Extrude planar faces in 3D
`Revolve`	Revolve planar faces in 3D
`Sweep`	Sweep one or several faces along a spine curve to create a solid in 3D
`CrossSection`	Create 2D geometry from intersection of 3D geometry with work plane

TABLE 3-5: BOOLEAN AND PARTITIONING OPERATIONS

NAME	DESCRIPTION
`Compose`	Compose geometry objects using a set formula
`Difference`	Subtract geometry objects from geometry objects
`Intersection`	Intersect geometry objects
`Union`	Unite geometry objects
`Partition`	Partition a 2D or 3D geometry using tool objects or (3D only) a work plane
`PartitionDomains`	Partition domains in 2D or 3D geometries along some partitioning lines, edges, or faces
`PartitionEdges`	Partition edges in 2D or 3D geometries at some partitioning vertices along the edges
`PartitionFaces`	Partition faces in 3D geometries at some partitioning curves on the edges

See `Compose, Union, Intersection, Difference` for information about those Boolean operations.

TABLE 3-6: LINEAR TRANSFORMATIONS

NAME	DESCRIPTION
`Array`	Rectangular or linear array of geometry objects
`Mirror`	Reflect objects in a plane (3D), a line (2D), or a point (1D)
`Rotate`	Rotate geometry objects about a center point

TABLE 3-6: LINEAR TRANSFORMATIONS

NAME	DESCRIPTION
`Scale`	Scale geometric objects about a center point
`Move`	Translate geometry objects
`Copy`	Make a displaced copy of geometry objects

See `Move, Copy` for details about those linear transformations.

TABLE 3-7: OBJECT TYPE CONVERSIONS

NAME	DESCRIPTION
`ConvertToSolid`	Unite and convert objects to a single solid object
`ConvertToSurface`	Unite and convert 3D objects to a single surface object
`ConvertToCurve`	Unite and convert 2D or 3D objects to a single curve object
`ConvertToPoint`	Unite and convert objects to a single point object

See `ConvertToSolid, ConvertToSurface, ConvertToCurve, ConvertToPoint` for information about those conversion operations.

TABLE 3-8: OTHER OPERATIONS

NAME	DESCRIPTION
`Chamfer`	Chamfer corners in 2D geometry objects
`Fillet`	Fillet corners in 2D geometry objects
`Tangent`	Line segment tangent to an edge in 2D
`Delete`	Delete entities (domains, boundaries, edges, or points) from objects, or delete entire geometry objects
`Split`	Split geometry objects into their constituent entities
`Finalize`	Form union or assembly by combining all geometry objects

TABLE 3-9: PROGRAMMING AND PARTS FEATURES

NAME	DESCRIPTION
`If, ElseIf, Else, EndIf`	Construct an If statement, enabling or disabling features depending on conditions in terms of parameters
`ParameterCheck`	Check the value of parameters.
`PartInstance`	Create an instance of a geometry part.

Selection Features

Table 3-10 lists the features that correspond to selections:

TABLE 3-10: SELECTIONS

NAME	DESCRIPTION
`AdjacentSelection`	Selection of entities or objects that are adjacent to given selections
`ExplicitSelection`	Explicit selection of entities or objects
`BallSelection`	Selection of entities or objects that (partly) lie inside a ball
`BoxSelection`	Selection of entities or objects that (partly) lie inside a box
`CylinderSelection`	Selection of entities or objects that (partly) lie inside a cylinder
`ComplementSelection`	Selection of entities or objects that is the complement of the input selections

TABLE 3-10: SELECTIONS

NAME	DESCRIPTION
`DifferenceSelection`	Selection of entities or objects that is the difference of the input selections
`IntersectionSelection`	Selection of entities or objects that is the intersection of the input selections
`UnionSelection`	Selection of entities or objects that is the union of the input selections

See `BallSelection, BoxSelection, CylinderSelection, Disk Selection` and `UnionSelection, IntersectionSelection, DifferenceSelection, ComplementSelection` for information about those selections.

Features for Virtual Operations

Table 3-11 lists the features that correspond to virtual operations:

TABLE 3-11: VIRTUAL GEOMETRY RELATED FEATURES (ONLY 2D AND 3D)

NAME	DESCRIPTION
`IgnoreVertices`	Virtually remove isolated vertices or vertices adjacent to two edges only
`IgnoreEdges`	Virtually remove isolated edges or edges adjacent to precisely two faces or between two domains
`IgnoreFaces`	Virtually remove isolated faces or faces between two domains
`CompositeEdges`	Form virtual composite edges from sets of connected edges by ignoring the vertices between the edges in each set
`CompositeFaces`	Form virtual composite faces from sets of connected faces by ignoring the edges between the faces in each set
`CompositeDomains`	Form virtual composite domains from sets of connected domains by ignoring the boundaries between the domains in each set
`CollapseEdges`	Virtually collapse each edge into a vertex by merging its adjacent vertices
`CollapseFaces`	Virtually collapse faces
	Virtually detect and collapse regions of faces narrower than a specified size
`MergeEdges`	Virtually merge edges adjacent to face
`MergeVertices`	Virtually merge one adjacent vertex of an edge with the other adjacent vertex

Features for Mesh Control

Table 3-12 lists the features that correspond to mesh control operations:

TABLE 3-12: MESH CONTROL RELATED FEATURES (ONLY 2D AND 3D)

NAME	DESCRIPTION
`MeshControlVertices`	Use vertices for mesh control only
`MeshControlEdges`	Use edges for mesh control only
`MeshControlFaces`	Use faces for mesh control only
`MeshControlDomains`	Use domains for mesh control only

GENERAL INFORMATION

TABLE 3-13: GENERAL GEOMETRY INFORMATION METHODS

METHOD	DESCRIPTION
`check`	Check object for errors
`getBoundingBox`	Get bounding box around object
`getSDim`	Get space dimension
`getType`	Get object type (solid, surface, curve, point, mixed, empty)
`hasCadRep`	Is represented using CAD kernel

GEOMETRIC ENTITY COUNTERS

TABLE 3-14: GEOMETRIC ENTITY COUNTERS

METHOD	DESCRIPTION
`getNEntities`	Get number of entities of different dimensions
`getNVertices`	Get number of vertices
`getNEdges`	Get number of edges
`getNFaces`	Get number of faces
`getNBoundaries`	Get number of boundaries
`getNDomains`	Get number of domains
`getNEntitiesMesh`	Get number of entities of different dimensions in the geometry used for meshing

ADJACENCY

TABLE 3-15: ADJACENCY BETWEEN GEOMETRIC ENTITIES

METHOD	DESCRIPTION
`getStartEnd`	Get start and end vertices of edges
`getUpDown`	Get up and down domain indices
`getUpDownExt`	Get up and down extended domain indices
`getVertexDomain`	Get domain index for isolated vertices
`getSD`	Get domain index for isolated vertices
`getAdj`	Get adjacency matrices
`getAdjOrient`	Get adjacency orientation
`getAdjSparse`	Get adjacency matrix in sparse format

EDGE EVALUATION

TABLE 3-16: EDGE EVALUATION METHODS

METHOD	DESCRIPTION
`edgeParamRange`	Get parameter range of edge
`edgeX`	Evaluate coordinates
`edgeDX`	Evaluate first derivative
`edgeDDX`	Evaluate second derivative
`edgeNormal`	Evaluate normal vector in 2D
`edgeCurvature`	Evaluate curvature
`edgeTorsion`	Evaluate torsion in 3D

FACE EVALUATION

TABLE 3-17: FACE EVALUATION METHODS

METHOD	DESCRIPTION
`faceParamRange`	Get parameter ranges of face
`faceX`	Evaluate coordinates
`faceDX`	Evaluate first derivatives
`faceDDX`	Evaluate second derivatives
`faceNormal`	Evaluate normal vector
`faceFF1`	Evaluate first fundamental form
`faceFF2`	Evaluate second fundamental form
`faceGaussCurvature`	Evaluate Gauss curvature
`faceMeanCurvature`	Evaluate mean curvature

GEOMETRY REPRESENTATION ARRAYS

TABLE 3-18: GET ARRAYS IN GEOMETRY REPRESENTATION

METHOD	DESCRIPTION
`getVertex`	Get vertex matrix
`getEdges`	Get edge matrix
`getFaces`	Get face matrix
`getPVertex`	Get parameter vertices (embeddings of vertices in faces)
`getPEdge`	Get parameter edges (embeddings of edges in faces)
`getVertexCoord`	Get vertex coordinates

Working with a Geometry Sequence

This section describes how to construct geometries using Java® methods. A *geometry* is defined by a *geometry sequence* consisting of *geometry features*. Each feature generates a set of *output geometry objects* when you *build* the feature. An *operation feature* takes previously generated geometry objects as input and usually deletes them. You can create named selections by adding *selection features*. Each geometry sequence in 1D ends with a `Finalize` feature that forms a single output object by uniting all existing geometry objects. A geometry sequence in 2D or 3D also contains a `Finalize` feature, but in 2D and 3D it is possible to add features corresponding to *virtual operations* after the `Finalize` feature (see `Virtual Operations` for more information). The output object of the last feature of a sequence is referred to as the *finalized geometry*. The finalized geometry is used for meshing and physics modeling.

In 3D, you can also add work planes (see Work Planes for more information), where you can add 2D geometry sequences that build 2D geometries that you can use to embed, extrude, and revolve in the 3D geometry.

	Methods on `model.component(`*`<ctag>`*`).geom(`*`<tag>`*`)` can also be used in work planes on `model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).feature(`*`<wptag>`*`).geom()`.

	The syntax that includes the component level, such as `model.component(`*`<ctag>`*`).geom(`*`<tag>`*`)...` is the default and is used throughout this chapter. To use the earlier `model.geom(`*`<tag>`*`)...` syntax, clear the **Use component syntax** check box on the **Methods** page in the **Preferences** dialog box.

	Geometry Modeling and CAD Tools in the *COMSOL Multiphysics Reference Manual*

Adding a Model Component (Geometry)

To add a new geometry to the model object `model`, enter

```
model.component(<ctag>).geom().create(<tag>,sDim);
```

where *`<tag>`* is the geometry's tag (an identifier of your choice), and `sDim` is its space dimension (1, 2, or 3).

The geometry is added to the last created model component. If no model component exists in the model, a model component node tagged `comp1` is automatically created for you. A physics interface using the geometry must belong to the same model component as the geometry.

You can change the model component of a geometry by entering

```
model.component(<ctag>).geom(<tag>);
```

where *`<ctag>`* is the tag of a component node.

Adding a Geometry Feature

To add a feature to a geometry tagged *`<tag>`*, enter

```
model.component(<ctag>).geom(<tag>).create(<ftag>,ftype);
```

where *`<ftag>`* is the feature's tag (an identifier of your choice), and *`ftype`* is the feature's type. Feature types are capitalized and case-sensitive, for example `Rectangle`.

When you add a feature, it is inserted after the *current feature*. You can get the tag of the current feature type by entering

```
String ftag = model.component(<ctag>).geom(<tag>).current();
```

If `ftag` is the empty string, the current feature is the beginning of the geometry sequence, that is, the empty state before all features. When the feature has been added, it automatically becomes current, but it is not built automatically.

All properties in a new feature get a default value.

Editing a Geometry Feature

To change a property value in a feature, enter

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
```

where *property* is a property name and *<value>* is a property value.

All numeric properties can be given either as a numeric value or as a string expression that can contain parameters defined in `model.param()`. When building the feature, the string expressions are evaluated using the current values of the parameters.

To get the value of a property, enter one of the following, depending on the type of the property:

```
double d = model.component(<ctag>).geom(<tag>).feature(<ftag>).getDouble(property);
String s = model.component(<ctag>).geom(<tag>).feature(<ftag>).getString(property);
double[] da = model.component(<ctag>).geom(<tag>).feature(<ftag>).
getDoubleArray(property);
String[] sa = model.component(<ctag>).geom(<tag>).feature(<ftag>).
getStringArray(property);
double[][] dm = model.component(<ctag>).geom(<tag>).feature(<ftag>).
getDoubleMatrix(property);
String[][] sm = model.component(<ctag>).geom(<tag>).feature(<ftag>).
getStringMatrix(property);
```

If you request a numerical value for a string property, it is evaluated using the current values of the parameters in `model.param()`.

- get* and Selection Access Methods
- set()

SELECTIONS

There are primitive features and operation features. Operations features take existing geometry objects as input and create new geometry objects from them. The input objects are usually specified in the `input` selection:

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input").
   set(inputObjects);
```

where `inputObjects` is a string array with object or feature names. If `inputObjects` contains a feature name, it refers to all objects generated by this feature. If you have defined a named selection of objects, you can refer to it using the `named` method (see Selection Features below).

Geometry Object Selection Methods

Usually, the input objects of an operation feature is removed when building the feature. To change this behavior, a property `keep` is available for many operations features. If `keep` is set to `on`, the input objects are kept when building the feature.

Building Geometry Features

To generate the output objects of a feature, you must ***build*** the feature. Enter

```
model.component(<ctag>).geom(<tag>).run(<ftag>);
```

to build the feature *<ftag>* and all its preceding features (the features are built in the order from the first to the last). When the build has completed, the feature *<ftag>* becomes current.

To build all preceding features of the feature *<ftag>*, enter

```
model.component(<ctag>).geom(<tag>).runPre(<ftag>);
```

To build all features, including the Finalize feature and the virtual operations, enter

```
model.component(<ctag>).geom(<tag>).run();
```

ERRORS

If an error occurs when building a feature, the build stops, and the feature before the failing feature becomes current. The failing feature gets an *error feature* appended, which contains the error message. To access the error message, enter

```
String msg = model.component(<ctag>).geom(<tag>).feature(<ftag>).message();
```

To access the error feature, its message and detailed message, enter

```
String msg = model.component(<ctag>).geom(<tag>).feature(<ftag>).
   problem("error").getString("message");
String det = model.component(<ctag>).geom(<tag>).feature(<ftag>).
   problem("error").getString("details");
```

WARNINGS

After a successful build, a feature can get warning features appended, which contain warning messages. To access the first warning message, enter

```
String msg = model.component(<ctag>).geom(<tag>).feature(<ftag>).message();
```

To access the warning features, their messages and detailed messages, enter

```
String msg = model.component(<ctag>).geom(<tag>).feature(<ftag>).
   problem(<wtag>).getString("message");
String det = model.component(<ctag>).geom(<tag>).feature(<ftag>).
   problem(<wtag>).getString("details");
```

where *<wtag>* is `warning1`, `warning2`, and so on.

Feature Status

The *status* of a feature can be one of the following:

- *Built* or *warning*. This means that the none of the feature's properties have changed since the feature was last built, and the features of the input objects are all built. If the status is *warning*, the feature contains warning messages.
- *Edited*. This means that some of the feature's properties have changed since the feature was last built.
- *Needs rebuild*. This means that the feature generating some input object is not built.
- *Error*. This means that the feature contains an error message.

You can examine the status of a feature by entering

```
String status = model.geom(<tag>).feature(<ftag>).status();
```

Accessing Geometry Object Names

Each feature produces one or several output geometry objects. To get the names of these objects, enter

```
String[] oNames = model.component(<ctag>).geom(<tag>).feature(<ftag>).objectNames();
```

To get the names of all currently existing geometry objects (the geometry objects that were generated by the last build), enter

```
String[] oNames = model.component(<ctag>).geom(<tag>).objectNames();
```

To access one of these objects, you can enter

```
GeomObject go = model.component(<ctag>).geom(<tag>).obj(<objname>);
```

where the string `<objname>` is an object name. If `<objname>` does not exist in the current state, you get an error message. You can get information about the geometry object `go` by using the *geometry information methods*, for example,

```
int numberOfFaces = go.getNFaces();
```

Geometry Object Information

To access the finalized geometry (the output of the last feature), use

```
model.component(<ctag>).geom(<tag>)
```

NAMING OF GEOMETRY OBJECTS

The names of the output objects of a feature are formed by appending characters after the feature's tag, in one of the following ways:

- `ftag(index)`. For example, `split1(1)`, `split1(2)`, `split1(3)` if the feature tagged `split1` has three output objects. This method is used for most features.
- `ftag(i1,i2,...)`. For example, `arr1(1,1)`, `arr1(1,2)`, `arr(2,1)`, `arr1(2,2)` for a 2-by-2 array feature tagged `arr1`. This method is only used for the `Array` feature.
- `ftag.objectNameIn2D`. For example, `wp1.r1`, `wp1.pt1(1)`, `wp1.pt1(2)` if the work plane feature `wp1` contains the 2D objects `r1`, `pt1(1)`, and `pt1(2)`. This method is only used for the `WorkPlane` feature.
- `ftag.objectNameIn3D`. For example, `cro1.blk1` and `cro1.cyl1`. This method is used for the `CrossSection` feature.
- `ftag.objectName`. This method can be used for the `Import` feature, and then `objectName` is taken from the CAD file.

Deleting and Disabling Geometry Features

To delete a feature, enter

```
model.component(<ctag>).geom(<tag>).feature().remove(<ftag>);
```

To disable a feature, enter

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).active(false);
```

The disabled feature does not affect the finalized geometry — its output is empty. To enable a disabled feature, enter

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).active(true);
```

You can get the enabled/disabled status of a feature by entering

```
boolean isEnabled = model.component(<ctag>).geom(<tag>).feature(<ftag>).active();
```

Deleting Geometry Objects

You can use the following operation to delete objects from the geometry sequence.

```
model.component(<ctag>).geom(<tag>).delete(String[]);
```

In the input string array you specify the names of the objects to delete. The operation deletes objects that correspond to primitive geometry features by removing these features from the sequence. The operation then deletes the remaining objects by adding and building a `Delete` feature with the objects in its selection.

When using the delete operation the status of the current feature and all its preceding features must be built.

Moving and Scaling Geometry Objects

You can use the following operations to move or scale objects from the geometry sequence.

```
model.component(<ctag>).geom(<tag>).move(String[] obj, double[] dist);
model.component(<ctag>).geom(<tag>).
   scale(String[] obj, double[] factor, double[] center);
model.component(<ctag>).geom(<tag>).scale(String[] obj, double factor, double[] center);
```

The input array `obj` specifies the objects to move or scale. The `dist` array specifies the move distance in each axis direction. The `factor` array specifies an anisotropic scaling and the `factor` scalar specifies an isotropic scaling. The `center` array specifies the scaling center point. When possible, the move and scale operations modify the corresponding geometry features in the sequence. Not all features can be moved or scaled by modifying their properties, in which case move or scale features are added to the geometry sequence instead.

When using the move or scale operations the status of the current feature and all its preceding features must be built.

Plotting a Geometry Sequence

Use the `image().plot()` method for plotting the geometry sequence in a window:

```
model.geom("geom1").image().plot();
```

See Plotting and Exporting Images for more information.

Geometry Settings

You can control the following general settings for a geometry:

- Length Unit
- Angular Unit
- Scale Values When Changing Unit
- Geometry Representation in 3D
- Default Repair Tolerances
- Automatic Rebuild

Length Unit

The default length unit is meter. To change the length unit, enter

```
model.component(<ctag>).geom(<tag>).lengthUnit(newLengthUnit);
```

where *newLengthUnit* is a string like `"mm"`, `"in"`, or `"ft"`.

To get the current length unit, enter

```
String currentUnit = model.geom(<tag>).lengthUnit();
```

The length unit is used in fields for lengths and for visualization of the geometry. In fields you can override the unit (for example, by entering `13[mm]`). When solving the model, all lengths are converted to meters.

Angular Unit

The default angular unit is degrees. To change the angular unit, enter

```
model.component(<ctag>).geom(<tag>).angularUnit(newAngularUnit);
```

where *newAngularUnit* is `deg` or `rad`.

To get the current angular unit, enter

```
String currentUnit = model.component(<ctag>).geom(<tag>).angularUnit();
```

The angular is used in fields for angles. You can override the unit, for example by entering `0.3[rad]`. Numeric inputs and outputs of trigonometric functions are always assumed to be in radians, though.

Scale Values When Changing Unit

When you change the length unit or angular unit there are two possibilities to interpret pure numeric values in the geometry and meshing sequences. The first possibility is to reinterpret the numeric value in the new unit; a circle of radius 1.0 (meter) becomes a circle of radius 1.0 (millimeter), assuming the length unit changes from meter to millimeter.

The other possibility is to scale the numbers; a circle of radius 1.0 (meter) becomes a circle of radius 1000.0 (millimeter). To control the behavior, use

```
model.component(<ctag>).geom(<tag>).scaleUnitValue(newScaleValue);
```

where *newScaleValue* is `true` if you want values to be scaled, and `false` otherwise. The default value is `false`.

To get the currently used method, enter

```
boolean currentScaleValue = model.component(<ctag>).geom(<tag>).scaleUnitValue();
```

Geometry Representation in 3D

This settings is only relevant if you have a license for the CAD Import Module. The geometry representation determines which kernel (geometric modeler) that COMSOL uses to represent and operate on the geometry objects: the CAD Import Module's kernel (Parasolid) or COMSOL's own kernel. To change the geometry representation, enter

```
model.component(<ctag>).geom(<tag>).geomrep(newGeomRep);
```

where *newGeomRep* is `comsol` or `cadps`.

- If you choose `cadps`, all objects and operations that support the CAD kernel (Parasolid kernel) use it. For example, the Work Plane, Extrude, and Revolve features currently do not support this kernel.
- If you choose `comsol`, all objects are represented using the COMSOL kernel.

When you change the geometry representation, all nodes that support the CAD kernel get an *edited* status. To rebuild the geometry using the new kernel, use the `run` method.

When you create a new model (application), its default geometry representation is controlled by the preference setting **Geometry>Geometry representation>In new applications** (`geometry.geomrep.default`). To change or read this preference setting, enter

```
ModelUtil.setDefaultGeometryKernel(defaultGeomRep);
ModelUtil.getDefaultGeometryKernel();
```

where *defaultGeomRep* is `cadps` or `comsol`.

When you open an existing model, you normally use the geometry representation used in the model. To always convert the geometry to the COMSOL kernel, change the preference setting **Geometry>Geometry representation>When opening an existing application** to **Convert to COMSOL kernel** (`geometry.geomrep.open`). To change or read this preference setting, enter

```
ModelUtil.setOpenGeometryKernel(openGeomRep);
ModelUtil.getOpenGeometryKernel();
```

where *openGeomRep* is `model` or `comsol`.

Default Repair Tolerances

The repair tolerance for the applicable geometry operations can be of three types: automatic (the default), relative, or absolute. The automatic repair tolerance provides suitable settings when using the CAD kernel; when using the COMSOL kernel, it sets a relative repair tolerance of `1e-6`. You specify the default repair tolerance type by entering:

```
model.component(<ctag>).geom(<tag>).repairTolType(<newRepairTolType>)
```

where *<newRepairTolType>* is any of `auto`, `relative`, or `absolute`.

The *default relative repair tolerance* is `1e-6` (it can be any positive scalar value smaller than 0.1). You can change it by entering

```
model.component(<ctag>).geom(<tag>).repairTol(<newRelativeRepairtol>);
```

When doing so, the software also sets the `repairTolType` to `relative`. To get the current default relative repair tolerance, enter

```
double reptol = model.component(<ctag>).geom(<tag>).repairTol();
```

The *default absolute repair tolerance* is `1e-6` (it can be any positive scalar value). You can change it by entering

```
model.component(<ctag>).geom(<tag>).absRepairTol(<newAbsoluteRepairtol>);
```

When doing so, the software also sets the `repairTolType` to `absolute`. To get the current default absolute repair tolerance, enter

```
double reptol = model.component(<ctag>).geom(<tag>).absRepairTol();
```

The default repair tolerance is the default value that is used when you add a new feature that has the repair tolerance properties — for example, Boolean operations and conversions. Changing the default repair tolerance does not affect the tolerances in existing features. Adjust the repair tolerance if you experience problems with a Boolean operation.

Automatic Rebuild

This setting controls if the geometry sequence is automatically rebuilt when clicking a node in the model tree outside the geometry sequence. You can change it by entering:

```
model.component(<ctag>).geom(<tag>).autoRebuild(<newAutoRebuild>);
```

where *<newAutoRebuild>* is `on` or `off`.

The default geometry representation is controlled by the preference setting **Geometry>Automatic rebuild> Default in new geometries**.

Work Planes

In 3D, you can create 3D objects by defining 2D objects in *work planes* and then *extruding* and *revolving* these into 3D objects. You can also get a *cross section* 2D object by intersecting a 3D object with the work plane.

To add a `WorkPlane` feature, use

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"WorkPlane");
```

You access a work planes 2D geometry sequence by the `geom()` method. To add a 2D feature to a work plane, use

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).geom().create(<ftag1>,ftype);
```

where *<ftag>* refers to a `WorkPlane` feature and *ftype* refers to a 2D feature type.

A work plane's geometry sequence does not contain a `Finalize` feature.

A work plane's geometry sequence inherits its settings from its 3D sequence.

For more information on the settings for a geometry sequence see Geometry Settings.

When you build a work plane feature its corresponding 2D sequence builds automatically and the geometry objects defined by the 2D sequence *embed* into 3D geometry objects in the 3D sequence. You can then extrude or revolve these embedded point, curve, or surface objects into curve, surface, or solid objects, respectively, by `Extrude` or `Revolve` features, respectively.

Methods on `model.component(<ctag>).geom(<tag>)` can also be used on `model.component(<ctag>).geom(<tag>).feature(<wptag>).geom()`.

Selections of Geometric Entities

Named Selections

You can create named selections of entities in geometry objects or of whole geometry objects in two ways:

- By setting the `selresult` property to `on` in an arbitrary geometry feature. This creates a selection containing the feature's output objects, and derived selections of entities for each entity type (domain, boundary, edge, and point). For the Import feature, there is an additional `selindividual` property, which creates selections corresponding to individual geometry objects.
- By adding a selection feature, see Using Selection Features. If this defines a selection of whole objects, derived selections of entities are also created for each entity type (domain, boundary, edge, and point).

You get the tags of the created named selections by

```
String[] selTags =
   model.component(<ctag>).geom(<tag>).feature(<ftag>).outputSelection();
```

You can access a named selection by `model.geom(`*`<gtag>`*`).selection(`*`<seltag>`*`)`, where *`<seltag>`* is the selection's tag. Usually, *`<seltag>`* is the same as the tag of the feature that created the selection, but derived selections of entities have a suffix `.dom`, `.bnd`, `.edg`, or `.pnt`.

You can use a named selection as an input selection in a geometry feature that comes after the feature that created the selection in the geometry sequence, as follows:

```
model.component(<ctag>).geom(<gtag>).selection(<propname>).named(<trimmedseltag>);
```

Here, *`<trimmedseltag>`* is the selection's tag without the suffix.

Each named selection of entities in the geometry sequence can also be used as a named selection on the finalized geometry. You can access this named selection by `model.component(`*`<ctag>`*`).selection(`*`<gtag>_<seltag>`*`)`. However, if the selection was derived from a selection of whole objects, you access the corresponding selection on the finalized geometry by `model.component(`*`<ctag>`*`).selection(`*`<gtag>_<trimmedseltag>_<lvl>`*`)`, where *`<lvl>`* is one of `dom`, `bnd`, `edg`, or `pnt`. Named selections on the finalized geometry are described in model.selection().

Using Selection Features

A selection features in the geometry sequence creates a selection of geometric entities or objects that is a subset of all entities or objects that were generated by the sequence of features preceding the selection feature.

- Use the ExplicitSelection feature to create a selection of entities or objects that you specify explicitly.
- Use the BallSelection, BoxSelection, CylinderSelection, or DiskSelection feature to create a selection of entities or objects that partly or completely lie inside a given ball, box, cylinder, or disk. The input entities or objects to select among can be all entities or objects generated by the preceding features, or a subset of these entities or objects defined by a set of input selections.
- Use the UnionSelection, IntersectionSelection, DifferenceSelection, and ComplementSelection features to combine a set of input selections using a Boolean operation.
- Use AdjacentSelection to create a selection of entities of a given dimension that are adjacent to entities in a set of input selections.

When using input selections, the input selections must be defined by features that come before the selection feature in the geometry sequence. You set the input selections in the `input` property (`add` and `subtract` for DifferenceSelection), where you use trimmed tags (that is, tags without the suffix) to refer to the input selections.

Usually, the trimmed tag is the same as the tag of the feature that defined the input selection. It can happen that an input selection selects entities or objects that no longer exist after building the feature preceding the selection feature. In this case, the input selection is interpreted by using an associative mapping to existing entities or objects.

Cumulative Selections

To create a cumulative selection tagged *<seltag>*, use

```
model.component(<ctag>).geom(<tag>).selection().create(<seltag>,"CumulativeSelection");
```

To make a geometry feature contribute its selection to a cumulative selection, use

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).set("contributeto",<seltag>);
```

To remove the contribution of a geometry feature to a cumulative selection, use

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).set("contributeto","none");
```

To control whether the cumulative selection is available outside the geometry sequence, use

```
model.component(<ctag>).geom(<tag>).selection(<seltag>).show(<boolean>);
```

To query whether the cumulative selection is available outside the geometry sequence, use

```
boolean show = model.component(<ctag>).geom(<tag>).selection(<seltag>).show();
```

Virtual Operations

About Virtual Operations

In 2D and 3D it is possible to reduce the number of vertices, edges, faces, and domains of the geometry by using *virtual operation features*. To add the first virtual operation feature to a sequence you need to build the finalize feature by entering

```
model.component(<ctag>).geom(<tag>).run("fin");
```

You can then add the virtual operation feature by entering

```
model.component(<ctag>).geom(<tag>).create(<ftag>,ftype);
```

where `<ftag>` is the feature's tag (an identifier of your choice), and `ftype` is the feature's type. To build the feature, enter

```
model.component(<ctag>).geom(<tag>).run(<ftag>);
```

To build all features, including the finalize feature and all virtual operation features, and to create the finalized geometry, enter

```
model.component(<ctag>).geom(<tag>).run();
```

The finalized geometry of a sequence that contains virtual operation features is referred to as a *virtual geometry*. If you form a composite edge, face, or domain by using a `CompositeEdges`, `CompositeFaces`, or `CompositeDomains` feature, respectively (or the analogues `IgnoreVertices`, `IgnoreEdges`, or `IgnoreFaces` features) the resulting edge, face, or domain is referred to as a *virtual composite edge*, *virtual composite face*, or *virtual composite domain*, respectively, or more generally, a *virtual composite entity*.

Mesh Control Entities

Sometimes it is desirable to use certain geometric entities only when constructing the mesh. For example, you can add a curve inside a domain to control mesh element size there. If you mark this curve as a *mesh control entity*, it is not included in the geometry used when defining the physics. An advantage is that the final mesh need not respect this curve exactly; it is used only to control element size. You can use the `keepformesh` property of the Composite and Ignore features described above to define mesh control entities. Alternatively, you can use the `MeshControlDomains`, `MeshControlVertices`, `MeshControlEdges`, or `MeshControlFaces` features.

Geometry Object Information

You can get the geometry object named *<objname>* via

```
model.component(<ctag>).geom(<tag>).obj(<objname>)
```

Accessing Geometry Object Names

The geometry itself,

```
model.component(<ctag>).geom(<tag>)
```

works as an object, namely the final geometry resulting from the sequence. To get information about these objects, you can apply the methods described in this section.

A geometry part does not have a finalized geometry, so these methods are not applicable for geometry parts. See Using Geometry Parts for information about applicable methods when working with geometry parts.

General Information

TABLE 3-19: GENERAL GEOMETRY INFORMATION METHODS

METHOD	OUTPUT TYPE
`check()`	void
`exists()`	Boolean
`getBoundingBox()`	double[sdim*2]
`getSDim()`	int
`getType()`	String
`hasCadRep()`	Boolean

- `check()` throws an exception if the object is invalid.
- `exists()` returns `true` if an object exists.
- `getBoundingBox()` returns a bounding box for the object in the order `xmin`, `xmax`, `ymin`, `ymax`, `zmin`, and `zmax`.
- `getSDim()` returns the space dimension of the geometry.
- `getType()` returns the object type: `solid`, `surface`, `curve`, `point`, `mixed`, or `empty`.
- `hasCadRep()` returns true if the object is represented using the CAD kernel (Parasolid).

Geometric Entity Counters

The following geometric entity counter methods are available:

TABLE 3-20: GEOMETRIC ENTITY COUNTER METHODS

METHOD	1D	2D	3D	OUTPUT TYPE
`getNEntities()`	√	√	√	int[]
`getNVertices()`	√	√	√	int
`getNEdges()`	√	√	√	int
`getNFaces()`			√	int
`getNBoundaries()`	√	√	√	int
`getNDomains()`	√	√	√	int
`getNEntitiesMesh()`	√	√	√	int[]

- `getNEntities` returns a vector of length 2 in 1D, length 3 in 2D, and length 4 in 3D. The vectors contain the number of geometric entities for each entity dimension. The methods `getNVertices`, `getNEdges`, `getNFaces`, `getNBoundaries`, and `getNDomains` return the number of entities of the specified type.
- `getNEntitiesMesh` returns a vector of length 2 in 1D, length 3 in 2D, and length 4 in 3D. The vectors contain the number of geometric entities for each entity dimension in the geometry used for meshing. If there are no mesh control entities in the geometry, the output is identical to that of `getNEntities.`

Adjacency

The following geometry adjacency information methods are available:

TABLE 3-21: GEOMETRY ADJACENCY INFORMATION METHODS

METHOD	1D	2D	3D	OUTPUT TYPE
`getStartEnd()`	√	√	√	int[2][]
`getUpDown()`	√	√	√	int[2][]
`getUpDownExt()`	√	√	√	int[2][]
`getVertexDomain()`		√	√	int[]
`getSD()`		√	√	double[]
`getAdj(int,int)`	√	√	√	int[][]
`getAdj(int,int,int)`	√	√	√	int[]
`getAdjOrient(int,int)`	√	√	√	int[][]
`getAdjOrient(int,int,int)`	√	√	√	int[][]
`getAdjSparse(int,int)`	√	√	√	int[3][]

- `getStartEnd` returns the start and end vertices of all edges in the first and second row of the returned matrix.
- `getUpDown` returns the up and down domain number for all boundaries in the first and second row of the returned matrix. All void regions have the domain number 0.
- `getUpDownExt` returns the up and down domain number for all boundaries in the first and second row of the returned matrix, using an extended domain numbering where void regions have different domain numbers. The infinite void region has domain number 0. The finite void regions have negative domain numbers. However, if `voidAreLabeled()` returns `false`, the extended domain numbering is not available, and then all void regions have domain number 0.
- `getVertexDomain` returns the domain index for each vertex. For nonisolated vertices, the domain index is -1.
- `getSD` returns the domain index for each vertex. For nonisolated vertices, the domain index is `NaN`.

- `a = getAdj(fromDim, toDim)` returns a matrix where `a[fromIdx]=getAdj(fromDim,toDim,fromIdx)` contains the entities in dimension `toDim` that are adjacent to entity `fromIdx` in dimension `fromDim`.
- `ao = getAdjOrient(fromDim, toDim)` returns a matrix where `ao[fromIdx]=getAdjOrient(fromDim,toDim,fromIdx)` contains the orientation flag for the entities in `getAdj(fromDim,toDim,fromIdx)`. The orientation flag is 1 if the adjacent entities have the same orientation, and -1 if they have the opposite orientation, and 2 if the relative orientation cannot be determined (for instance, for an edge interior to a face).
- `as = getAdjSparse(fromDim, toDim)` returns the adjacency matrix from entities in dimension `fromDim` to entities in dimension `toDim` on a sparse format, that is, `as[0]` are the entity numbers in dimension `fromDim`, `as[1]` are the entity numbers in dimension `toDim`, and `as[2]` are the corresponding orientation flags.

Evaluation on an Edge

The following edge evaluation methods are available in 2D and 3D:

TABLE 3-22: EDGE EVALUATION METHODS IN 2D AND 3D

METHOD	2D	3D	OUTPUT TYPE
`edgeParamRange(int)`	√	√	double[2]
`edgeX(int, double[])`	√	√	double[][D]
`edgeDX(int, double[])`	√	√	double[][D]
`edgeDDX(int, double[])`	√	√	double[][D]
`edgeNormal(int, double[])`	√		double[][D]
`edgeCurvature(int, double[])`	√	√	double[]
`edgeTorsion(int, double[])`		√	double[]

The first input argument of all methods is the edge number. The second input argument, when it exists, is an array of parameter values for which to perform evaluation on the edge. For all but the first method, the first index in the output corresponds to the different parameter values, and the second index corresponds to the spatial coordinates.

- `edgeParamRange` returns the parameter range for evaluation on the edge.
- `edgeX` evaluates the parameters to coordinate values.
- `edgeDX` evaluates the parameters to first order derivative values.
- `edgeDDX` evaluates the parameters to second order derivative values.
- `edgeNormal` evaluates the parameters to normal vector values.
- `edgeCurvature` evaluates the parameters to curvature values.
- `edgeTorsion` evaluates the parameters to torsion values.

Evaluation on a Face

Use the following method for face evaluation in 3D. They do not work on virtual geometry objects.

TABLE 3-23: FACE EVALUATION METHODS IN 3D

METHOD	OUTPUT TYPE
`faceParamRange(int)`	double[4]
`faceX(int, double[][2])`	double[][3]
`faceDX(int, double[][2])`	double[][3][2]
`faceDDX(int, double[][2])`	double[][3][2][2]
`faceNormal(int, double[][2])`	double[][3]

TABLE 3-23: FACE EVALUATION METHODS IN 3D

METHOD	OUTPUT TYPE
`faceFF1(int, double[][2])`	double[][2]
`faceFF2(int, double[][2])`	double[][2]
`faceGaussCurvature(int, double[][2])`	double[]
`faceMeanCurvature(int, double[][2])`	double[]

The first input argument of all methods is the face number. The second input argument, when it exists, is a matrix of parameter points, for which to perform evaluation. For all but the first method, the first index in the output corresponds to the different parameter points.

- `faceParamRange` returns two parameter ranges for evaluation on the face.
- `faceX` evaluates the parameters to coordinate values.
- `faceDX` evaluates the parameters to first order derivative values.
- `faceDDX` evaluates the parameters to second order derivative values.
- `faceNormal` evaluates the parameters to normal vector values.
- `faceFF1` evaluates the parameters to the first fundamental form values.
- `faceFF2` evaluates the parameters to the second fundamental form values.
- `faceGaussCurvature` evaluates the parameters to Gauss curvature values.
- `faceMeanCurvature` evaluates the parameters to mean curvature values.

Geometry Representation Arrays

Use the following methods to access the arrays in the internal representation of COMSOL Multiphysics geometry objects. They do not work on objects represented using the CAD kernel, assembly geometries, or virtual geometries.

TABLE 3-24: GET ARRAYS IN GEOMETRY REPRESENTATION

METHOD	1D	2D	3D	OUTPUT TYPE
`getVertex()`	√	√	√	double[][]
`getEdge()`		√	√	double[][]
`getFace()`			√	double[][]
`getPVertex()`			√	double[][]
`getPEdge()`			√	double[][]
`getVertexCoord()`	√	√	√	double[][]
`voidsAreLabeled()`	√	√	√	Boolean

- In 2D and 3D, `getVertex` returns (sdim+2)-by-nv matrix representing the vertices of the object. The first sdim rows are the coordinates of the vertices. Row sdim+1 contains the domain number if the vertex is isolated and is unspecified otherwise. The last row contains a relative local tolerance for the vertex. For nontolerant vertices the tolerance is NaN. This method does not work on virtual geometry objects.
- In 1D, `getVertex` returns a 3-by-`nvtx` matrix representing the vertices of the 1D object. Row 1 provides the coordinates of the vertices. Rows 2 and 3 provide the up and down domain numbers, respectively.
- `getPVertex` returns a 6-by-`npv` matrix containing embeddings of vertices in faces. Row 1 contains the vertex index (that is, column from `getVertex`), rows 2 and 3 contain (s, t) coordinates of the vertex on the face, row 4 contains a face index, and row 5 contains the manifold index into the manifolds. Row 6 contains a relative local tolerance for the vertex. This method does not work on virtual geometry objects.

- In 3D, `getEdge` returns a 7-by-`ne` matrix representing the edges of the 3D object. Rows 1 and 2 contain the start and end vertex indices of the edge (0 if they do not exist), respectively. Rows 3 and 4 give the parameter values of these vertices. Row 5 gives the index of a domain if the edge is not adjacent to a face, and is unspecified otherwise. Row 6 gives a sign and an index to the underlying manifold. The sign indicates the direction of the edge relative the curve. Finally, row 7 contains a relative local tolerance for the edge. This method does not work on virtual geometry objects.
- In 2D, `getEdge` returns a 8-by-ne matrix representing the edges of the 2D object. Rows 1 and 2 contain the start and end vertex indices of the edge, respectively (0 if they do not exist). Rows 3 and 4 give the parameter values of these vertices. Rows 5 and 6 contain the left and right domain number of the edge, respectively. Row 7 gives a sign and an index to the array of underlying curves. The sign indicates the direction of the edge relative the curve. Row 8 contains a relative local tolerance for the edge.
- `getPEdge` returns a 10-by-`npe` matrix representing the embeddings of the edges in faces. The first row gives the index of the edge in `getEdge`. Rows 2 and 3 contain the start and end vertex indices from `getPVertex`, respectively. Rows 4 and 5 give the parameter values of these vertices. Row 6 and 7 give the indices of the faces to the left and right of the edge, respectively. Row 8 gives a sign and index to the parameter curve (if any), and row 9 gives the index to the surface. Row 10 contains a relative local tolerance for the edge. This method does not work on virtual geometry objects.
- `getFace` returns a 4-by-`nf` matrix representing the faces of the 3D geometry. Rows 1 and 2 contain the up and down domain index of the face, respectively, and row 3 contains the manifold index of the face. Row 4 contains a relative local tolerance for the face. This method does not work on virtual geometry objects.
- `getVertexCoord` returns a matrix with the vertex coordinates. Its dimension is the space dimension times the number of vertices.
- `voidsAreLabeled` returns `true` if all finite void regions are labeled with negative domain indices in the serialization (mphtxt or mphbin file). This also affects the domain indices in the following methods: `getAdjExt()`, `getAdjOrientExt()`, `getUpDownExt()`, `getFace()`, `getEdge()`, and `getVertex()`. It returns `false` if some finite void regions might be denoted with 0 in the serialization, like in version 4.2.

Measurements

Geometric measurements is a tool to measure geometric entities and objects. You access it by entering

```
model.component(<ctag>).geom(<tag>).measure()
```

using the `GeomSequence.measure()` method.

To make a measurement on the finalized geometry, use `GeomSequence.measureFinal()` instead:

```
model.component(<ctag>).geom(<tag>).measureFinal()
```

It supports the applicable measurement options (for computing a volume, for example) used with the `measure` method in the section below.

Measuring Geometric Entities in Objects

To select entities you want to measure, enter

```
model.component(<ctag>).geom(<tag>).measure().selection().init(entDim);
model.component(<ctag>).geom(<tag>).measure().selection().set(<objname>,entities);
```

where *entDim* is the dimension of the entities, *<objname>* is the object name, and *entities* is an integer array containing the entity numbers.

To get the volume/area/length of the selected entities, enter

```
double vol = model.component(<ctag>).geom(<tag>).measure().getVolume();
```

To get the area/length of the boundary of the selected entities, enter

```
double bndVol = model.component(<ctag>).geom(<tag>).measure().getBoundaryVolume();
```

If you have selected two vertices, you can get their distance by entering

```
double[] d = model.component(<ctag>).geom(<tag>).measure().getVtxDistance();
```

`d[0]` is the distance, and `d[i]` is the distance in the `i`th coordinate (`i = 1, 2, 3`).

If you have selected one vertex, you can get its coordinates by entering

```
double[] coord = model.component(<ctag>).geom(<tag>).measure().getVtxCoord();
```

Measuring Objects

To select objects you want to measure, enter

```
model.component(<ctag>).geom(<tag>).measure().selection().init();
model.component(<ctag>).geom(<tag>).measure().selection().set(<objnames>);
```

where *<objnames>* is a string array containing the object names.

To get the total number of entities in the selected objects, enter

```
int[] entitiesPerDimension =
   model.component(<ctag>).geom(<tag>).measure().getNEntities();
```

Inserting Geometry Sequences from File

To insert a geometry sequence from an MPH-file, enter

```
model.component(<ctag>).geom(<tag>).insertFile(<filename>, <sequencename>);
```

where *<filename>* and *<sequencename>* are strings.

To insert a geometry sequence from a different model component, enter

```
model.component(<ctag>).geom(<tag>).insertSequence(<ctag2>, <sequencename>);
```

where *<ctag2>* and *<sequencename>* are strings.

Example of Importing Geometry Sequences

The following sequence imports three different geometry sequences from two different files:

Code for Use with Java

```
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("g", 2);
g.insertFile("filename", "geom1");
ModelUtil.load("Model2", "filename2");
g.insertSequence("Model2", "geom1/wp1");
g.insertSequence("Model2", "geom1/wp2");
```

Code for Use with MATLAB

```
model.component.create('comp1');
g = model.geom.create('g', 2);
g.insertFile('filename', 'geom1');
ModelUtil.load('Model2', 'filename2');
g.insertSequence('Model2', 'geom1/wp1');
g.insertSequence('Model2', 'geom1/wp2');
```

Exporting Geometry to File

To export the result of the Finalize feature to a file, enter

```
model.component(<ctag>).geom(<tag>).exportFinal(<filename>);
```

where *<filename>* is a string.

To export selected geometry objects to a file, first select the objects to export using

```
model.component(<ctag>).geom(<tag>).export().selection().set(<objnames>);
```

where *<objnames>* is a string array of object names. Then export them by entering

```
model.component(<ctag>).geom(<tag>).export(<filename>);
```

The file can be of any of the following formats:

TABLE 3-25: VALID FILE FORMATS

FILE FORMAT	NOTE	FILE EXTENSIONS
COMSOL Multiphysics Binary		.mphbin
COMSOL Multiphysics Text		.mphtxt
Parasolid Binary (3D)	1, 2	.x_b
Parasolid Text (3D)	1, 2	.x_t
ACIS Binary (3D)	1, 3	.sab
ACIS Text (3D)	1, 3	.sat
STL Binary (3D)	4	.stl
STL Text (3D)	4	.stl
DXF (2D)		.dxf

[1] This format requires a license for the CAD Import Module, Design Module, or a LiveLink product for a CAD package.

[2] The exported Parasolid file format version is 31.0.

[3] Use `model.geom(<tag>).export().setAcisVersion(<version>)` to specify the ACIS file format version ("*4.0*", "*7.0*"; or the default "*2016 1.0*").

[4] Use `model.geom(<tag>).export().setSTLFormat(<format>)` to specify the STL file format ("binary" or "text").

Exporting to an ACIS File

When exporting to an ACIS file you can set the ACIS file format version using

```
model.component(<ctag>).geom(<tag>).export().setAcisVersion(<version>);
```

where *<version>* is a string `4.0`, `7.0`, or `2016 1.0`. Default is `2016 1.0`.

Exporting to a Parasolid File

When exporting to Parasolid text or binary format, a unit conversion can optionally be performed during export. Use the following method to select the export length unit:

```
model.component(<ctag>).geom(<tag>).export().setLengthUnit(<unit>);
```

where *<unit>* is either `fromgeom` to disable unit conversion or a COMSOL Multiphysics length unit, such as `m` for meters or `in` for inches.

Exporting to an STL File

To export to an STL file, start with specifying a file format using

```
model.component(<ctag>).geom(<tag>).export().setSTLFormat(<format>);
```

where *<format>* is string with only two allowed values: `binary` and `text`

Use the following methods to select domains or boundaries to export:

```
model.component(<ctag>).geom(<tag>).export().selection().init(<edim>);
model.component(<ctag>).geom(<tag>).export().selection().set(<objnames>, <entlst>);
```

Use the following methods to select objects to export:

```
model.component(<ctag>).geom(<tag>).export().selection().init();
model.component(<ctag>).geom(<tag>).export().selection().set(<objnames>);
```

Finish the export by using the following line

```
model.component(<ctag>).geom(<tag>).export(<filename>);
```

Compatibility for mphbin/mphtxt in 2D and 3D

If you want to open a COMSOL Multiphysics geometry file in an earlier versions of COMSOL Multiphysics, you might need to set the COMSOL Multiphysics version using

```
model.component(<ctag>).geom(<tag>).export().setCompat(<ver>);
```

where *<ver>* is a string `4.0` (only 3D), `4.0a` (only 3D), `4.2a`, `4.3b`, or `5.1`.

Using Geometry Parts

For a description of geometry parts, see Using Geometry Parts in the *COMSOL Multiphysics Reference Manual*.

To create a geometry part, enter

```
model.geom().create(<tag>, "Part", sDim);
```

where `<tag>` is the parts tag, and `sDim` is its space dimension (1, 2, or 3).

To add an input parameter to the part, enter

```
model.geom(<tag>).inputParam().set(<name>, <expr>, <descr>);
```

where the description `<descr>` can be omitted.

Similarly, add a local parameter by

```
model.geom(<tag>).localParam().set(<name>, <expr>, <descr>);
```

The containers `model.component(<ctag>).geom(<tag>).inputParam()` and `model.component(<ctag>).geom(<tag>).localParam()` also support the other methods listed in `model.param() and model.result().param()`.

To load one or more geometry parts, enter

```
model.geom().load(<tags>, <filename>, <partTagsInFile>);
```

where `<tags>` is a list of part tags, `<filename>` is the filename of the MPH-file where the parts are defined, and `<partTagsInFile>` is a list of the parts' tags in that file. If `model.geom(<gtag>)` is a geometry part, `model.geom(<gtag>).loaded()` returns true if the part was created by loading it from a file.

To get the filename of a loaded part, enter

```
model.geom(<gtag>).filename();
```

To change the filename of a loaded part, enter

```
model.geom(<gtag>).filename(<filename>);
```

where `<filename>` is the new filename.

For a loaded part, to return the comments from the MPH-file, enter

```
model.geom(<gtag>).commentsInFile();
```

For a loaded part, to return the last modification date from the MPH-file, enter

```
model.geom(<gtag>).dateModifiedInFile();
```

To get the tag that a loaded part has in the MPH-file, enter

```
model.geom(<gtag>).tagInFile();
```

To get the label that a loaded part has in the MPH-file, enter

```
model.geom(<gtag>).labelInFile();
```

For a loaded part, to return the version from the MPH-file, enter

```
model.geom(<gtag>).versionInFile();
```

To reload (update) a loaded part after its definition has been changed, enter

```
model.geom(<gtag>).reload();
```

To call a geometry part in a component geometry, add a PartInstance feature:

```
model.component(<ctag>).geom(<gtag>).create(<ftag>, "PartInstance");
```

See `PartInstance` for details.

To debug a call to part, you can step into it using

```
model.component(<ctag>).geom(<gtag>).stepInto(<ftag>);
```

You can then apply the usual geometry sequence methods on the local part instance, for example,

```
model.component(<ctag>).geom(<gtag>).feature(<ftag>).geom().run(<ftag2>);
```

to build the feature *<ftag2>* in the local part instance.

To make the part a part variant, enter

```
model.geom(<tag>).partVariant();
```

To check if the part is a part variant, enter

```
model.geom(<tag>).isPartVariant();
```

There is also a `selcolorlevel` property for geometry parts, which is a string array (by default all `none`) that indicates the colors of the selections (a read-only property). It is only available for domains and boundaries in 3D and domains in 2D.

Geometry Commands

Geometry Commands (A to L)

- AdjacentSelection
- Array
- BallSelection, BoxSelection, CylinderSelection, Disk Selection
- BezierPolygon
- Block
- Chamfer
- Circle
- CollapseEdges
- CollapseFaces
- Compose, Union, Intersection, Difference
- CompositeDomains
- CompositeEdges
- CompositeFaces
- Cone
- ConvertToSolid, ConvertToSurface, ConvertToCurve, ConvertToPoint
- CrossSection
- Cylinder
- Delete
- ECone
- EditObject
- Ellipse
- Ellipsoid
- ExplicitSelection
- Extrude
- Fillet
- Finalize
- FromMesh
- Helix
- Hexahedron
- If, ElseIf, Else, EndIf
- IgnoreEdges
- IgnoreFaces
- IgnoreVertices
- Import DXF
- Import Geometry Sequence
- Import Mesh Part or Meshing Sequence
- Import mphbin/mphtxt
- Interpolation Curve
- Interpolation Curve
- Interval
- LineSegment

AdjacentSelection

Create a selection of entities or objects that are adjacent to given selections.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"AdjacentSelection");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

AdjacentSelection creates a selection of all entities of dimension `outputdim` that are adjacent to at least one entity in the `input` selections. If the output selection has lower dimension than the input selections, you can use the `exterior` and `interior` properties to exclude or include output entities that are exterior/interior to the union of the input selections.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	none | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`entitydim`	0 | 1 | 2 | 3	space dimension	Dimension of input entities.
`exterior`	on | `off`	on	Include output entities that are exterior to the union of the input selections.
`input`	String[]	{}	Tags of input selections.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
interior	on | off	off	Include output entities that are interior to the union of the input selections.
outputdim	0 | 1 | 2 | 3	space dimension - 1	Dimension of entities to select.
selkeep	on | off	on	Keep the selection within the geometry sequence.
selshow	on | off	on	Show selection in physics, materials, and so on; in part instances; or in 3D from a plane geometry.
contributeto	String	none	Tag of cumulative selection to contribute to.

See Selections of Geometric Entities for general information about selections.

EXAMPLE

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("sph1", "Sphere");
g.run("sph1");
g.create("sel1", "ExplicitSelection");
g.feature("sel1").selection("selection").init(0);
g.feature("sel1").selection("selection").set("sph1", new int[]{4});
g.create("adjsel1", "AdjacentSelection");
g.feature("adjsel1").set("entitydim", 0);
g.feature("adjsel1").set("input", new String[]{"sel1"});
g.run("adjsel1");
g.create("del1", "Delete");
g.feature("del1").selection("input").named("adjsel1");
g.run("del1");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('sph1', 'Sphere');
g.run('sph1');
g.create('sel1', 'ExplicitSelection');
g.feature('sel1').selection('selection').init(0);
g.feature('sel1').selection('selection').set('sph1', 4);
g.create('adjsel1', 'AdjacentSelection');
g.feature('adjsel1').set('entitydim', 0);
g.feature('adjsel1').set('input', 'sel1');
g.run('adjsel1');
g.create('del1', 'Delete');
g.feature('del1').selection('input').named('adjsel1');
g.run('del1');
```

SEE ALSO

BallSelection, BoxSelection, CylinderSelection, Disk Selection, ExplicitSelection, UnionSelection, IntersectionSelection, DifferenceSelection, ComplementSelection

Array

Create a block-shaped (3D), rectangular (2D, 3D), or linear array of geometry objects.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Array");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Array")` to create an array of geometry objects.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the objects to array. The default selection is empty.

The following properties are available:

TABLE 3-26: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`input`	Selection		Objects to array.
`displ`	double[sdim]	1	Displacements in axis directions.
`size`	int | int[sdim]	1	Array size.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects of this feature.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	The highest available entity level except `obj`; usually `dom`.	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.

If `size` is a scalar, a linear (oblique) array with `size` copies of the input objects is constructed. The displacement between two consecutive copies is given by the vector `displ`. The names of the output objects are `ftag(i)`, where `ftag` is the tag of the feature, and `i` is a 1-based index. If there are more than one input object, the output objects are named `ftag(i,in)`, where `in` is a 1-based index corresponding to the input objects.

2D: If `size` is an array of length 2, a rectangular array with `size[0]`-by-`size[1]` copies of the input object is constructed. The *x*- and *y*-displacements are `displ[0]` and `displ[1]`, respectively. The names of the output objects are `ftag(i1,i2)`, where `ftag` is the name of the feature, and `i1` and `i2` are 1-based indices. If there are more than one input object, the output objects are named `ftag(i1,i2,in)`, where `in` is a 1-based index corresponding to the input objects.

3D: If `size` is an array of length 3, a three-dimensional (block shaped) array with `size[0]`-by-`size[1]`-by-`size[2]` copies of the input object is constructed. The x-, *y*-, and *z*-displacements are `displ[0]`, `displ[1]`, and `displ[2]`, respectively. The names of the output objects are `ftag(i1,i2,i3)`, where `ftag` is the name of the feature, and `i1`, `i2`, and `i3` are 1-based indices. If there are more than one input object, the output objects are named `ftag(i1,i2,i3,in)`, where `in` is a 1-based index corresponding to the input objects.

The input object is deleted and an identical object is constructed as a part of the array.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

In COMSOL Multiphysics 5.2, the `selresult` property replaced the `createselection` property. `createselection` is still supported for backward compatibility.

`model.geom(<tag>).create(<ftag>,"arrayr")` constructs an `Array` feature

EXAMPLE

The following sequence creates a block with four equally-sized holes:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("cyl1","Cylinder");
g.create("arr1","Array");
g.feature("arr1").selection("input").set("cyl1");
g.feature("arr1").set("displ", "4 4 0");
g.feature("arr1").set("size", "2 2 1");
g.create("blk1","Block");
g.feature("blk1").set("size", "10 14 5");
g.feature("blk1").set("pos", "-3 -5 -4");
g.create("dif1","Difference");
g.feature("dif1").selection("input").set("blk1");
g.feature("dif1").selection("input2").set("arr1");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('cyl1','Cylinder');
g.create('arr1','Array');
g.feature('arr1').selection('input').set('cyl1');
g.feature('arr1').set('displ', '4 4 0');
g.feature('arr1').set('size', '2 2 1');
g.create('blk1','Block');
g.feature('blk1').set('size', '10 14 5');
g.feature('blk1').set('pos', '-3 -5 -4');
g.create('dif1','Difference');
g.feature('dif1').selection('input').set('blk1');
g.feature('dif1').selection('input2').set('arr1');
g.run;
```

SEE ALSO

`Move, Copy`

BallSelection, BoxSelection, CylinderSelection, Disk Selection

Create selections of geometric entities or objects that (partly) lie inside a ball, box, cylinder, or disk.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"BallSelection");
model.component(<ctag>).geom(<tag>).create(<ftag>,"BoxSelection");
model.component(<ctag>).geom(<tag>).create(<ftag>,"CylinderSelection");
model.component(<ctag>).geom(<tag>).create(<ftag>,"DiskSelection");
model.component(<ctag>).geom(<tag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).getType(property);
```

DESCRIPTION

The following general properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
angletol	double	5	Angle tolerance for continuity evaluation.
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property.
condition	intersects | inside | somevertex | allvertices	intersects	Condition for inclusion of an entity.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
entitydim	-1 | 0 | 1 | 2 | 3	space dimension	Dimension of entities to select. -1 means Object.
groupcontang	on | off	off	Continuous tangent mode.
input	String[]	{}	Tags of input selections, only used when inputent is selections.
inputent	all | selections	all	Select among all entities or entities defined by input property.
selkeep	on | off	on	Keep the selection within the geometry sequence.
selshow	on | off	on	Show selection in physics, materials, and so on; in part instances; or in 3D from a plane geometry.
contributeto	String	none	Tag of cumulative selection to contribute to.

For BallSelection, you define the ball using the following properties (using the geometry sequence's length unit):

PROPERTY	VALUE	DEFAULT	DESCRIPTION
posx	double	0	Center of ball, first coordinate.
posy	double	0	Center of ball, second coordinate.
posz	double	0	Center of ball, third coordinate.
r	double	0	Radius of ball.

For BoxSelection, you define the box using the following properties (using the geometry sequence's length unit):

PROPERTY	VALUE	DEFAULT	DESCRIPTION
xmax	double	inf	Maximum x-coordinate of box.
xmin	double	-inf	Minimum x-coordinate of box.
ymax	double	inf	Maximum y-coordinate of box.
ymin	double	-inf	Minimum y-coordinate of box.
zmax	double	inf	Maximum z-coordinate of box.
zmin	double	-inf	Minimum z-coordinate of box.

For CylinderSelection, you define the cylinder using the following properties (using the geometry sequence's length unit):

PROPERTY	VALUE	DEFAULT	DESCRIPTION
angle1	double	0	Start angle.
angle2	double	360	End angle (default: 360 degrees; that is, a full cylinder).

PROPERTY	VALUE	DEFAULT	DESCRIPTION
axis	double[]	{0,0,0}	Direction of cylinder axis. Vector has length 3 if axistype is cartesian and length 2 is axistype is spherical. Not used if axistype is x, y, or z.
axistype	x | y | z | cartesian | spherical	z	Type of axis or coordinate system used for axis. The value is synchronized with axis.
bottom	double	-inf	Coordinate of bottom face in local coordinate system.
pos	double[]	{0,0,0}	Base point.
r	double (nonnegative)	0	Outer radius.
rin	double (nonnegative)	0	Inner radius.
top	double	inf	Coordinate of top face in local coordinate system.

For DiskSelection, you define the disk using the following properties (using the geometry sequence's length unit):

PROPERTY	VALUE	DEFAULT	DESCRIPTION
angle1	double	0	Start angle.
angle2	double	360	End angle (default: 360 degrees; that is, a full disk).
posx	double	0	Center of disk, first coordinate.
posy	double	0	Center of disk, second coordinate.
r	double (nonnegative)	0	Outer radius.
rin	double (nonnegative)	0	Inner radius.

You select the input entities or objects to select among using the properties entitydim, inputent, and input. For a boundary or edge selection in 2D or 3D, you can force the selection to select whole groups of entities by setting the property groupcontang to on. Each group consists of adjacent entities that meet at an angle less than angletol.

The output entities/objects are determined by the property condition:

- intersects: All entities/objects that intersect the ball/box/cylinder are included.
- inside: All entities/objects that are completely inside the ball/box/cylinder are included.
- somevertex: All entities/objects that have at least one adjacent vertex inside the ball/box/cylinder are included.
- allvertices: All entities/objects that have all adjacent vertices inside the ball/box/cylinder are included.

For intersects and inside, the rendering mesh is used for the calculation. You can set the resolution of the rendering mesh using

```
ModelUtil.setPreference("graphics.rendering.detail",<detail>);
```

where *<detail>* is coarse, normal, fine, or wireframe.

See Selections of Geometric Entities for general information about selections.

EXAMPLE

In a 10-by-10 array of squares, delete the squares that lie in the box $x>9.5$, $y>9.5$.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
```

```
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
g.create("sq1", "Square");
g.create("arr1", "Array");
g.feature("arr1").selection("input").set("sq1");
g.feature("arr1").set("fullsize", new int[]{10,10});
g.feature("arr1").set("displ", new double[]{2,2});
g.run("arr1");
g.create("boxsel1","BoxSelection");
g.feature("boxsel1").set("entitydim", -1);
g.feature("boxsel1").set("xmin", 9.5);
g.feature("boxsel1").set("ymin", 9.5);
g.create("del1", "Delete");
g.feature("del1").selection("input").init();
g.feature("del1").selection("input").named("boxsel1");
g.run("del1");
// g.objectNames().length = 75
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
g.create('sq1', 'Square');
g.create('arr1', 'Array');
g.feature('arr1').selection('input').set('sq1');
g.feature('arr1').set('fullsize', [10,10]);
g.feature('arr1').set('displ', [2,2]);
g.run('arr1');
g.create('boxsel1','BoxSelection');
g.feature('boxsel1').set('entitydim', -1);
g.feature('boxsel1').set('xmin', 9.5);
g.feature('boxsel1').set('ymin', 9.5);
g.create('del1', 'Delete');
g.feature('del1').selection('input').init;
g.feature('del1').selection('input').named('boxsel1');
g.run('del1');
% length(g.objectNames)= 75
```

SEE ALSO

AdjacentSelection, ExplicitSelection, UnionSelection, IntersectionSelection, DifferenceSelection, ComplementSelection

BezierPolygon

Create a curve or solid polygon consisting of Bézier segments in 2D or 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"BezierPolygon");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"BezierPolygon")` to create a Bézier polygon or a line segment. The following properties are available

TABLE 3-27: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`degree`	int[] | int	1	Degree of Bézier segments.
`p`	double[][]		Control points.
`type`	`solid` | `open` | `closed`	`solid` (2D) `open` (3D)	Object type. `solid` is not available in 3D.
`w`	double[]		Weights.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom` in 2D; `edg` in 3D.	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`workplanesrc`	`this` | Part Instance feature	`this`	Part Instance feature to take the work plane from (in 3D only).
`workplane`	`xyplane` | Work plane feature	`xyplane`	Work Plane feature that defines the coordinate system (in 3D only). The default, `xyplane`, is the global Cartesian coordinate system.

If `type` is `open` or `closed`, a curve consisting of line, quadratic, or cubic rational Bézier segments is constructed. If `type` is `solid`, the solid enclosed by such a closed polygon is constructed. If `type` is `closed` or `solid`, but the first and last control points are different, an extra linear segment is added to close the curve.

The degree of the `n`th segment is `degree[n]`, and it must be 1 (linear), 2 (quadratic), or 3 (cubic). The `n`th segment has `degree[n]+1` control points and weights. The weights are stored consecutively in the array `w`, which has length `degree[0]+...+degree[N-1]+N`, where `N` is the number of segments. The `i`th coordinates of the control points are stored consecutively in the array `p[i]`. Adjacent segments share the common control point, which means that `p[i]` has length `degree[0]+...+degree[N-1]+1`.

For a linear or cubic segment, the default weights are 1. For a quadratic segment, the default weights are $1, 1/\sqrt{2}, 1$.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

EXAMPLE

Construct a solid triangle `b1` and an elliptic arc `b2`:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("b1","BezierPolygon");
g.feature("b1").set("p", new double[][]{{0, 0, 2}, {1, 0 ,0}});
```

```
g.create("b2","BezierPolygon");
g.feature("b2").set("type","open");
g.feature("b2").set("degree",2);
g.feature("b2").set("p", new double[][]{{0, 1, 0}, {1, 2, 0}});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('b1','BezierPolygon');
g.feature('b1').set('p', [[0, 0, 2]; [1, 0 ,0]]);
g.create('b2','BezierPolygon');
g.feature('b2').set('type','open');
g.feature('b2').set('degree',2);
g.feature('b2').set('p', [[0, 1, 0]; [1, 2,0]]);
g.run;
```

SEE ALSO

Polygon

Block

Create a right-angled solid or surface block in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Block");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Block")` to create a block. The following properties are available:

TABLE 3-28: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`axis`	double[]	`{0,0,1}`	Direction of the edge on the local z-axis. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`base`	`corner` | `center`	`corner`	Positions the object either centered about `pos` or with one corner in `pos`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`layer`	double[]		Thicknesses of layers.
`layertop`	`on` | `off`	`off`	Apply layers on top.
`layerbottom`	`on` | `off`	`on`	Apply layers on bottom.

TABLE 3-28: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
layerleft	on | off	off	Apply layers to the left.
layerright	on | off	off	Apply layers to the right.
layerfront	on | off	off	Apply layers on front.
layerback	on | off	off	Apply layers on back.
size	double[]	{1,1,1}	Edge lengths.
pos	double[]	{0,0,0}	Position of the object.
rot	double	0	Rotational angle about axis.
type	solid | surface	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"block2") constructs a solid block.

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"block3") constructs a surface block.

The following properties are also available:

TABLE 3-29: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ax2	double[]	{0,0}	Alias for axis when axistype is spherical.
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian.
lx, ly, lz	double	1	Alias for size.
x, y, z	double	0	Alias for pos.

The property const is no longer available.

EXAMPLE

The following commands create a solid and surface block, where the position is defined in the two alternative ways.

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("b1","Block");
g.feature("b1").set("size","1 2.1 0.5");
g.feature("b1").set("base","center");
g.feature("b1").set("pos","1 0 1");
g.feature("b1").set("axis","1 0 0");
g.feature("b1").set("rot",30);
```

```
double[] a = g.feature("b1").getDoubleArray("pos");
g.create("b2","Block");
g.feature("b2").set("type","surface");
g.feature("b2").set("size","1 2.1 0.5");
g.feature("b2").set("pos",a);
String b = g.feature("b2").getString("pos");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('b1','Block');
g.feature('b1').set('size','1 2.1 0.5');
g.feature('b1').set('base','center');
g.feature('b1').set('pos','1 0 1');
g.feature('b1').set('axis','1 0 0');
g.feature('b1').set('rot',30);
a = g.feature('b1').getDoubleArray('pos');
g.create('b2','Block');
g.feature('b2').set('type','surface');
g.feature('b2').set('size','1 2.1 0.5');
g.feature('b2').set('pos',a);
b = g.feature('b2').getString('pos');
```

SEE ALSO

Hexahedron

Chamfer

Create flattened corners in 2D objects. The Design Module also supports 3D chamfers.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Chamfer");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Chamfer")` to chamfer corners in 2D.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("point")` to select the corners to chamfer. The default selection is empty.

TABLE 3-30: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`dist`	double	0	Distance from vertex to chamfer.
`point`	Selection		Vertices to chamfer.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.

TABLE 3-30: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selresultshow	all | obj | dom | bnd | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

EXAMPLE

Chamfer a rectangle.

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("r1","Rectangle");
g.create("cha1","Chamfer");
g.feature("cha1").selection("point").set("r1(1)",new int[]{1,2,3,4});
g.feature("cha1").set("dist",0.1);
g.run();
```

Code for use MATLAB

```
Model model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('r1','Rectangle');
g.create('cha1','Chamfer');
g.feature('cha1').selection('point').set('r1(1)',{1,2,3,4});
g.feature('cha1').set('dist',0.1);
g.run;
```

DIAGNOSTICS

If a chamfer cannot be created according to the specified properties, this vertex is ignored. When the chamfers generate intersections with other edges in the geometry, an error message is given.

SEE ALSO

Fillet

Circle

Create a circle or disk in 2D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Circle");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Circle")` to create a disk in 2D. The following properties are available:

TABLE 3-31: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`angle`	double	360	Circle sector angle.
`base`	`corner` | `center`	`center`	Positions the object either centered about `pos` or with the lower-left corner of a surrounding box in `pos`
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`layer`	double[]		Thicknesses of layers.
`pos`	double[]	`{0,0}`	Position of the object.
`r`	double	1	Radius.
`rot`	double	0	Rotational angle about `pos`.
`type`	`solid` | `curve`	`solid`	Object type.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"circ2")` creates a solid disk.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"circ1")` creates a circle curve.

The following properties are also available:

TABLE 3-32: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
x, y	double	0	Alias for pos.

The property `const` is no longer available.

EXAMPLE

The sequence below creates a unit disk (solid circle object).

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("c1","Circle");
g.feature("c1").set("pos",new double[]{2,3});
String base = g.feature("c1").getString("base");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('c1','Circle');
g.feature('c1').set('pos',[2,3]);
base = g.feature('c1').getString('base');
g.run;
```

SEE ALSO

`Ellipse`

CollapseEdges

Collapse edges.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"CollapseEdges");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"CollapseEdges")` to collapse edges.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the edges to collapse. The default selection is empty.

The feature collapses an edge by removing it, merging its adjacent vertices to the vertex with lowest index, and reconnecting the adjacent edges to the merged vertex.

The output object is a virtual geometry.

The following properties are available:

TABLE 3-33: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Edges to collapse.
`ignoremerged`	`on` | `off`	`on`	Specifies if the operation tries to ignore the resulting merged vertices.

SEE ALSO

`MergeVertices`, `CollapseFaces`, `CollapseFaceRegions`

CollapseFaces

Collapse faces.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"CollapseFaces");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>),"CollapseFaces")` to collapse faces.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the faces to collapse. The default selection is empty.

The feature collapses a face by removing it, merging its adjacent opposite edges into one or more edges or collapsing all adjacent edges into one vertex, and reconnecting the adjacent faces to the merged edges or vertex.

The output object is a virtual geometry.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`collvtxtol`	`auto` | `manual`	`auto`	Use an automatic or manual tolerance for the maximum perimeter of a face to be collapsed into a vertex.
`input`	`Selection`		Faces to collapse.
`ignoremerged`	`on` | `off`	`off`	Specifies if the operation tries to ignore the resulting merged entities.
`maxfaceperimeter`	`double`	`0.001`	The maximum perimeter of a face to be collapsed into a vertex when `collvtxtol` is set to `manual`.

SEE ALSO

`MergeEdges`, `CollapseEdges`, `CollapseFaceRegions`

CollapseFaceRegions

Collapse face regions.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"CollapseFaceRegions");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>),"CollapseFaceRegions")` to collapse narrow face regions.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the faces where narrow regions should be collapsed. The default selection is empty.

The feature collapses narrow face regions by determining narrow regions of a face and then collapsing those resulting sliver faces.

The output object is a virtual geometry.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`input`	`Selection`		Faces for which narrow regions should be collapsed.
`maxwidth`	`double`	`0.001`	The maximum width of a face region to be collapsed when `narrowtol` is set to `manual`.
`narrowtol`	`auto` | `manual`	`auto`	Use an automatic or manual tolerance for the maximum width of a face region to be collapsed.

SEE ALSO

`MergeEdges`, `CollapseEdges`, `CollapseFaces`

Compose, Union, Intersection, Difference

Compose objects using a Boolean set formula.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Compose");
model.component(<ctag>).geom(<tag>).create(<ftag>,"Union");
model.component(<ctag>).geom(<tag>).create(<ftag>,"Intersection");
model.component(<ctag>).geom(<tag>).create(<ftag>,"Difference");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,operationName)` to combine geometric objects in different ways.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property)` to select the objects to combine. The default selection is empty.

The following properties are available:

TABLE 3-34: VALID PROPERTIES FOR THE COMPOSE AND BOOLEAN OPERATIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`absrepairtol`	double	`...geom(<tag>).absRepairTol()`	Absolute repair tolerance.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`formula`	String		Set formula (only for Compose feature).
`input`	Selection		Objects to compose.
`input2`	Selection		Objects to subtract (only for Difference feature).
`intbnd`	`on` | `off`	`on`	Keep interior boundaries.
`keep`	`on` | `off`	`off`	Keep input objects.
`repairtol`	double	`...geom(<tag>).repairTol()`	Relative repair tolerance, relative to size of union of inputs.
`repairtoltype`	`auto` | `relative` | `absolute`	`...geom(<tag>).repairTolType()`	Repair tolerance type: automatic, relative, or absolute.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

The following Boolean operation is performed:

- For `Compose`, the input objects are combined using the set formula in the property `formula`. The operators `+`, `*`, and `-` correspond to the set operations union, intersection, and difference, respectively. The precedence of the operators `+` and `-` are the same. `*` has higher precedence.
- For `Union`, the objects in `input` are united.
- For `Intersection`, the objects in `input` are intersected.
- For `Difference`, the objects in `input2` are subtracted from the union of the objects in `input` to form a set difference.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

The following properties are also supported, see the `Delete` feature:

TABLE 3-35: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`edge`	`all` | `none`	`none`	Delete isolated edges on a face (3D). Delete interior edges and edges not adjacent to a domain (2D; alias for `indbnd`).
`face`	`all` | `none`	`none`	Delete interior faces (3D; alias for `intbnd`).
`point`	`all` | `none`	`none`	Delete isolated vertices (points) on a face (3D) or in a domain (2D).

The property `out` is no longer available.

SEE ALSO

`ConvertToSolid`, `ConvertToSurface`, `ConvertToCurve`, `ConvertToPoint`, `Finalize`, `Partition`

CompositeDomains

Form composite domains.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"CompositeDomains");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"CompositeDomains")` to form composite domains.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the domains to composite. The default selection is empty.

The feature forms a composite domain for each connected domain component of the selected domains by ignoring the boundaries between the domains. The output object is a virtual geometry.

The following properties are available:

TABLE 3-36: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`ignoreadj`	`on` | `off`	`on`	Ignore edges (3D only) and vertices on boundary.
`input`	Selection		Edges to composite.
`keepformesh`	`on` | `off`	`off`	Keep input domains for mesh control.

Use `ignoreadj` to specify if the feature also removes the ignorable edges (3D only) and vertices on the boundary of each resulting composite domain.

Use `keepformesh` to keep the input domains while meshing, to help you in constructing the mesh.

EXAMPLE

Create a composite domain of domain 2 and 3.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom", 2);
g.create("r1", "Rectangle");
g.create("c1", "Circle");
g.run("fin");
g.create("cmd1","CompositeDomains");
g.feature("cmd1").selection("input").set("fin", 2, 3);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom', 2);
g.create('r1', 'Rectangle');
g.create('c1', 'Circle');
g.run('fin');
g.create('cmd1','CompositeDomains');
g.feature('cmd1').selection('input').set('fin', 2, 3);
g.run;
```

SEE ALSO

`CompositeEdges`, `CompositeFaces`, `IgnoreEdges`, `IgnoreFaces`

CompositeEdges

Form composite edges.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"CompositeEdges");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"CompositeEdges")` to form composite edges.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the edges to concatenate. The default selection is empty.

The feature forms a composite edge for each connected edge component (of manifold type) of the selected edges by ignoring the vertices between the edges. The output object is a virtual geometry.

The following properties are available:

TABLE 3-37: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Edges to composite.
`keepformesh`	on | `off`	`off`	Keep input edges for mesh control.

Use `keepformesh` to keep the input edges while meshing, to help you in constructing the mesh.

Note that the operation never forms composite edges that are closed loops or periodic, that is, every resulting edge has distinct start and end vertices.

EXAMPLE

Compose edges 2 and 4 of a circle into one edge.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
g.create("c1", "Circle");
g.run("fin");
g.create("cme1", "CompositeEdges");
g.feature("cme1").selection("input").set("fin", 2, 4);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
g.create('c1', 'Circle');
g.run('fin');
g.create('cme1', 'CompositeEdges');
g.feature('cme1').selection('input').set('fin', 2, 4);
g.run;
```

SEE ALSO

`CompositeDomains`, `CompositeFaces`, `IgnoreVertices`

CompositeFaces

Form composite faces.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"CompositeFaces");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"CompositeFaces")` to form composite faces.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the faces to concatenate. The default selection is empty.

The feature forms a composite face for each connected face component (of manifold type) of the selected faces by ignoring the edges between the faces. The output object is a virtual geometry.

The following properties are available:

TABLE 3-38: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Faces to composite.
`ignorevtx`	`on` | `off`	`on`	Ignore vertices on boundary.
`keepformesh`	`on` | `off`	`off`	Keep input faces for mesh control.

Use `ignorevtx` to specify if the feature also removes the ignorable vertices on the boundary of each resulting composite face.

Use `keepformesh` to keep the input faces while meshing, to help you in constructing the mesh.

EXAMPLE

A COMSOL Multiphysics standard cone has six faces. Using the following composite face operation, the result is a cone with three faces: top, bottom, and side.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("cone1", "Cone");
g.run("fin");
g.create("cmf1", "CompositeFaces");
g.feature("cmf1").selection("input").set("fin", 1, 2, 5, 6);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('cone1', 'Cone');
g.run('fin');
g.create('cmf1', 'CompositeFaces');
g.feature('cmf1').selection('input').set('fin', [1, 2, 5, 6]);
g.run;
```

SEE ALSO

`CompositeDomains`, `CompositeEdges`, `IgnoreEdges`

Cone

Create a right circular cone or cone frustum (conical frustum, truncated cone) in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Cone");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Cone")` to create a cone. The following properties are available:

TABLE 3-39: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`ang`	double	`arctan(1/2)` (about 26.565 degrees)	The cone's semiangle; that is, the angle between the axis and a generator of the conical surface.
`axis`	double[]	`{0,0,1}`	Direction of the axis. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.

TABLE 3-39: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
h	double	1	Height.
layer	double[]		Thicknesses of layers.
layertop	on | off	off	Apply layers on top.
layerbottom	on | off	off	Apply layers on bottom.
layerside	on | off	on	Apply layers on side.
pos	double[]	{0,0,0}	Center of the bottom circle.
r	double	1	Radius of bottom circle.
rot	double	0	Rotational angle about axis.
rtop	double	0.5	Radius of top circle.
specifytop	angle | radius	angle	If axistype is angle, the radius of the top circle is given by the ang property. If axistype is radius, the radius of the top circle is given by the rtop property.
type	solid | surface	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"cone3") creates a solid cone.

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"cone2") creates a surface cone.

The following properties are also available:

TABLE 3-40: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ax2	double[]	{0,0}	Alias for axis when axistype is spherical.
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian.
x, y, z	double	0	Alias for pos.

The property const is no longer available.

EXAMPLE

Create a cone with an apex:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
double h = 3;
double r = 2;
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.angularUnit("rad");
g.create("c1","Cone");
g.feature("c1").set("r",r);
g.feature("c1").set("h",h);
g.feature("c1").set("ang", Math.atan(r/h));
double ang = g.feature("c1").getDouble("ang");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
h = 3;
r = 2;
g = model.component('comp1').geom.create('geom1',3);
g.angularUnit('rad');
g.create('c1','Cone');
g.feature('c1').set('r',r);
g.feature('c1').set('h',h);
g.feature('c1').set('ang', atan2(r,h));
ang = g.feature('c1').getDouble('ang');
```

Create a truncated and rotated cone:

Code for Use with Java

```
g.create("c2","Cone");
g.feature("c2").set("pos", "1 -2 4");
g.feature("c2").set("axis", "1 -1 0.3");
g.feature("c2").set("rot",Math.PI/3);
g.run();
```

Code for Use with MATLAB

```
g.create('c2','Cone');
g.feature('c2').set('pos', '1 -2 4');
g.feature('c2').set('axis', '1 -1 0.3');
g.feature('c2').set('rot', pi/3);
g.run;
```

SEE ALSO

Cylinder, ECone

ConvertToSolid, ConvertToSurface, ConvertToCurve, ConvertToPoint

Unite and convert objects to a solid, surface, curve, or point object.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"ConvertToSolid");
model.component(<ctag>).geom(<tag>).create(<ftag>,"ConvertToSurface");
model.component(<ctag>).geom(<tag>).create(<ftag>,"ConvertToCurve");
model.component(<ctag>).geom(<tag>).create(<ftag>,"ConvertToPoint");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,convertOperation)` to reduce or extend the topological dimension of objects.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the objects to convert. The default selection is empty.

The following properties are available:

TABLE 3-41: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`absrepairtol`	double	`...geom(<tag>).absRepairTol()`	Absolute repair tolerance.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`input`	Selection		Objects to convert.
`keep`	`on` | `off`	`off`	Keep input objects.
`repairtol`	double	`...geom(<tag>).repairTol()`	Relative repair tolerance, relative to size of union of inputs.
`repairtoltype`	`auto` | `relative` | `absolute`	`...geom(<tag>).repairTolType()`	Repair tolerance type: automatic, relative, or absolute.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom` for `ConvertToSolid`; `bnd` for `ConvertToSurface`; `bnd` (2D) or `edg` (3D) for `ConvertToCurve`; and `pnt` for `ConvertToPoint`.	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

The input objects are united, and the resulting object is then converted to the requested type.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

SEE ALSO

`Compose, Union, Intersection, Difference`

CrossSection

Create a 2D geometry from a cross section of a 3D geometry.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"CrossSection");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

In a 2D geometry, use `model.component(<ctag>).geom(<tag>).create(<ftag>,"CrossSection")` to create 2D geometry objects by intersecting 3D geometry objects with a work plane. Select the work plane using the `workplane` property, whose value is the 3D sequence's tag followed by a slash and the work plane feature's tag, for example `geom1/wp1`. By default, you get the last work plane in the last 3D geometry.

In a 2D sequence of a work plane feature, use `model.component(<ctag>).geom(<tag>).feature(<wptag>).geom().create(<ftag>,"CrossSection")` to create 2D geometry objects by intersecting 3D geometry objects with the work plane.

By default, you get the intersection for all 3D objects that were generated by the features preceding the work plane feature. To select a subset of these objects, set the `intersect` property to `selected`, and use the property `input` to select the 3D objects to intersect.

The following properties are available:

TABLE 3-42: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`absrepairtol`	double	`...geom(<tag>).absRepairTol()`	Absolute repair tolerance.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`input`	Selection	empty	Selection of objects to intersect.
`intersect`	`all` | `selected`	`all`	Intersect all objects or selected objects.
`repairtol`	double	`...geom(<tag>).repairTol()`	Relative repair tolerance, relative to size of each input object.
`repairtoltype`	`auto` | `relative` | `absolute`	`...geom(<tag>).repairTolType()`	Repair tolerance type: automatic, relative, or absolute.
`selfrom3D`	`true` | `false`	`false`	Create selections from the 3D geometry.
`selfrom3dshow`	`true` | `false`	`false`	Show created selections from 3D in, for example, material and physics settings. Not available for in work planes.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `pnt` | `off`	`dom`	Show selections, if `selresult` is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`workplane`	String		Work plane to intersect with.

EXAMPLE

Create a work plane though the axis of a torus. In a 2D axisymmetric geometry, create the cross section of the torus using the work plane. Note that the last `run()` command removes the part of the cross section that falls in the region $r<0$.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
```

```
model.component().create("comp1");
GeomSequence g1 = model.component("comp1").geom().create("geom1", 3);
g1.create("tor1", "Torus");
g1.run("tor1");
g1.create("wp1", "WorkPlane");
g1.feature("wp1").set("planetype", "circularedge");
g1.feature("wp1").selection("circedge").set("tor1", 15);

model.component().create("comp2");
GeomSequence g2 =model.component("comp2").geom().create("geom2", 2);
g2.axisymmetric(true);
g2.create("cro1", "CrossSection");
g2.run("cro1"); // Two circles
g2.run(); // One circle
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g1 = model.component('comp1').geom.create('geom1', 3);
g1.create('tor1', 'Torus');
g1.run('tor1');
g1.create('wp1', 'WorkPlane');
g1.feature('wp1').set('planetype', 'circularedge');
g1.feature('wp1').selection('circedge').set('tor1', 15);

model.component.create('comp2');
g2 = model.component('comp2').geom.create('geom2', 2);
g2.axisymmetric(true);
g2.create('cro1', 'CrossSection');
g2.run('cro1'); % Two circles
g2.run; % One circle
```

SEE ALSO

`WorkPlane`

Cylinder

Create a solid or hollow (surface) cylinder in 3D. The cylinder is a right circular cylinder; that is, a cylinder that has circles as bases aligned one directly above the other.

SYNTAX

`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).create(`*`<ftag>`*`,"Cylinder");`
`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).feature(`*`<ftag>`*`).set(`*`property`*`,`*`<value>`*`);`
`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).feature(`*`<ftag>`*`).get`*`Type`*`(`*`property`*`);`

DESCRIPTION

Use `model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).create(`*`<ftag>`*`,"Cylinder")` to create a cylinder. The following properties are available:

TABLE 3-43: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`axis`	double[]	`{0,0,1}`	Direction of the axis. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.

TABLE 3-43: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
layer	double[]		Thicknesses of layers.
layertop	on | off	off	Apply layers on top.
layerbottom	on | off	off	Apply layers on bottom.
layerside	on | off	on	Apply layers on side.
h	double	1	Height.
pos	double[]	{0,0,0}	Center of the bottom circle.
r	double	1	Radius of bottom circle.
rot	double	0	Rotational angle about axis.
type	solid | surface	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"cylinder3") creates a solid cylinder.

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"cylinder2") creates a surface cylinder.

The following properties are also available:

TABLE 3-44: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ax2	double[]	{0,0}	Alias for axis when axistype is spherical
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian
x, y, z	double	0	Alias for pos

The property const is no longer available.

EXAMPLE

The following commands generate a surface cylinder and a solid cylinder:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.angularUnit("rad");
g.create("c2","Cylinder");
g.feature("c2").set("type","surface");
g.feature("c2").set("r",0.5);
g.feature("c2").set("h",4);
g.feature("c2").set("pos","1 1 0");
g.feature("c2").set("axis","pi/2 0");
g.create("c3","Cylinder");
g.feature("c3").set("r",20);
g.feature("c3").set("h",40);
g.feature("c3").set("pos","0 0 -100");
g.feature("c3").set("axis","1 1 1");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.angularUnit('rad');
g.create('c2','Cylinder');
g.feature('c2').set('type','surface');
g.feature('c2').set('r',0.5);
g.feature('c2').set('h',4);
g.feature('c2').set('pos','1 1 0');
g.feature('c2').set('axis','pi/2 0');
g.create('c3','Cylinder');
g.feature('c3').set('r',20);
g.feature('c3').set('h',40);
g.feature('c3').set('pos','0 0 -100');
g.feature('c3').set('axis','1 1 1');
g.run;
```

SEE ALSO

Cone, ECone

Delete

Delete vertices, edges, faces, domains, or geometric objects.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Delete");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Delete")` to delete geometric entities.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the entities to delete. The default selection is empty.

TABLE 3-45: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Vertices, edges, faces, domains, or objects to delete.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`compat`	`4.2a` | `4.3`	`4.3`	Algorithm version.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

Deleting a domain, face, or edge automatically deletes all lower-dimensional adjacent entities, except those needed to bound surviving entities.

In 2D and 3D, vertices that are adjacent to an edge cannot be deleted.

In 3D, an edge can be deleted if it has no adjacent faces, or if it is interior to a face.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

In version 4.3, the algorithm was changed slightly. The main difference is that the old algorithm preserved the object type for solid, surface, and curve objects. To get the old behavior, set `compat` to `4.2a`.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"del")` creates a `Delete` feature.

EXAMPLE

Delete face 5 from a surface block:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g =model.component("comp1").geom().create("geom1",3);
g.create("blk1","Block");
g.feature("blk1").set("type", "surface");
g.run("blk1");
g.create("del1","Delete");
g.feature("del1").selection("input").set("blk1",5);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
```

```
g.create('blk1','Block');
g.feature('blk1').set('type', 'surface');
g.run('blk1');
g.create('del1','Delete');
g.feature('del1').selection('input').set('blk1',5);
g.run;
```

SEE ALSO

`Compose, Union, Intersection, Difference`

ECone

Create a solid or surface eccentric oblique cone or frustum in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"ECone");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"ECone")` to create an eccentric oblique cone. The following properties are available:

TABLE 3-46: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`angle`	double	360	Ellipse sector angle.
`axis`	double[]	`{0,0,1}`	Direction of the normal to the bottom ellipse. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`displ`	double[2]	`{0,0}`	Displacement of top ellipse relative to bottom ellipse in the local coordinate system.
`h`	double	1	Height.
`pos`	double[3]	`{0,0,0}`	Center of the bottom ellipse.
`r`	double	1	Radius of bottom ellipse.
`rat`	double	`0.5`	Ratio between perimeter for top ellipse and bottom ellipse.
`rot`	double	0	Rotational angle about `axis`.
`semiaxes`	double[2]	`{1,1}`	Semiaxes of bottom ellipse.
`type`	`solid` | `surface`	`solid`	Object type.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.

TABLE 3-46: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"econe3") creates a solid eccentric cone.

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"econe2") creates a surface eccentric cone.

The following properties are also available:

TABLE 3-47: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
a, b	double	1	Alias for semiaxes.
ax2	double[]	{0,0}	Alias for axis when axistype is spherical.
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian.
x, y, z	double	0	Alias for pos.

The property const is no longer available.

EXAMPLES

Create a truncated eccentric cone with the base face in the *xy*-plane:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("e1","ECone");
g.feature("e1").set("semiaxes","10 40");
g.feature("e1").set("h",20);
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('e1','ECone');
g.feature('e1').set('semiaxes','10 40');
g.feature('e1').set('h',20);
```

Create an eccentric cone with an apex, that is, a singular patch, on top:

Code for Use with Java

```
g.create("e2","ECone");
g.feature("e2").set("semiaxes","1 2");
g.feature("e2").set("h",4);
g.feature("e2").set("rat",0);
```

```
g.feature("e2").set("displ","1 1");
g.feature("e2").set("pos","100 100 100");
g.feature("e2").set("axis","0 1 4");
g.feature("e2").set("rot",45);
g.run();
```

Code for Use with MATLAB

```
g.create('e2','ECone');
g.feature('e2').set('semiaxes','1 2');
g.feature('e2').set('h',4);
g.feature('e2').set('rat',0);
g.feature('e2').set('displ','1 1');
g.feature('e2').set('pos','100 100 100');
g.feature('e2').set('axis','0 1 4');
g.feature('e2').set('rot',45);
g.run;
```

SEE ALSO

`Cone`, `Cylinder`

EditObject

Create an edit object feature in 2D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"EditObject");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).vertexNew();
model.component(<ctag>).geom(<tag>).feature(<ftag>).vertexDelete(<vertex>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).vertexSnap(<vertex>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).startVertexDisconnect(<edge>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).endVertexDisconnect(<edge>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).edgeNew();
model.component(<ctag>).geom(<tag>).feature(<ftag>).edgeDelete(<edge>);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"EditObject")` to create an edit object feature.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).vertexNew()` to add a new vertex to the object.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).vertexDelete(<vertex>)` to delete *<vertex>* from the object.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).vertexSnap(<vertex>)` to delete *<vertex>* from the object, and move any adjacent edges to the closest remaining vertex.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).startVertexDisconnect(<edge>)` to create a new vertex and use this vertex as the start vertex for *<edge>*.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).endVertexDisconnect(<edge>)` to create a new vertex and use this vertex as the end vertex for *<edge>*.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).edgeNew()` to add a new edge to the object.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).edgeDelete(<edge>)` to delete *<edge>* from the object.

The following properties are available:

TABLE 3-48: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
input	Selection		Geometry object to edit.
vertex	integer | ""		Vertex to edit.
xvertex	double	0	x-coordinate of vertex being edited.
yvertex	double	0	y-coordinate of vertex being edited.
edge	integer | ""		Edge to edit.
x	double[]		x-coordinates of control points of edge being edited.
y	double[]		y-coordinates of control points of edge being edited.
weights	double[]		Weights of control points of edge being edited.
knots	double[]		Knots of NURBS curve for edge being edited.
degree	1 | 2 | 3		Degree of edge being edited.
start	integer | ""		Start vertex of edge being edited.
end	integer | ""		End vertex of edge being edited.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

EXAMPLE

The following sequence edits a circle, setting the degree of one edge to one to create a straight edge:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
g.create("c1", "Circle");
g.run("c1");
g.create("edo1", "EditObject");
g.feature("edo1").selection("input").set(new String[]{"c1"});
g.feature("edo1").set("edge", "1");
g.feature("edo1").set("degree", "1");
g.run("edo1");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
g.create('c1', 'Circle');
```

```
g.run('c1');
g.create('edo1', 'EditObject');
g.feature('edo1').selection('input').set({'c1'});
g.feature('edo1').set('edge', '1');
g.feature('edo1').set('degree', '1');
g.run('edo1');
```

SEE ALSO

BezierPolygon

Ellipse

Create a solid or curved ellipse in 2D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Ellipse");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Ellipse")` to create an ellipse. The following properties are available:

TABLE 3-49: VALID PROPERTIES FOR ELLIPSE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
base	corner | center	center	Positions the object either centered about pos or with the lower left corner of surrounding box in pos.
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
layer	double[]		Thicknesses of layers.
pos	double[]	{0,0}	Position of the object.
rot	double	0	Rotational angle about pos.
semiaxes	double[]	{1,1}	Semiaxes.
type	solid | curve	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"ellip2")` is a solid ellipse.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"ellip1")` is an ellipse curve.

The following properties are also available:

TABLE 3-50: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
a, b	double	1	Alias for `semiaxes`.
x, y	double	0	Alias for `pos`.

The property `const` is no longer available.

EXAMPLE

The following sequence creates a solid ellipse:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("e1","Ellipse");
g.feature("e1").set("semiaxes","1 0.3");
g.feature("e1").set("rot",45);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('e1','Ellipse');
g.feature('e1').set('semiaxes','1 0.3');
g.feature('e1').set('rot',45);
g.run;
```

SEE ALSO

`Circle`

Ellipsoid

Create a solid or surface ellipsoid in 3D.

SYNTAX

`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).create(`*`<ftag>`*`,"Ellipsoid");`
`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).feature(`*`<ftag>`*`).set(`*`property`*`,`*`<value>`*`);`
`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).feature(`*`<ftag>`*`).get`*`Type`*`(`*`property`*`);`

DESCRIPTION

Use `model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).create(`*`<ftag>`*`,"Ellipsoid")` to create an ellipsoid. The following properties are available:

TABLE 3-51: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`axis`	double[]	`{0,0,1}`	Direction of the local z-axis. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.

TABLE 3-51: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
layer	double[]		Thicknesses of layers.
pos	double[]	{0,0,0}	Center.
rot	double	0	Rotational angle about axis.
semiaxes	double[3]	{1,1,1}	Semiaxes.
type	solid | surface	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"ellipsoid3") creates a solid ellipsoid.

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"ellipsoid2") creates a surface ellipsoid.

The following properties are also available:

TABLE 3-52: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
a, b, c	double	1	Alias for semiaxes.
ax2	double[]	{0,0}	Alias for axis when axistype is spherical.
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian.
x, y, z	double	0	Alias for pos.

The property const is no longer available.

EXAMPLE

The following commands create a surface and solid ellipsoid, where the position and semiaxes are defined in two alternative ways:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("e2","Ellipsoid");
g.feature("e2").set("type","surface");
g.feature("e2").set("pos","0 1 0");

g.create("e3","Ellipsoid");
g.feature("e3").set("semiaxes","12 10 8");
```

```
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('e2','Ellipsoid');
g.feature('e2').set('type','surface');
g.feature('e2').set('pos','0 1 0');

g.create('e3','Ellipsoid');
g.feature('e3').set('semiaxes','12 10 8');
g.run;
```

SEE ALSO

Sphere

ExplicitSelection

Create explicit selections of geometric entities or objects.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"ExplicitSelection");
model.component(<ctag>).geom(<tag>).feature().selection("selection");
model.component(<ctag>).geom(<tag>).feature().set(property,<value>);
model.component(<ctag>).geom(<tag>).feature().getType(property);
```

DESCRIPTION

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
angletol	double	5	Angle tolerance for continuity evaluation.
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property..
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
groupcontang	on | off	off	Continuous tangent mode.
selection	Selection	empty	Selection of entities or objects.
selkeep	on | off	on	Keep the selection within the geometry sequence.
selshow	on | off	on	Show selection in physics, materials, and so on; in part instances; or in 3D from a plane geometry.
contributeto	String	none	Tag of cumulative selection to contribute to.

Use the selection methods described in the section “Geometry Object Selection Methods” under `model.component(<ctag>).geom()` to specify the selection `model.component(<ctag>).geom(<tag>).feature().selection("selection")`.

For a boundary or edge selection in 2D or 3D, you can force the selection to select whole groups of entities by setting the property `groupcontang` to `on`. Each group consists of adjacent entities that meet at an angle less than `angletol`.

See Selections of Geometric Entities for general information about selections.

COMPATIBILITY

The following alias can also be used:

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Selection");
```

EXAMPLE

The sequence below creates a block and a cylinder and creates a selection of face 4 of the block. This corresponds to faces 9 and 13 in the finalized geometry.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("blk1", "Block");
g.run("blk1");
g.create("sel1","ExplicitSelection");
g.feature("sel1").selection("selection").init(2);
g.feature("sel1").selection("selection").set("blk1", new int[]{4});
g.create("cyl1", "Cylinder");
g.run();
int[] faces = model.selection("geom1_sel1").entities(2);
// faces = 9, 13
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('blk1', 'Block');
g.run('blk1');
g.create('sel1','ExplicitSelection');
g.feature('sel1').selection('selection').init(2);
g.feature('sel1').selection('selection').set('blk1', 4);
g.create('cyl1', 'Cylinder');
g.run;
faces = model.selection('geom1_sel1').entities(2);
% faces = 9, 13
```

SEE ALSO

AdjacentSelection, BallSelection, BoxSelection, CylinderSelection, Disk Selection, UnionSelection, IntersectionSelection, DifferenceSelection, ComplementSelection

Extrude

Extrude planar faces into 3D objects.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Extrude");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Extrude")` to extrude objects from a work plane or planar faces in the 3D geometry.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the work plane objects to extrude. The default selection is all available objects from the last preceding work plane.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("inputface")` to select the faces to extrude. Faces are extruded when the `workplane` property is `none`; otherwise work plane objects are extruded.

The following properties are available:

TABLE 3-53: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`crossfaces`	`on` | `off`	`on`	Keep cross-sectional faces.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`displ`	double[n_d][2]	`{{0,0}}`	Displacement (parallel to work plane) of extrusion top (of each layer) in local coordinate system.
`distance`	double | double[n_d]	1	Extrusion distance(s), that is, local z-coordinate for the top (of each layer). Used if `specify` is set to `distances`.
`extrudefrom`	`workplane` | `faces`		Extrude work plane objects or planar faces in 3D.
`includeinput`	boolean	`true`	Include (planar) input faces when forming the extruded object.
`input`	Selection	all objects	Objects to extrude.
`intputface`	Selection		Faces to extrude.
`polres`	double	50	Polygon resolution of edges.
`reverse`	`on` | `off`	`off`	Reverse the extrude direction.
`scale`	double[n_d][2]	`{{1,1}}`	Scale of extrusion top (of each layer).
`twist`	double | double[n_d]	0	Twist angle (of each layer).
`specify`	`distances` | `vertices`	`distances`	Specification of extrusion distances: as distances using the `distance` property or by specifying vertices in the 3D geometry using the `vertex` property.
`vertex`	Selection		Vertices to extrude to. Used if `specify` is set to `vertices`.
`workplane`	String		Work plane to extrude.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, of resulting objects in physics, materials, and so on, or in part instances. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

Each planar input is extruded in n_d layers defined by a local coordinate system. By default, n_d=1. The property `distance` is the extrusion distance (of each layer) in the z-axis direction of the local system. The properties `displ`, `scale`, and `twist` define the translation displacements, scale factors and rotation of the top (of each layer) with respect to the bottom of the extruded object. The last array dimension in the properties `displ`, `scale`, and `twist` can be omitted if the same value is desired for all layers.

When extruding work plane objects, the local system is defined as the local system of the work plane. When extruding faces, the local system is defined by the face with the smallest face number in the object that comes first in the geometry sequence. The local *z*-axis is parallel to the face normal and located at the center of the face. The local *x*-axis is defined by the tangent direction corresponding to the first parameter in the surface representation for the face.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

The cubic interpolated extrusion is no longer supported.

The following property is also supported:

TABLE 3-54: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`face`	`all` | `none`	`all`	Cross-sectional faces to delete, alias for `crossfaces`.
`keep`	`on` | `off`	`off`	Alias for `unite` property with opposite value.

EXAMPLE

Creation of a cylinder of height 1.3:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("wp1","WorkPlane");
g.feature("wp1").geom().create("c1","Circle");
g.run("wp1");
g.create("e1","Extrude");
g.feature("e1").set("distance",1.3);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('wp1','WorkPlane');
g.feature('wp1').geom.create('c1','Circle');
g.run('wp1');
g.create('e1','Extrude');
g.feature('e1').set('distance',1.3);
g.run;
```

SEE ALSO

`Revolve`, `WorkPlane`

Fillet

Create circular rounded corners (fillets) in 2D geometry objects. The Design Module supports 3D fillets.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Fillet");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Fillet")` to round corners in 2D.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("point")` to select which corners to round. The default selection is empty.

TABLE 3-55: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`point`	Selection		Vertices to fillet.
`radius`	double	0	Radius of fillet.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

EXAMPLE

Fillet a rectangle object:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("r1","Rectangle");
g.create("fil1","Fillet");
g.feature("fil1").selection("point").set("r1(1)",new int[]{1,2,3,4});
g.feature("fil1").set("radius",0.1);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('r1','Rectangle');
g.create('fil1','Fillet');
g.feature('fil1').selection('point').set('r1(1)',1:4);
g.feature('fil1').set('radius',0.1);
g.run;
```

DIAGNOSTICS

If `Fillet` does not succeed in creating a rounded corner according to the specified radius, the vertex is skipped. When a fillet intersects another edge, the function generates an error message.

SEE ALSO

`Chamfer`

Finalize

Form a union or assembly by combining all geometry objects.

SYNTAX

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

The Finalize feature (Form Union/Assembly) combines all available geometry objects in the sequence to form a single geometry object. In 2D and 3D you can modify this object by using virtual operations. The output of the last geometry feature is the *finalized geometry* used when meshing and when setting up physics. If the property `action` is set to `union`, and multiple geometry objects are present in the geometry sequence, the objects are combined into a single object with multiple domains corresponding to the input objects and overlaps between these. In a 1D and 2D axisymmetric geometry, the `union` action also removes the part of the geometry that falls in the region $r<0$.

Set the property `action` to `assembly` to keep multiple objects in the finalized geometry. Use this option when modeling physics that needs separate geometry objects, for example, when modeling mechanical contact.

TABLE 3-56: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`absrepairtol`	double	`1e-6`	Absolute repair tolerance.
`action`	`union` | `assembly`	`union`	Handling of multiple objects,
`createpairs`	`on` | `off`	`on`	Create pairs (used if `action=assembly`),
`imprint`	`on` | `off`	`off`	Create imprints (used if `action=assembly`),
`repairtol`	double	`1e-6`	Relative repair tolerance, relative to size of union of inputs.
`repairtoltype`	`auto` | `relative` | `absolute`	`auto`	Repair tolerance type: automatic, relative, or absolute.
`pairtype`	`identity` | `contact`	`identity`	Type of pairs to create,
`splitpairs`	`on` | `off`	`off`	Create one pair for each connected set of touching boundaries,

SEE ALSO

`Compose, Union, Intersection, Difference`

FromMesh

Create geometry (deformed configuration) from a (deformed) mesh.

SYNTAX

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

To create a geometry sequence from a deformed mesh, use the `createDeformedConfig` method on a solution dataset, see `Solution`. Such a geometry sequence contains a `FromMesh` feature. This feature has the following properties

TABLE 3-57: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`solnum`	nonnegative integer	Last solution	The index of the solution to use.

`model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()` updates the geometry based on the current value of the solution in the feature's corresponding solver sequence.

Helix

Create a solid, surface, or curve helix (coil) with a circular cross section in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Helix");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Helix")` to create a helix. The following properties are available:

TABLE 3-58: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
axialpitch	double	0.3	Axial pitch.
axis	double[]	{0,0,1}	Direction of the helix axis. Vector has length 3 if axistype is cartesian, and length 2 if axistype is spherical.
axistype	x | y | z | cartesian | spherical	z	Coordinate system used for axis. The value is synchronized with axis.
chirality	right | left	right	Chirality.
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
endcaps	paraaxis | perpaxis | perpspine	paraaxis	Direction of end caps.
grep	bezier | spline	spline	Geometry representation.
pos	double[]	{0,0,0}	Position of the object.
radialpitch	double	0	Radial pitch.
rmaj	double	1	Major radius.
rmin	double	0.1	Minor radius.
rot	double	0	Rotational angle about axis.
rtol	double	1e-4	Relative tolerance.
turns	double	3	Number of turns.
type	solid | surface	solid	Object type.
twistcomp	on | off	on	Twist compensation.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.

TABLE 3-58: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

EXAMPLE

The following sequence generates a surface helix and a solid helix:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
GeomFeature h = g.create("h1","Helix");
h.set("type","surface");
h.set("rmaj",2);
h.set("rmin",0.3);
h.set("axialpitch",1);

GeomFeature h2 = g.create("h2","Helix");
h2.set("rmaj",10);
h2.set("rmin",2);
h2.set("axialpitch",1);
h2.set("pos","0,0,-100");
h2.set("axis","1,1,1");
h2.set("rot",60);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
h = g.create('h1','Helix');
h.set('type','surface');
h.set('rmaj',2);
h.set('rmin',0.3);
h.set('axialpitch',1);

h2 = g.create('h2','Helix');
h2.set('rmaj',10);
h2.set('rmin',2);
h2.set('axialpitch',1);
h2.set('pos','0,0,-100');
h2.set('axis','1,1,1');
h2.set('rot',60);
g.run;
```

SEE ALSO

Torus, Sweep

Hexahedron

Create a solid or surface hexahedron bounded by bilinear faces.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Hexahedron");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Hexahedron")` to create a general hexahedron. The following properties are available:

TABLE 3-59: VALID PROPERTY/VALUE PAIRS FOR HEXAHEDRON

PROPERTY NAME	PROPERTY VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
p	double[3][8]	{{0,0,1,1,0,0,1,1}, {0,1,1,0,0,1,1,0}, {0,0,0,0,1,1,1,1}}	Corner coordinates.
type	solid | surface	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For a hexahedron approximately aligned to the coordinate planes, the points in p are ordered as follows:

- The first four points and the last four points projected down to the (x, y)-plane defines two negatively oriented quadrangles (quadrilaterals).
- The corresponding plane for the second quadrangle must lie above the plane of the first quadrant in the z direction.
- Generally oriented hexahedra have the points of p ordered in a similar way, except for a rigid transformation of the defining point set.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

EXAMPLE

The following command generates a solid hexahedron object:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("h1","Hexahedron");
```

```
g.feature("h1").set("p",new double[][]
      {{0,0.0,1,1.0,0,0,1.0,1},
       {0,0.8,1,0.0,0,1,1.2,0},
       {0,0.1,0,0.2,1,1,2.0,1}});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('h1','Hexahedron');
g.feature('h1').set('p',...
   [[0,0.0,1,1.0,0,0,1.0,1];...
   [0,0.8,1,0.0,0,1,1.2,0];...
   [0,0.1,0,0.2,1,1,2.0,1]]);
g.run;
```

SEE ALSO

`Block`, `Pyramid`, `Tetrahedron`

If, ElseIf, Else, EndIf

Construct an If statement, enabling or disabling features depending on conditions in terms of parameters.

SYNTAX

`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).create(`*`<ftag>`*`,`*`<type>`*`);`
`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).createAfter(`*`<ftag>`*`,`*`<type>`*`,`*`<postag>`*`);`
`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).feature(`*`<ftag>`*`).set(`*`property`*`,`*`<value>`*`);`
`model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).feature(`*`<ftag>`*`).get`*`Type`*`(`*`property`*`);`

DESCRIPTION

Use `model.component(`*`<ctag>`*`).geom(`*`<tag>`*`).create(`*`<ftag>`*`,`*`<type>`*`)` to add an If, ElseIf, Else, or EndIf feature after the current feature.

Use `model.component(`*`<ctag>`*`).geom(<tag>).feature().createAfter(`*`<ftag>`*`,`*`<type>`*`,`*`<postag>`*`)` to add an If, ElseIf, Else, or EndIf feature after the feature tagged *`<postag>`*.

The following property is available for If and ElseIf only:

TABLE 3-60: VALID PROPERTY

NAME	VALUE	DEFAULT	DESCRIPTION
condition	double	1	Logical condition in terms of parameters.

EXAMPLE

Build a block if `variant = 1`, else build a cone:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.param().set("variant", "1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("if1", "If");
g.feature("if1").set("condition", "variant==1");
g.create("blk1", "Block");
g.create("else1", "Else");
g.create("cone1", "Cone");
g.create("endif1", "EndIf");
g.run();
model.param().set("variant", "2");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.param.set('variant', '1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('if1', 'If');
g.feature('if1').set('condition', 'variant==1');
g.create('blk1', 'Block');
g.create('else1', 'Else');
g.create('cone1', 'Cone');
g.create('endif1', 'EndIf');
g.run;
model.param.set('variant', '2');
g.run;
```

IgnoreEdges

Ignore edges by removing selected edges that are isolated, adjacent to precisely two faces, or between two domains.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"IgnoreEdges");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"IgnoreEdges")` to ignore edges.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the edges to ignore. The default selection is empty.

The feature removes the selected edges that are isolated, that are adjacent to precisely two faces, or that are between two domains. If an edge is adjacent to two faces in 3D, the operations forms a composite face, if an edge is between two domains in 2D, the operation forms composite domain. The output object is a virtual geometry.

The following properties are available:

TABLE 3-61: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Edges to ignore.
`ignorevtx`	`on` | `off`	`on`	Ignore vertices on boundary.
`keepformesh`	`on` | `off`	`off`	Keep edges for mesh control.

Use `ignorevtx` to specify if the feature also removes the ignorable vertices on the boundary of each resulting composite face.

Use `keepformesh` to keep the ignored edges while meshing, to help you in constructing the mesh.

EXAMPLE

Create a sphere and ignore all edges and, implicitly, all vertices.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("sph1", "Sphere");
g.create("ige1", "IgnoreEdges");
g.feature("ige1").selection("input").set("fin(1)", 1,2,3,4,5,6,7,8,9,10,11,12);
g.run("ige1");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('sph1', 'Sphere');
g.create('ige1', 'IgnoreEdges');
g.feature('ige1').selection('input').set('fin(1)', 1:12);
g.run('ige1');
```

SEE ALSO

CompositeFaces, IgnoreFaces, IgnoreVertices, MeshControlEdges

IgnoreFaces

Ignore faces by removing the selected faces that are isolated or that are between two domains.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"IgnoreFaces");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"IgnoreFaces")` to ignore faces in 3D.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the faces to ignore. The default selection is empty.

The feature removes the selected faces that are isolated or that are between two domains. In the latter case, the operation forms a composite domain. The output object is a virtual geometry.

The following properties are available:

TABLE 3-62: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
input	Selection		Faces to ignore.
ignoreadj	on | off	on	Ignore edges and vertices on boundary.
keepformesh	on | off	off	Keep faces for mesh control.

Use `ignoreadj` to specify if the feature also removes the ignorable edges and vertices on the boundary of each resulting composite domain.

Use `keepformesh` to keep the ignored faces while meshing, to help you in constructing the mesh.

EXAMPLE

Ignore faces to form one composite domain. The operation also creates composite faces and composite edges.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("blk1", "Block");
g.create("cyl1", "Cylinder");
g.run("fin");
g.create("igf1", "IgnoreFaces");
g.feature("igf1").selection("input").set("fin", 6, 7, 10);
g.run("igf1");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component().create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('blk1', 'Block');
g.create('cyl1', 'Cylinder');
g.run('fin');
g.create('igf1', 'IgnoreFaces');
g.feature('igf1').selection('input').set('fin', [6, 7, 10]);
g.run('igf1');
```

SEE ALSO

`CompositeDomains`, `IgnoreEdges`, `IgnoreVertices`, `MeshControlFaces`

IgnoreVertices

Ignore vertices by removing the selected vertices that are isolated or that are adjacent to precisely two edges.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"IgnoreVertices");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"IgnoreVertices")` to ignore vertices.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the vertices to ignore. The default selection is empty.

The feature removes the selected vertices that are isolated or that are adjacent to precisely two edges. If a vertex is adjacent to two edges, the operation forms a composite edge. The output object is a virtual geometry.

The following properties are available:

TABLE 3-63: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Vertices to ignore.
`keepformesh`	on | off	`off`	Keep vertices for mesh control.

Use `keepformesh` to keep the ignored vertices while meshing, to help you in constructing the mesh.

EXAMPLE

Create an ellipse and ignore vertices 1 and 3, which gives you two remaining edges in the final geometry.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
model.mesh().create("mesh1", "geom1");
g.create("e1", "Ellipse");
g.run("fin");
g.create("igv1", "IgnoreVertices");
g.feature("igv1").selection("input").set("fin", 1, 3);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
```

```
g = model.component('comp1').geom.create('geom1', 2);
model.mesh.create('mesh1', 'geom1');
g.create('e1', 'Ellipse');
g.run('fin');
g.create('igv1', 'IgnoreVertices');
g.feature('igv1').selection('input').set('fin', 1, 3);
g.run;
```

SEE ALSO

CompositeEdges, IgnoreEdges, IgnoreFaces, MeshControlVertices

Import DXF

Import geometry objects from a DXF file to a 2D geometry.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Import");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Import")` to create a geometry import feature. When the property `filename` is set to a file recognized as a DXF CAD drawing, the property `type` is set to `dxf` and the following properties are available:

TABLE 3-64: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`alllayers`	String[]		Read-only property that returns all layers in the DXF file. Access it using `model.component(<ctag>).geom(<tag>).feature(<ftag>).getStringArray('alllayers');`
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`convert`	`solid` | `curve` | `off`	`solid`	Unite all objects in each layer, and convert it to a solid or curve object.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`filename`	String		File name.
`layers`	String[]	all layers	Layers to import.
`repairgeom`	`on` | `off`	`on`	Repair geometry.
`repairtol`	double	`1e-5`	Repair tolerance, relative to size of union of imported objects.
`type`	`dxf`		Type of import.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.

TABLE 3-64: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selindividual	on | off	off	Create selections of individual objects.
selindividualshow	all | dom | bnd | pnt | off	dom	Show selections of individual objects in physics, materials, and so on; in part instances; or in 3D if in a Work Plane's Plane Geometry, when selindividual is on.
contributeto	String	none	Tag of cumulative selection to contribute to.

The file specified by filename can be of any of the following formats:

TABLE 3-65: SUPPORTED FILE FORMATS

FILE FORMAT	FILE EXTENSIONS
DXF	.dxf

The imported objects are represented using the COMSOL geometry modeler.

The method

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()
```

imports the file again.

If selresult is set to on, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point), for use in the geometry sequence. To access the object selection, use model.geom(*<tag>*).selection(*<ftag>*), where *<tag>* is the geometry tag and *<ftag>* is the feature tag. To access the other selections, use model.geom(*<tag>*).selection(*<ftag>*.*<lvl>*), where *<tag>* is the geometry tag, *<ftag>* is the feature tag, and *<lvl>* is one of dom, bnd, edg, or pnt (edg is not available for DXF import in 2D). If, in addition, selresultshow is set to a value other than off, all or some of these selections appear for use outside the geometry sequence. To access these selections, use model.selection(*<tag>*_*<ftag>*_*<lvl>*), where *<tag>* is the geometry tag, *<ftag>* is the feature tag, and *<lvl>* is one of dom, bnd, edg, or pnt (edg is not available for DXF import in 2D).

If selindividual is set to on, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point) of each individual object, for use in the geometry sequence. To access the object selections, use model.geom(*<tag>*).selection(*<otag>*), where *<otag>* is a tag derived from the name of the imported object. For standard object names of the form *<ftag>*(*<n>*), where *<n>* is an object number, the corresponding *<otag>* is *<ftag>*_*<n>*. To access the other selections, use model.geom(*<tag>*).selection(*<otag>*_*<lvl>*), where *<otag>* is a tag derived from the name of the imported object. If, in addition, selindividualshow is set to a value other than off, all or some of these selections appear for use outside the geometry sequence. To access these selections, use model.selection(*<tag>*_*<otag>*_*<lvl>*), where *<otag>* is a tag derived from the name of the imported object. For standard object names of the form *<ftag>*(*<n>*), where *<n>* is an object number, the corresponding *<otag>* is *<ftag>*_*<n>*.

COMPATIBILITY

The following property is also supported:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
coercion	solid | face | curve | off	solid	Alias for convert. The value face is equivalent to solid.

Import Geometry Sequence

Import geometry objects from another geometry sequence.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Import");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Import")` to create a geometry import feature. Set the property `mesh` to the tag of a meshing sequence of another model component in the model.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`sequence`	String		Tag of other geometry sequence.
`type`	`sequence`		Type of import.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`selindividual`	`on` | `off`	`off`	Create selections of individual objects.
`selindividualshow`	`all` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, when `selindividual` is `on`, of individual objects in physics, materials, and so on; in part instances; or in 3D from a plane geometry.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

When building, the import feature takes all the existing objects in the specified sequence and imports them into the feature's sequence.

The method

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()
```

imports the sequence again. The imported objects are represented using the COMSOL Multiphysics geometry modeler or the CAD Import Module's geometry modeler (Parasolid).

If `selresult` is set to `on`, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point), for use in the geometry sequence. To access the object selection, use `model.geom(<tag>).selection(<ftag>)`, where `<tag>` is the geometry tag and `<ftag>` is the feature tag. To access the other selections, use `model.geom(<tag>).selection(<ftag>.<lvl>)`, where `<tag>` is the geometry tag, `<ftag>` is the feature tag, and `<lvl>` is one of `dom`, `bnd`, `edg`, or `pnt` (`edg` is not available for DXF import in 2D). If, in addition, `selresultshow` is set to a value other than `off`, all or some of these selections appear for use outside the geometry sequence. To access these selections, use `model.selection(<tag>_<ftag>_<lvl>)`, where `<tag>` is the geometry tag, `<ftag>` is the feature tag, and `<lvl>` is one of `dom`, `bnd`, `edg`, or `pnt` (`edg` is not available for DXF import in 2D).

If `selindividual` is set to `on`, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point) of each individual object, for use in the geometry sequence. To access the object selections, use

model.geom(<tag>).selection(<otag>), where <otag> is a tag derived from the name of the imported object. For standard object names of the form <ftag>(<n>), where <n> is an object number, the corresponding <otag> is <ftag>_<n>. To access the other selections, use model.geom(<tag>).selection(<otag>_<lvl>), where <otag> is a tag derived from the name of the imported object. If, in addition, selindividualshow is set to a value other than off, all or some of these selections appear for use outside the geometry sequence. To access these selections, use model.selection(<tag>_<otag>_<lvl>), where <otag> is a tag derived from the name of the imported object. For standard object names of the form <ftag>(<n>), where <n> is an object number, the corresponding <otag> is <ftag>_<n>.

Import Mesh Part or Meshing Sequence

Create a geometry object from an imported mesh.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Import");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

Use model.component(<ctag>).geom(<tag>).create(<ftag>,"Import") to create a geometry import feature. Set the property sequence to the tag of another geometry sequence in the model.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
mesh	String	none	Tag of meshing sequence or mesh part to import, or none to create a new mesh part from a mesh file.
meshfilename	String		Path to mesh file to import when mesh is set to none.
type	Mesh		Type of import.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
selindividual	on | off	off	Create selections of individual objects.
selindividualshow	all | dom | bnd | edg | pnt | off	dom	Show selections of individual objects in physics, materials, and so on, or in part instances, when selindividual is on.
contributeto	String	none	Tag of cumulative selection to contribute to.
defectremoval	double	1.0	Relative size factor for identification local defects (3D only).
simplifymesh	on | off	on	Boolean specifying if the original mesh should be simplified (3D only).
simplifytol	double	0.01	Relative simplification tolerance (3D only).

When building, the import feature takes the finalized mesh (if the sequence imports a mesh) or the current mesh (if it is not an imported mesh) of the specified sequence and constructs a corresponding geometry object.

The method

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()
```

imports the sequence again. The imported objects are represented using the COMSOL Multiphysics geometry modeler. The CAD Import Module's geometry modeler (Parasolid) does not support these types of geometries.

If `selresult` is set to `on`, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point), for use in the geometry sequence. To access the object selection, use `model.geom(<tag>).selection(<ftag>)`, where *<tag>* is the geometry tag and *<ftag>* is the feature tag. To access the other selections, use `model.geom(<tag>).selection(<ftag>.<lvl>)`, where *<tag>* is the geometry tag, *<ftag>* is the feature tag, and *<lvl>* is one of `dom`, `bnd`, `edg`, or `pnt`. If, in addition, `selresultshow` is set to a value other than `off`, all or some of these selections appear for use outside the geometry sequence. To access these selections, use `model.selection(<tag>_<ftag>_<lvl>)`, where *<tag>* is the geometry tag, *<ftag>* is the feature tag, and *<lvl>* is one of `dom`, `bnd`, `edg`, or `pnt`.

If `selindividual` is set to `on`, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point) of each individual object, for use in the geometry sequence. To access the object selections, use `model.geom(<tag>).selection(<otag>)`, where *<otag>* is a tag derived from the name of the imported object. For standard object names of the form *<ftag>*`(`*<n>*`)`, where *<n>* is an object number, the corresponding *<otag>* is *<ftag>*`_`*<n>*. To access the other selections, use `model.geom(<tag>).selection(<otag>_<lvl>)`, where *<otag>* is a tag derived from the name of the imported object. If, in addition, `selindividualshow` is set to a value other than `off`, all or some of these selections appear for use outside the geometry sequence. To access these selections, use `model.selection(<tag>_<otag>_<lvl>)`, where *<otag>* is a tag derived from the name of the imported object. For standard object names of the form *<ftag>*`(`*<n>*`)`, where *<n>* is an object number, the corresponding *<otag>* is *<ftag>*`_`*<n>*.

Import mphbin/mphtxt

Import geometry objects from a file using COMSOL Multiphysics geometry formats: binary or text.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Import");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Import")` to create a geometry import feature. When the property `filename` is set to a file recognized as an mphbin or mphtxt file, the property `type` is set to `native` and the following properties are available:

TABLE 3-66: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.

TABLE 3-66: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
filename	String		File name.
type	native		Type of import.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
selindividual	on | off	off	Create selections of individual objects.
selindividualshow	all | dom | bnd | edg | pnt | off	dom	Show selections, when selindividual is on, of individual objects in physics, materials, and so on; in part instances; or in 3D from a plane geometry.
contributeto	String	none	Tag of cumulative selection to contribute to.
includevirtual	boolean	true	Include virtual operations when importing the geometry. Not available in 1D and in work planes, where virtual operations are always excluded.

The file specified by filename can be of any of the following formats:

TABLE 3-67: SUPPORTED FILE FORMATS

FILE FORMAT	FILE EXTENSIONS
COMSOL Multiphysics Binary	.mphbin
COMSOL Multiphysics Text	.mphtxt

The imported objects are represented using COMSOL's geometry kernel or the CAD Import Module's geometry kernel (Parasolid).

The method

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()
```

imports the file again.

If selresult is set to on, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point), for use in the geometry sequence. To access the object selection, use model.geom(<tag>).selection(<ftag>), where <tag> is the geometry tag and <ftag> is the feature tag. To access the other selections, use model.geom(<tag>).selection(<ftag>.<lvl>), where <tag> is the geometry tag, <ftag> is the feature tag, and <lvl> is one of dom, bnd, edg, or pnt (edg is not available for DXF import in 2D). If, in addition, selresultshow is set to a value other than off, all or some of these selections appear for use outside the geometry sequence. To access these selections, use model.selection(<tag>_<ftag>_<lvl>), where <tag> is the geometry tag, <ftag> is the feature tag, and <lvl> is one of dom, bnd, edg, or pnt (edg is not available for DXF import in 2D).

If selindividual is set to on, a selection is created for all resulting entities of each type (object, domain, boundary, edge, and point) of each individual object, for use in the geometry sequence. To access the object selections, use model.geom(<tag>).selection(<otag>), where <otag> is a tag derived from the name of the imported object. For standard object names of the form <ftag>(<n>), where <n> is an object number, the corresponding <otag> is <ftag>_<n>. To access the other selections, use model.geom(<tag>).selection(<otag>_<lvl>), where <otag> is a tag derived from the name of the imported object. If, in addition, selindividualshow is set to a value other than off, all or some of these selections appear for use outside the geometry sequence. To access these selections, use model.selection(<tag>_<otag>_<lvl>), where <otag> is a tag derived from the name of the

imported object. For standard object names of the form `<ftag>(<n>)`, where `<n>` is an object number, the corresponding `<otag>` is `<ftag>_<n>`.

Interpolation Curve

Create a curve interpolating or approximating a sequence of points in 2D or 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"InterpolationCurve");
model.component(<ctag>).geom(<tag>).feature(<ftag>).importToTable();
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

To create an interpolation curve use `model.component(<ctag>).geom(<tag>).create(<ftag>,"InterpolationCurve")` The following properties are available:

TABLE 3-68: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`endcond`	`zerocurv` | `tangent`	`zerocurv`	Condition at endpoint: zero curvature or a tangent condition.
`endtang`	double[sdim]	`{1,0}` or `{1,0,0}`	Tangent direction at endpoint (if `endcond` is `tangent`).
`filename`	String		If source is file, the file that contains the data.
`rtol`	double	0	Maximum relative error. 0 implies interpolation.
`source`	`table` | `file` | `vectors`	`table`	Whether data is specified as vectors, a table, or read from a file.
`struct`	`sectionwise` | `spreadsheet`	`spreadsheet`	The data format if source is file.
`table`	double[][]		Data points, size N*sdim.
`type`	`open` | `closed` | `solid`	`open`	Type of curve.
`x`	double[]	`{}`	x-coordinates for data points.
`y`	double[]	`{}`	y-coordinates for data points.
`z`	double[]	`{}`	z-coordinates for data points.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom` in 2D; `edg` in 3D.	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`startcond`	`zerocurv` | `tangent`	`zerocurv`	Condition at starting point: zero curvature or a tangent condition.

TABLE 3-68: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
starttang	double[sdim]	{1,0} or {1,0,0}	Tangent direction at starting point (if startcond is tangent).
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from (in 3D only).
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system (in 3D only). The default, xyplane, is the global Cartesian coordinate system.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).importToTable()` to read data from the file defined by the `filename` property and store the data in the `table` property. The `source` property is also changed to `table`.

When building the feature, if the start condition or end condition is zero curvature, the corresponding (currently inactive) tangent direction property should be set to the tangent vector of the resulting curve.

If `source` is `file`, the interpolation curve is not automatically rebuilt when the data in the file changes. Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()` to rebuild the interpolation curve after such a change.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

EXAMPLE

The following commands create a curve interpolating four points in 2D:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
g.create("ic1","InterpolationCurve");
g.feature("ic1").set("table",new double[][]{{0,0}, {1,0}, {1,1}, {0,1}});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
g.create('ic1','InterpolationCurve');
g.feature('ic1').set('table',[[0,0]; [1,0]; [1,1]; [0,1]]);
g.run;
```

SEE ALSO

BezierPolygon

Interval

Create one or several connected intervals in 1D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Interval");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Interval")` to create one or more intervals. The following properties are available:

TABLE 3-69: VALID PROPERTY/VALUE PAIRS FOR INTERVAL

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`coord`	double[]	`{0,1}`	Coordinates in table (used when `coordsource` is set to `table`).
`coordsource`	`table` | `vector`	`table`	Data source for coordinates: a table or a vector of coordinates (used when `specify` is set to `coord`).
`coordvec`	double[]	`{0,1}`	Coordinates in table (used when `coordsource` is set to `table`).
`left`	double	`0`	Left endpoint (used when `specify` is set to `len`).
`lensource`	`table` | `vector`	`table`	Data source for interval lengths: a table or a vector of lengths (used when `specify` is set to `len`).
`len`	double[]	`{1}`	Lengths in table (used when `lensource` is set to `table`).
`lensource`	`table` | `vector`	`table`	Data source for interval lengths: a table or a vector of lengths (used when `specify` is set to `len`).
`lenvec`	double[]	`{1}`	Lengths in vector field (used when `lensource` is set to `table`).
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `off`	`dom`	Show selections, if `selresult` is `on`, of resulting objects in physics, materials, and so on, or in part instances. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`specify`	`coord` | `len`	`coord`	Specify coordinates or interval lengths.

To specify one interval, set the properties `p1` and `p2`. Then, `intervals` is automatically set to `one`.

To specify a sequence of connected intervals, set the property `p`. Then, `intervals` is automatically set to `many`.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"solid1")` creates an interval.

The properties above are new in 5.4; there is backward compatibility with respect to the previous properties as follows:

- The property `intervals` set to `one` corresponds to `coordsource` set to `table`.
- The property `intervals` set to `many` corresponds to `coordsource` set to `vector`.
- Setting or getting the value of the property `p1` operates on the first element of the `coord` array.
- Setting or getting the value of the property `p2` operates on the last (or second) element of the `coord` array.
- Setting or getting the value of the property `p` operates on the `coordvec` array.

EXAMPLE

The following commands create a solid consisting of two intervals:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",1);
```

```
g.create("i1","Interval");
g.feature("i1").set("p","0 1 3");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',1);
g.create('i1','Interval');
g.feature('i1').set('p','0 1 3');
g.run;
```

SEE ALSO

`BezierPolygon`

LineSegment

Create line segments in 2D and 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"LineSegment");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"LineSegment")` to create a line segment. The following properties are available:

TABLE 3-70: VALID PROPERTY/VALUE PAIRS FOR LINESEGMENT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`specify1`	`vertex` | `coord`	`vertex`	Type of starting point specification.
`specify2`	`vertex` | `coord`	`vertex`	Type of endpoint specification.
`coord1`	double[]	zero vector	Coordinates for starting point (with `specify1` set to `coord`).
`coord2`	double[]	zero vector	Coordinates for endpoint (with `specify2` set to `coord`).
`vertex1`	Selection	0	Starting point (with `specify1` set to `vertex`).
`p2`	Selection	1	Endpoint (with `specify2` set to `vertex`).
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `off`	`dom`	Show selections, if `selresult` is `on`, of resulting objects in physics, materials, and so on, or in part instances. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.

TABLE 3-70: VALID PROPERTY/VALUE PAIRS FOR LINESEGMENT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`workplanesrc`	`this` | Part Instance feature	`this`	Part Instance feature to take the work plane from (in 3D and for coordinates only).
`workplane`	`xyplane` | Work plane feature	`xyplane`	Work Plane feature that defines the coordinate system (in 3D and for coordinates only). The default, `xyplane`, is the global Cartesian coordinate system.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

EXAMPLE

The following commands create a block in 3D and a line segment from a vertex in that block to a point with the coordinates (0, 1, 2):

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("blk1", "Block");
g.create("ls1", "LineSegment");
g.feature("ls1").set("specify1", "vertex");
g.feature("ls1").set("specify2", "coord");
g.feature("ls1").selection("vertex1").set("blk1(1)", new int[]{1});
g.feature("ls1").set("coord2", new double[]{0, 1, 2});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('blk1', 'Block');
g.create('ls1', 'LineSegment');
g.feature('ls1').set('specify1', 'vertex');
g.feature('ls1').set('specify2', 'coord');
g.feature('ls1').selection('vertex1').set('blk1(1)', 1);
g.feature('ls1').set('coord2', [0, 1, 2]);
g.run;
```

SEE ALSO

`BezierPolygon`

MergeEdges

Merge edges adjacent to faces.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"MergeEdges");
model.component(<ctag>).geom(<tag>).feature().selection(property);
model.component(<ctag>).geom(<tag>).feature().set(property,<value>);
model.component(<ctag>).geom(<tag>).feature().getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"MergeEdges")` to merge edges adjacent to face.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("keepedg")` to select the edges to keep. The default selection is empty.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("removeedg")` to select the edges to remove. The default selection is empty.

The feature merges the edges by collapsing the face between the edges and reconnecting the faces adjacent to the removed edges to the resulting merged edges.

The output object is a virtual geometry.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
keepedg	Selection		Edges to keep.
removeedg	Selection		Edges to remove.

SEE ALSO

CollapseFaces, CollapseFaceRegions

MergeVertices

Merge two vertices.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"MergeVertices");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"MergeVertices")` to merge two vertices.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("keepvtx")` to select the vertex to keep. The default selection is empty.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("removevtx")` to select the vertex to remove. The default selection is empty.

The feature merges the two vertices by collapsing the edge between the vertices and reconnecting the edges adjacent to the removed vertex to the resulting merged vertex.

The output object is a virtual geometry.

The following properties are available:

TABLE 3-71: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
keepvtx	Selection		Vertex to keep.
removevtx	Selection		Vertex to remove.

SEE ALSO

CollapseEdges

MeshControlDomains

Define mesh control domains.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlDomains");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlDomains")` to define mesh control domains.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the domains to include. The default selection is empty.

The feature creates a composite domain by removing all faces (in 3D) or edges (in 2D) between the selected domains and adjacent domains. The removed entities are kept for mesh control.

The following property is available:

TABLE 3-72: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Edges to ignore.

SEE ALSO

`MeshControlFaces`, `MeshControlEdges`

MeshControlEdges

Define mesh control edges.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlEdges");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlEdges")` to define mesh control edges.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the edges to include. The default selection is empty.

The feature removes the selected edges that are isolated, that are adjacent to precisely two faces (in 3D), or that are between two domains (in 2D). The edges are kept for mesh control.

The following properties are available:

TABLE 3-73: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`input`	Selection		Edges to ignore.
`includevtx`	`on` | `off`	`on`	Include start and end vertices.

Use `includevtx` to specify if the feature also removes the ignorable start and end vertices of the edge.

SEE ALSO

IgnoreEdges, MeshControlDomains, MeshControlFaces, MeshControlVertices

MeshControlFaces

Define mesh control faces.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlFaces");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlFaces")` to define mesh control faces in 3D.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the faces to include. The default selection is empty.

The feature removes the selected faces that are isolated or that are between two domains. The faces are kept for mesh control.

The following properties are available:

TABLE 3-74: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
input	Selection		Faces to include.
includeadj	on | off	on	Include edges and vertices on boundary.

Use `includeadj` to specify if the feature also includes the ignorable edges and vertices on the boundary of each resulting composite domain.

SEE ALSO

IgnoreFaces, MeshControlDomains, MeshControlEdges, MeshControlVertices

MeshControlVertices

Define mesh control vertices.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlVertices");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"MeshControlVertices")` to define mesh control vertices.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the vertices to include. The default selection is empty.

The feature removes the selected vertices that are isolated or that are adjacent to precisely two edges. The vertices are kept for mesh control.

The following properties are available:

TABLE 3-75: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
input	Selection		Vertices to include.

SEE ALSO

IgnoreVertices, MeshControlFaces, MeshControlEdges

Mirror

Reflect (mirror) objects in a plane (3D), a line (2D), or a point (1D).

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Mirror");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Mirror")` to mirror geometry objects.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the objects to mirror. The default selection is empty.

The following properties are available:

TABLE 3-76: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active. 2D and 3D only.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom. 2D and 3D only.
input	Selection		Objects to reflect.
keep	on | off	off	Keep input objects.
pos	double[]	0	A point to be fixed during reflection.
axis	double[]	{0 0 1} (3D) {1 0} (2D) {1} (1D)	Vector in the direction to reflect.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.

In 3D, the input objects are reflected in the plane through pos with normal vector axis. In 2D, the input objects are reflected in the line through pos with normal vector axis. In 1D, the input objects are reflected in the point pos.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

The property `out` is no longer available.

EXAMPLE

A 2D example, mirroring a rectangle:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("r1","Rectangle");
g.create("m1","Mirror");
g.feature("m1").selection("input").set("r1");
g.feature("m1").set("pos","2 2");
g.feature("m1").set("axis","1 1");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('r1','Rectangle');
g.create('m1','Mirror');
g.feature('m1').selection('input').set('r1');
g.feature('m1').set('pos','2 2');
g.feature('m1').set('axis','1 1');
g.run;
```

A 3D example, mirroring a block:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("blk1","Block");
g.create("m1","Mirror");
g.feature("m1").selection("input").set("blk1");
g.feature("m1").set("pos","2 2 2");
g.feature("m1").set("axis","1 1 1");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('blk1','Block');
g.create('m1','Mirror');
g.feature('m1').selection('input').set('blk1');
g.feature('m1').set('pos','2 2 2');
g.feature('m1').set('axis','1 1 1');
g.run;
```

SEE ALSO

`Move, Copy`, `Rotate`, `Scale`

Move, Copy

Move or copy geometry objects by translation.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Move");
model.component(<ctag>).geom(<tag>).create(<ftag>,"Copy");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Move")` to move geometry objects.

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Copy")` to move a copy of geometry objects.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the objects to move or copy. The default selection is empty.

The following properties are available:

TABLE 3-77: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`displ`	double[] | double[][]	0	Displacement vector(s).
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, of resulting objects in physics, materials, and so on, or in part instances. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`workplanesrc`	`this` | Part Instance feature	`this`	Part Instance feature to take the work plane from (in 3D only).
`workplane`	`xyplane` | Work plane feature	`xyplane`	Work Plane feature that defines the coordinate system (in 3D only). The default, `xyplane`, is the global Cartesian coordinate system.

If `displ` is a one-dimensional array, a single copy of each input object is created using the translation vector `displ`. If `displ` is a two-dimensional array, several copies can be created, where the `n`th copy has translation `displ[i][n]` in the `i`th coordinate.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

EXAMPLE

The sequence below moves a circle from the origin to (2, 3):

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("c1","Circle");
g.create("m1","Move");
g.feature("m1").selection("input").set("c1");
g.feature("m1").set("displ", new double[][]{{2},{3}});
```

```
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('c1','Circle');
g.create('m1','Move');
g.feature('m1').selection('input').set('c1');
g.feature('m1').set('displ', [2,3]);
g.run;
```

SEE ALSO

`Array`, `Mirror`, `Rotate`, `Scale`

ParameterCheck

Check the values of parameters.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"ParameterCheck");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
```

DESCRIPTION

User `model.component(<ctag>).geom(<tag>).create(<ftag>,"ParameterCheck")` to check parameter values and issue an error if the check condition is fulfilled (being nonzero); for example, the condition `r>30[mm]` results in an error is the value of parameter `r` is larger than 30 mm. The following properties are available:

TABLE 3-78: VALID PROPERTY/VALUE PAIRS FOR PARAMETERCHECK

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`condition`	double	1	The condition that checks some value of the parameters. The error appears if the value of the condition is nonzero.
`message`	string	empty string	The error message that is displayed if condition is fulfilled.

ParametricCurve

Create a parametric curve defined by coordinate expressions in 2D or 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"ParametricCurve");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"ParametericCurve")` to create a parametric curve. Self-intersecting curves are not supported, except the case of a closed curve (that is, when the starting point and endpoint coincide). The following properties are available:

TABLE 3-79: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`axis`	double[]	`{0,0,1}`	Direction of the z-axis of the local coordinate system. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`coord`	`String[2]` | `String[3]`	empty	Coordinates of parametric curve as function of parameter.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`maxknots`	int	1000	Maximum number of knots.
`parname`	String	s	Parameter name.
`parmax`	double	1	Maximum parameter value.
`parmin`	double	0	Minimum parameter value.
`pos`	double[]	`{0,0,0}`	Position of the object.
`reparameterize`	`true` | `false`	`false`	Reparameterize the curve using the arc length.
`rot`	double	0	Rotational angle about `axis`.
`rtol`	double	`1e-6`	Relative tolerance.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`bnd` in 2D; `edg` in 3D	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`workplanesrc`	`this` | Part Instance feature	`this`	Part Instance feature to take the work plane from (in 3D only).
`workplane`	`xyplane` | Work plane feature	`xyplane`	Work Plane feature that defines the coordinate system (in 3D only). The default, `xyplane`, is the global Cartesian coordinate system.

The expressions in `coord` can contain functions defined in the model. If the definition of such a function is changed, the parametric curve is not automatically rebuilt. Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()` to rebuild the parametric curve after such a change.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

EXAMPLE

The following commands create a parametric curve in 3D with the shape of a helix:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("pc1","ParametricCurve");
g.feature("pc1").set("parmax","2*pi");
g.feature("pc1").set("coord",new String[]{"cos(s)","sin(s)","s*0.2"});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('pc1','ParametricCurve');
g.feature('pc1').set('parmax','2*pi');
g.feature('pc1').set('coord',{'cos(s)','sin(s)','s*0.2'});
g.run;
```

SEE ALSO

BezierPolygon, ParametricSurface

ParametricSurface

Create a parametric surface defined by coordinate expressions in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"ParametricSurface");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"ParametericSurface")` to create a parametric surface. Self-intersecting surfaces are not supported. The following properties are available:

TABLE 3-80: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
axis	double[]	{0,0,1}	Direction of the z-axis of the local coordinate system. Vector has length 3 if axistype is cartesian, and length 2 if axistype is spherical.
axistype	x | y | z | cartesian | spherical	z	Coordinate system used for axis. The value is synchronized with axis.
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
coord	String[3]	empty	Coordinates of parametric surface as function of parameters.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.

TABLE 3-80: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
maxknots	int	10	Maximum number of knots in each parameter coordinate.
parname1	String	s1	First parameter name.
parname2	String	s2	Second parameter name.
parmax1	double	1	Maximum value of first parameter.
parmax2	double	1	Maximum value of second parameter.
parmin1	double	0	Minimum value of first parameter.
parmin2	double	0	Minimum value of second parameter.
pos	double[]	{0,0,0}	Position of the object.
rot	double	0	Rotational angle about axis.
rtol	double	1e-6	Relative tolerance.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	bnd	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

The expressions in coord can contain functions defined in the model. If the definition of such a function is changed, the parametric surface is not automatically rebuilt. Use model.component(*<ctag>*).geom(*<tag>*).feature(*<ftag>*).importData() to rebuild the parametric surface after such a change.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

EXAMPLE

The following commands create a parametric surface in 3D with the shape of a twisted rectangle:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("ps1","ParametricSurface");
g.feature("ps1").set("parmin1","-1");
g.feature("ps1").set("parmax2","pi");
g.feature("ps1").set("coord",new String[]{"s1*cos(s2)","s1*sin(s2)","s2"});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('ps1','ParametricSurface');
g.feature('ps1').set('parmin1','-1');
g.feature('ps1').set('parmax2','pi');
g.feature('ps1').set('coord',{'s1*cos(s2)','s1*sin(s2)','s2'});
g.run;
```

SEE ALSO

ParametricCurve

PartInstance

Create an instance of a geometry part.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"PartInstance");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).geom().geomSequenceMethod;
```

DESCRIPTION

This feature creates an instance of a geometry part with new values of its input parameters. Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).geom()` to access its local copy of the part.

The following properties are available:

TABLE 3-81: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`part`	String		Tag of part to call, or `local` to use a local part.
`inputname`	String[]		Names of the input parameters (read-only).
`inputexpr`	String[]		Expressions for the input parameters.

The default for `part` is the first part in `model.geom()`, or `local` if there is none.

In 3D, the following additional properties are available to control the positioning of the output objects:

TABLE 3-82: VALID PROPERTY/VALUE PAIRS IN 3D

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`workplanepart`	String	`xyplane`	Tag of work plane in the geometry part, or `xyplane`.
`workplanesrc`	String	`this`	Tag of PartInstance feature to take work plane from, or `this` to take it from this sequence.
`workplane`	String	`xyplane`	Tag of work plane to match, or `xyplane`.
`displ`	double[3]	`{0,0,0}`	Displacement vector.
`axistype`	`x` | `y` | `z` | `Cartesian` | `spherical`	`z`	Type of rotation axis specification.
`axis`	double[]	`{0,0,1}`	Direction of rotation axis. Vector has length 3 if axistype is Cartesian and length 2 if axistype is spherical.
`rot`	double	0	Rotation angle.

In 2D, the following additional properties are available to control the positioning of the output objects:

TABLE 3-83: VALID PROPERTY/VALUE PAIRS IN 2D

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`displ`	double[2]	`{0,0}`	Displacement vector.
`rot`	double	0	Rotation angle.

For each geometric entity level (object, domain, boundary, edge, and point) that exists in the geometry, there is in addition the following properties related to the output selections for that level:

TABLE 3-84: VALID PROPERTY/VALUE PAIRS FOR OUTPUT SELECTIONS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`selkeepnoncontr`	`on` | `off`	`on`	Keep all noncontributing selections.
`seltag`*`level`*	String[]		Tags of selections (read-only).
`selname`*`level`*	String[]		Names of selections (read-only).
`selcontributeto`*`level`*	String[]	all `none`	Tags of cumulative selections to contribute to, or `none` to not contribute.
`selkeep`*`level`*	String[] with on/off values	all `off`	Keep selection from part (only used when `selkeepnoncontr` is `off`).
`selshow`*`level`*	String[] with on/off values	all `on`	Show selection in physics, materials, and so on; in part instances; or in 3D from a plane geometry.

where *`level`* is `obj`, `dom`, `bnd`, `edg`, or `pnt` for geometry objects, domains, boundaries, edges, and points, respectively.

COMPATIBILITY

In version 5.1, the following properties were deprecated and replaced:

TABLE 3-85: DEPRECATED PROPERTIES

PREVIOUS NAME	NEW NAME IN 5.1
`arg`	`inputname`
`argexpr`	`inputexpr`
`argvalue`	`inputvalue`
`argdescr`	`inputdescr`
`subsequence`	`part`
`workplanesub`	`workplanepart`

EXAMPLE

Create a geometry part that makes a torus of revolution angle a, where a is an argument (default value: 90 degrees). Then add work planes for the two planar face to make it easy to position the result:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
GeomSequence p = model.geom().create("part1", "Part", 3);
p.inputParam().set("a", 90);
p.create("tor1", "Torus");
p.feature("tor1").set("angle", "a");
p.run("tor1");
p.create("wp1", "WorkPlane");
p.feature("wp1").set("planetype", "faceparallel");
p.feature("wp1").selection("face").set("tor1", new int[]{1});
p.feature("wp1").set("reverse", "on");
p.create("wp2", "WorkPlane");
p.feature("wp2").set("planetype", "faceparallel");
p.feature("wp2").selection("face").set("tor1", new int[]{6});
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
p = model.geom.create('part1', 'Part', 3);
p.inputParam.set('a', 90);
p.create('tor1', 'Torus');
p.feature('tor1').set('angle', 'a');
p.run('tor1');
```

```
p.create('wp1', 'WorkPlane');
p.feature('wp1').set('planetype', 'faceparallel');
p.feature('wp1').selection('face').set('tor1', 1);
p.feature('wp1').set('reverse', 'on');
p.create('wp2', 'WorkPlane');
p.feature('wp2').set('planetype', 'faceparallel');
p.feature('wp2').selection('face').set('tor1', 6);
```

Create two part instances of this geometry part. The first has $\alpha = 90$ (the default value), and the second has $\alpha = 120$. The objects are positioned so that the two circular faces match, with a rotation angle of 50 degrees.

Code for Use with Java

```
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("pi1", "PartInstance");
g.create("pi2", "PartInstance");
g.feature("pi2").setIndex("inputexpr", 120, 0);
g.feature("pi2").set("workplanepart", "wp1");
g.feature("pi2").set("workplanesrc", "pi1");
g.feature("pi2").set("workplane", "wp2");
g.feature("pi2").set("rot", 50);
g.run("pi2");
```

Code for Use with MATLAB

```
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('pi1', 'PartInstance');
g.create('pi2', 'PartInstance');
g.feature('pi2').setIndex('inputexpr', 120, 0);
g.feature('pi2').set('workplanepart', 'wp1');
g.feature('pi2').set('workplanesrc', 'pi1');
g.feature('pi2').set('workplane', 'wp2');
g.feature('pi2').set('rot', 50);
g.run('pi2');
```

SEE ALSO

`If, ElseIf, Else, EndIf`

Partition

Partition 2D and 3D geometry objects using tool objects or a work plane.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Partition");
model.component(<ctag>).geom(<tag>).feature().selection(property);
model.component(<ctag>).geom(<tag>).feature().set(property,<value>);
model.component(<ctag>).geom(<tag>).feature().getType(property);
```

DESCRIPTION

The Partition Boolean operation partitions each input object using a set of tool objects or (in 3D only) a work plane. That is, within the input object new boundaries, edges, and vertices are created that come from the tools or the work plane.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
absrepairtol	double	...geom(<tag>). absRepairTol()	Absolute repair tolerance.
contributeto	String	none	Tag of cumulative selection to contribute to.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
input	Selection	empty	Objects to partition.
keepinput	on | off	off	Keep input objects.
keeptool	on | off	off	Keep tool objects.
partitionwith	objects | workplane	objects	Partition with tool objects or a work plane.
repairtol	double	...geom(<tag>).repairTol()	Relative repair tolerance, relative to size of union of inputs.
repairtoltype	auto | relative | absolute	...geom(<tag>).repairTolType()	Repair tolerance type: automatic, relative, or absolute.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
tool	Selection	empty	Tool objects.
workplane	String		Work plane to partition with.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

The keep property has been deprecated in version 5.3a. Instead, use the new properties keepinput and keeptool. If you set keep to on, both keepinput and keeptool. If you get the value of keep, it is on if keepinput and keeptool are on.

EXAMPLE

Create an interior boundary in a cylinder by partitioning it with an oblique work plane:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("cyl1", "Cylinder");
g.feature("cyl1").set("h", 10);
g.create("wp1", "WorkPlane");
g.feature("wp1").set("planetype", "general");
g.feature("wp1").setIndex("genpoints", 4, 0, 2);
g.feature("wp1").setIndex("genpoints", 5, 1, 2);
g.feature("wp1").setIndex("genpoints", 5, 2, 2);
g.create("par1", "Partition");
g.feature("par1").selection("input").set("cyl1");
g.feature("par1").set("partitionwith", "workplane");
g.run("par1");
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom', 3);
g.create('cyl1', 'Cylinder');
g.feature('cyl1').set('h', 10);
g.create('wp1', 'WorkPlane');
g.feature('wp1').set('planetype', 'general');
g.feature('wp1').setIndex('genpoints', 4, 0, 2);
g.feature('wp1').setIndex('genpoints', 5, 1, 2);
g.feature('wp1').setIndex('genpoints', 5, 2, 2);
```

```
g.create('par1', 'Partition');
g.feature('par1').selection('input').set('cyl1');
g.feature('par1').set('partitionwith', 'workplane');
g.run('par1');
```

SEE ALSO

`Compose, Union, Intersection, Difference`, `WorkPlane`, `PartitionDomains`, `PartitionEdges`

PartitionDomains

Partition domains in 2D or 3D geometries with curves and surfaces defined in various ways.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"PartitionDomains");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature().set(property,<value>);
model.component(<ctag>).geom(<tag>).feature().getType(property);
```

DESCRIPTION

The Partition Domains operation partitions selected domains using curves or surfaces defined by vertices, edges, faces, work planes, or objects.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`absrepairtol`	double	`...geom(<tag>).absRepairTol()`	Absolute repair tolerance.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`domain`	Selection		Selection of domains to partition.
`edge`	Selection		Edges that define the partitioning curves (2D).
`extendededge`	Selection		Edges whose underlying curves define the partitioning curves (2D).
`extendedface`	Selection		Faces whose underlying surfaces define the partitioning surfaces (3D).
`face`	Selection		Faces that define the partitioning surfaces (3D).
`keepobject`	`on` | `off`	`on`	Keep objects used to partition the geometry with, when `partitionwith` is set to `objects`.
`object`	Selection		Geometry objects used to partition domains.
`partitionwith`	`linesegments` | `lines` | `edges` | `extendededges` | `objects` in 2D `workplane` | `faces` | `extendedfaces` | `objects` in 3D	`linesegments` in 2D, `workplane` in 3D	Method for partitioning the domains. The `objects` option is not available for partitioning domains after a form union/assembly operation.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
repairtol	double	...geom(<tag>).repairTol()	Relative repair tolerance, relative to size of union of inputs.
repairtoltype	auto | relative | absolute	...geom(<tag>).repairTolType()	Repair tolerance type: automatic, relative, or absolute.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
vertexsegment	Selection		Vertices that define the line segments (2D).
vertexline	Selection		Vertices that define the lines (2D).
workplane	String		Work plane to partition with (3D).

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

SEE ALSO

Partition, PartitionEdges, PartitionFaces

PartitionEdges

Partition edges in 2D or 3D geometries at some positions along the edges.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"PartitionEdges");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature().set(property,<value>);
model.component(<ctag>).geom(<tag>).feature().getType(property);
```

DESCRIPTION

The Partition Edges operation partitions selected edges at specified locations. You can specify the positions using parameters based on the arc length or existing vertices whose orthogonal projections on the edges specify the positions.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
edge	Selection		Selection of edges to partition.
position	arclength | projection	arclength	Specifies the position along the selected edges.
param	double[]		Relative arc length parameters.
vertexproj	Selection		Vertices to project on the selected edges.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

SEE ALSO

Partition, PartitionDomains, PartitionFaces

PartitionFaces

Partition faces in 3D geometries at some positions on the faces.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"PartitionFaces");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature().set(property,<value>);
model.component(<ctag>).geom(<tag>).feature().getType(property);
```

DESCRIPTION

The Partition Faces operation partitions selected faces at specified locations. You can specify the positions using vertices to defined curve segments, adjacent edges that are extended, or a work plane.

The following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
extendededge	Selection		Planar edges defining partitioning lines, circles, or planes.
face	Selection		Faces to partition.
partitionwith	workplane | curvesegments | extendededges	curvesegments	Method for partitioning the faces.
vertexsegment	Selection		Vertices that define the curve segments.
workplane	String		Work plane to partition with.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

SEE ALSO

Partition, PartitionDomains, PartitionEdges

Point

Create a point object in 1D, 2D, or 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Point");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Point")` to create one or more points. The following property is available:

TABLE 3-86: VALID PROPERTY/VALUE PAIR

PROPERTY NAME	PROPERTY VALUE	DEFAULT	DESCRIPTION
p	double[] | double[][]	0	Coordinates.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | bnd | pnt | off	pnt in 2D and 3D; bnd in 1D	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from (in 3D only).
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system (in 3D only). The default, xyplane, is the global Cartesian coordinate system.

If p is a one-dimensional array, a single point with these coordinates is constructed. If p is a two-dimensional array, a point object containing several points is constructed, where the nth point has ith coordinate p[i][n].

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

The following aliases work in 1D, 2D, and 3D, respectively:

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"point1");
model.component(<ctag>).geom(<tag>).create(<ftag>,"point2");
model.component(<ctag>).geom(<tag>).create(<ftag>,"point3");
```

EXAMPLE

The following commands generate a point at (1, 2) in a 2D geometry:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("p1","Point");
g.feature("p1").set("p",new double[][]{{1},{2}});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('p1','Point');
g.feature('p1').set('p',[1,2]);
g.run;
```

Polygon

Create curve or solid polygon consisting of line segments in 2D or 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Polygon");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Polygon")` to create a polygon or a line segment. The following properties are available

TABLE 3-87: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`filename`	String		If `source` is `file`, the file that contains the vertex coordinates.
`source`	`table` | `file` | `vectors`	`vectors`	Whether vertex coordinates are specified as vectors, a table, or read from a file.
`table`	double[][]		The vertex coordinates when `source` is `table`, size N*sdim.
`type`	`solid` | `open` | `closed`	`solid` (2D) `open` (3D)	Object type. `solid` is not available in 3D.
`x`	double[]	{}	x-coordinates for vertices.
`y`	double[]	{}	y-coordinates for vertices.
`z`	double[]	{}	z-coordinates for vertices.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom` in 2D; `edg` in 3D.	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`workplanesrc`	`this` | Part Instance feature	`this`	Part Instance feature to take the work plane from (in 3D only).
`workplane`	`xyplane` | Work plane feature	`xyplane`	Work Plane feature that defines the coordinate system (in 3D only). The default, `xyplane`, is the global Cartesian coordinate system.

If `type` is `open` or `closed`, a curve consisting of line segments is constructed. If `type` is `solid`, the solid enclosed by such a closed polygon is constructed. If `type` is `closed` or `solid`, but the first and last control points are different, an extra segment is added to close the curve.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).importToTable()` to read data from the file defined by the `filename` property and store the data in the `table` property. The `source` property is also changed to `table`.

If `source` is `file`, the polygon is not automatically rebuilt when the data in the file changes. Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).importData()` to rebuild the polygon after such a change.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"line1")` constructs an open polygon.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"poly1")` constructs a closed polygon.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"line2")` or
`model.component(<ctag>).geom(<tag>).create(<ftag>,"poly2")` constructs a solid polygon.

EXAMPLE

Construct a solid triangle `pol1`:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("pol1","Polygon");
g.feature("pol1").set("x","0,0,2").set("y","1,0,0");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('pol1','Polygon');
g.feature('pol1').set('x','0,0,2').set('y','1,0,0');
g.run;
```

SEE ALSO

`BezierPolygon`

Pyramid

Create solid or surface rectangular pyramid or frustum in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Pyramid");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Pyramid")` to create a pyramid. The following properties are available:

TABLE 3-88: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`a, b`	double	1	Side lengths for bottom rectangle.
`axis`	double[]	`{0,0,1}`	Direction of the axis orthogonal to the bottom rectangle. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`h`	double	1	Height.
`pos`	double[]	`{0,0,0}`	Center of the bottom rectangle.
`rat`	double	`0.5`	Ratio of perimeter of top rectangle and bottom rectangle.
`rot`	double	0	Rotational angle about `axis`.
`type`	`solid` | `surface`	`solid`	Object type.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, of resulting objects in physics, materials, and so on, or in part instances. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`workplanesrc`	`this` | Part Instance feature	`this`	Part Instance feature to take the work plane from.
`workplane`	`xyplane` | Work plane feature	`xyplane`	Work Plane feature that defines the coordinate system. The default, `xyplane`, is the global Cartesian coordinate system.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"pyramid3")` creates a solid pyramid.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"pyramid2")` creates a surface pyramid.

The following properties are also available:

TABLE 3-89: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ax2	double[]	`{0,0}`	Alias for `axis` when `axistype` is `spherical`.

TABLE 3-89: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian.
x, y, z	double	0	Alias for pos.

The property const is no longer available.

EXAMPLE

Create a pyramid frustum with the base face in the *xy*-plane:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("e1","Pyramid");
g.feature("e1").set("a",10).set("b",40);
g.feature("e1").set("h",20);
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('e1','Pyramid');
g.feature('e1').set('a',10).set('b',40);
g.feature('e1').set('h',20);
```

Create a pyramid with an apex:

Code for Use with Java

```
g.create("e2","Pyramid");
g.feature("e2").set("a",1).set("b",2);
g.feature("e2").set("h",4);
g.feature("e2").set("rat",0);
g.feature("e2").set("pos","100 100 100");
g.feature("e2").set("axis","0 1 4");
g.feature("e2").set("rot",45);
g.run();
```

Code for Use with MATLAB

```
g.create('e2','Pyramid');
g.feature('e2').set('a',1).set('b',2);
g.feature('e2').set('h',4);
g.feature('e2').set('rat',0);
g.feature('e2').set('pos','100 100 100');
g.feature('e2').set('axis','0 1 4');
g.feature('e2').set('rot',45);
g.run;
```

SEE ALSO

Cone, ECone

Rectangle

Create a solid or curve rectangle in 2D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Rectangle");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Rectangle")` to create a rectangle. The following properties are available:

TABLE 3-90: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`base`	`corner` | `center`	`corner`	Positions the object either centered about `pos` or with the lower-left corner in `pos`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`layer`	double[]		Thicknesses of layers.
`layerleft`	on | `off`	`off`	Apply layers to the left.
`layerright`	on | `off`	`off`	Apply layers to the right.
`layertop`	on | `off`	`off`	Apply layers on top.
`layerbottom`	on | `off`	`on`	Apply layers on bottom.
`pos`	double[]	`{0,0}`	Position of the object.
`rot`	double	0	Rotational angle about `pos`.
`size`	double[]	`{1,1}`	Side lengths.
`type`	`solid` | `curve`	`solid`	Object type.
`selresult`	on | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"rect2")` creates a solid rectangle.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"rect1")` creates a curve rectangle.

The following properties are also available:

TABLE 3-91: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`lx`, `ly`	double	1	Alias for `size`.
`x`, `y`	double	0	Alias for `pos`.

The property `const` is no longer available.

RemoveDetails

Remove small details from the geometry.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"RemoveDetails");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"RemoveDetails")` to automatically remove small details from the geometry. You can also add extra local virtual operations using the following syntax (in this example, adding an IgnoreEdges operation):

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).create("IgnoreEdges", "ige1");
```

You can then build that local virtual operation using

```
model.component(<ctag>).geom(<tag>).run("<ftag>/ige1");
```

You can also use the selection property `input`:

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input");
```

If the RemoveDetails operation is in the automatic state, use the `.problems()` syntax to retrieve information on warnings (if any). The problem list is cleared if you switch to the manual state.

The following properties are available:

TABLE 3-92: VALID PROPERTY/VALUE PAIRS FOR REMOVEDETAILS.

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`automatic`	`on` | `off`	`on`	Mode of operation.
`contangletol`	double	`5 degrees`	Maximum allowed angular tangent deviation across a vertex or edge to be ignored.
`contvertices`	boolean	`true`	Specifies if vertices with continuous tangent are ignored.
`detailsizetype`	`auto` | `relative` | `absolute`	`auto`	Detail size type: automatic, relative, or absolute.
`input`	Selection		Entities for which to remove small details.
`maxrelsize`	double	`0.01`	Maximum relative detail size, relative to size of geometry.
`maxabssize`	double		Maximum absolute detail size.
`selection`	`geometry` | `entities`	`geometry`	Remove small details from the entire geometry or from geometric entities specified using the input.
`shortedges`	boolean	`true`	Specifies if short edges are removed.
`sliverfaces`	boolean	`true`	Specifies if sliver faces are removed.
`smallfaces`	boolean	`true`	Specifies if small faces are removed.
`thindomains`	boolean	`true`	Specifies if thin domains (that is, domains with a thickness less than the specified detail size) are removed.

Revolve

Revolve planar faces in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Revolve");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Revolve")` to revolve objects from a work plane.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the work plane objects to revolve. The default selection is all available objects from the last preceding work plane.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("inputface")` to select the faces to revolve. Faces are revolved when the `workplane` property is `none`; otherwise, work plane objects are revolved.

The following properties are available:

TABLE 3-93: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`angle1`	double	0	Start revolution angle.
`angle2`	double	0	End revolution angle.
`angtype`	`specang` | `full`	`specang`	Type of specification.
`axis`	double[2]	`{0,1}`	Direction of axis of revolution (in local coordinate system).
`axis3`	double[3]	`{0,1,0}`	Direction of axis of revolution (in 3D coordinate system).
`axistype`	`2d` | `3d`	`2d`	Type of revolution axis.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`input`	Selection	all objects	Objects to revolve.
`intputface`	Selection		Faces to revolve.
`origfaces`	`on` | `off`	`on`	Keep original faces.
`polres`	double	50	Polygon resolution of edges.
`pos`	double[2]	`{0,0}`	A point on the axis of revolution (in work plane's coordinate system).
`pos3`	double[3]	`{0,0,0}`	A point on the axis of revolution (in 3D coordinate system).
`revolvefrom`	`workplane` | `faces`		Revolve work plane objects or faces from 3D objects.
`unite`	`on` | `off`	`on`	Unite revolved objects with input objects.
`workplane`	`String`		Work plane to revolve or none to revolve faces.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections of resulting objects in physics, materials, and so on, or in part instances. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

Each 2D object in `input` or planar face in `inputface` is revolved about the revolution axis. The range of angles is given by the properties `angle1` and `angle2`. If `axistype` is `2d`, the revolution axis is defined in a local coordinate

system. The revolution axis goes through `pos` with direction `axis`. If `axistype` is `3d`, the revolution axis is defined in the 3D coordinate system. The revolution axis goes through `pos3` with direction `axis3`.

When revolving work plane objects, the local system is defined as the local system of the work plane. When revolving faces, the local system is defined by the face with the smallest face number in the object that comes first in the geometry sequence. The local z-axis is parallel to the face normal and located at the center of the face. The local x-axis is defined by the tangent direction corresponding to the first parameter in the surface representation for the face.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

Additional properties:

TABLE 3-94: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`angles`	double | double[2]	`2*pi`	Alias for `angle1` and `angle2`.
`keep`	on | `off`	`off`	Alias for `unite` property with opposite value.
`revaxis`	double[2][2]	`{{0,0}, {0,1}}`	Alias for `pos` (first column) and `axis` (second column).

EXAMPLE

Create torus about the y-axis:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.geom().create("geom1",3);
g.create("wp1","WorkPlane");
g.feature("wp1").geom().create("c1", "Circle");
g.feature("wp1").geom().feature("c1").set("pos", "2 0");
g.run("wp1");
g.create("r1","Revolve");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
g = model.geom.create('geom1',3);
g.create('wp1','WorkPlane');
g.feature('wp1').geom.create('c1', 'Circle');
g.feature('wp1').geom.feature('c1').set('pos', '2 0');
g.run('wp1');
g.create('r1','Revolve');
g.run;
```

SEE ALSO

`Extrude`, `WorkPlane`

Rotate

Rotate objects about a point in 2D or an axis in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Rotate");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Rotate")` to rotate geometry objects.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the objects to rotate. The default selection is empty.

The following properties are available:

TABLE 3-95: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`axis`	double[]	`{0,0,1}`	Rotation axis in 3D. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`input`	Selection		Objects to rotate.
`keep`	`on` | `off`	`off`	Keep input objects.
`pos`	double[]		Center of rotation.
`rot`	double[]	0	Rotation angles for one or more rotations of the input objects.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.
`workplanesrc`	`this` | Part Instance feature	`this`	Part Instance feature to take the work plane from (in 3D only).
`workplane`	`xyplane` | Work plane feature	`xyplane`	Work Plane feature that defines the coordinate system (in 3D only). The default, `xyplane`, is the global Cartesian coordinate system.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

The possibility to set and get a rotation matrix has been removed.

The property `out` is no longer available.

EXAMPLE

The commands below create and then rotate an ellipse by 10 degrees about (2, 3):

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
```

```
g.create("e1","Ellipse");
g.feature("e1").set("semiaxes","1 3");
g.create("r1","Rotate");
g.feature("r1").selection("input").set("e1");
g.feature("r1").set("rot",10);
g.feature("r1").set("pos", "2 3");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('e1','Ellipse');
g.feature('e1').set('semiaxes','1 3');
g.create('r1','Rotate');
g.feature('r1').selection('input').set('e1');
g.feature('r1').set('rot',10);
g.feature('r1').set('pos', '2 3');
g.run;
```

SEE ALSO

`Mirror`, `Move`, `Copy`, `Scale`

Scale

Scale objects around a point.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Scale");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Scale")` to scale geometry objects.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the objects to scale. The default selection is empty.

The following properties are available:

TABLE 3-96: VALID PROPERTIES FOR SCALE

NAME	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`factor`	double | double[]	1	Scale factor(s).
`input`	Selection		Objects to scale.
`keep`	`on` | `off`	`off`	Keep input objects.
`pos`	double[]	0	Center of scaling.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.

TABLE 3-96: VALID PROPERTIES FOR SCALE

NAME	VALUE	DEFAULT	DESCRIPTION
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from (in 3D only).
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system (in 3D only). The default, xyplane, is the global Cartesian coordinate system.

If factor is an array, the inputs are scaled by the factor[i] in the ith coordinate.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

EXAMPLE

The sequence below scales the unit circle by (1, 2) about (2, 3):

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("c1","Circle");
g.create("s1","Scale");
g.feature("s1").selection("input").set("c1");
g.feature("s1").set("factor", "1,2");
g.feature("s1").set("pos",new double[]{2,3});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('c1','Circle');
g.create('s1','Scale');
g.feature('s1').selection('input').set('c1');
g.feature('s1').set('factor', '1,2');
g.feature('s1').set('pos',[2,3]);
g.run;
```

COMPATIBILITY

The property out is no longer available.

SEE ALSO

Mirror, Move, Copy, Rotate

Sphere

Create a solid ball or surface sphere in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Sphere");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Sphere")` to create a sphere. The following properties are available:

TABLE 3-97: VALID PROPERTY/VALUE PAIRS FOR SPHERE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
axis	double[]	{0,0,1}	Direction of the local z-axis. Vector has length 3 if axistype is cartesian, and length 2 if axistype is spherical.
axistype	x | y | z | cartesian | spherical	z	Coordinate system used for axis. The value is synchronized with axis.
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
layer	double[]		Thicknesses of layers.
pos	double[]	{0,0,0}	Center.
r	double	1	Radius.
rot	double	0	Rotational angle about axis.
type	solid | surface	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"sphere3")` creates a solid sphere.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"sphere2")` creates a surface sphere.

The following properties are also available:

TABLE 3-98: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ax2	double[]	{0,0}	Alias for axis when axistype is spherical.
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian.
x, y, z	double	0	Alias for pos.

The property const is no longer available.

EXAMPLE

The following commands create a surface and solid sphere, where the position and radius are defined differently:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("s2","Sphere");
g.feature("s2").set("type","surface");
g.feature("s2").set("pos","0 1 0");
g.create("s3","Sphere");
g.feature("s3").set("r",4);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('s2','Sphere');
g.feature('s2').set('type','surface');
g.feature('s2').set('pos','0 1 0');
g.create('s3','Sphere');
g.feature('s3').set('r',4);
g.run;
```

SEE ALSO

Ellipsoid

Split

Split (explode) objects into domains, faces, edges, or vertices.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Split");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Split")` to split geometry objects.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("input")` to select the objects to split. The default selection is empty.

TABLE 3-99: VALID PROPERTY/VALUE PAIRS FOR SPLIT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`input`	Selection		Objects to split.
`keep`	`on` | `off`	`off`	Keep input objects.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `edg` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

- A solid object is split into solids corresponding to its domains.
- A surface object is split into surface objects corresponding to its faces.
- A curve object is split into curve objects corresponding to its edges.
- A point object is split into point objects corresponding to its vertices.
- A general (mixed) object is split into solids (corresponding to the domains), surface objects (corresponding to faces not adjacent to a domain), curve objects (corresponding to edges not adjacent to a face or domain), and point objects (corresponding to vertices not adjacent to an edge, face, or domain).

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

EXAMPLE

Split union of a solid circle and a solid rectangle.

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("r1","Rectangle");
g.create("c1","Circle");
g.create("u1","Union");
g.feature("u1").selection("input").set(new String[]{"r1","c1"});
g.create("spl1","Split");
g.feature("spl1").selection("input").set("u1");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('r1','Rectangle');
g.create('c1','Circle');
```

```
g.create('u1','Union');
g.feature('u1').selection('input').set({'r1','c1'});
g.create('spl1','Split');
g.feature('spl1').selection('input').set('u1');
g.run;
```

SEE ALSO

`Compose`, `Union`, `Intersection`, `Difference`, `Delete`

Square

Create a solid or curve square in 2D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Square");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Square")` to create a square. The following properties are available:

TABLE 3-100: VALID PROPERTY/VALUE PAIRS FOR SQUARE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`base`	`corner` | `center`	`corner`	Positions the object either centered about `pos` or with the lower left corner in `pos`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`layer`	double[]		Thicknesses of layers.
`layerleft`	`on` | `off`	`off`	Apply layers to the left.
`layerright`	`on` | `off`	`off`	Apply layers to the right.
`layertop`	`on` | `off`	`off`	Apply layers on top.
`layerbottom`	`on` | `off`	`on`	Apply layers on bottom.
`pos`	double[]	`{0,0}`	Position of the object.
`rot`	double	0	Rotational angle about `pos`.
`size`	double	1	Side length.
`type`	`solid` | `curve`	`solid`	Object type.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `dom` | `bnd` | `pnt` | `off`	`dom`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"square2")` creates a solid square.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"square1")` creates a curve square.

The following properties are also available:

TABLE 3-101: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`l`	double	1	Alias for `size`.
x, y	double	0	Alias for pos.

The property `const` is no longer available.

EXAMPLE

The sequence below creates a unit solid square:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("sq1","Square");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom',2);
g.create('sq1','Square');
g.run;
```

SEE ALSO

`Rectangle`

Sweep

Sweep one or several faces along a spine curve into a solid in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Sweep");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Sweep")` to sweep faces along a spine curve.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("face")` to select the faces to sweep.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("edge")` to select the edges to sweep along.

Use `model.component(<ctag>).geom(<tag>).feature(<ftag>).selection("diredge")` to select the edge whose direction defines the positive sweep direction. If this selection is empty, it is automatically set when the `edge` selection is set. The `diredge` selection can be empty if the `edge` selection contains a single edge.

The following properties are available:

TABLE 3-102: VALID PROPERTY/VALUE PAIRS FOR SWEEP

PROPERTY	VALUES	DEFAULT	DESCRIPTION
adjustlen	double	0	Spine adjustment parameter length. Used when align is set to adjustspine.
align	noadjust | adjustspine | moveface	noadjust	Type of alignment between face and spine curve.
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
diredge	Selection		Direction-defining edge.
edge	Selection		Edges that form spine curve.
face	Selection		Faces to sweep.
grep	bezier | spline	spline	Geometry representation.
includefinal	on | off	off	Include all used input objects in Finalize operation.
keep	on | off	on	Keep input objects.
maxknots	int	1000	Maximum number of knots.
parameterization	arclength | normalizedarclength | internal	arclength	Parameterization of the spine curve: arc length, normalized arc length, or the internal parameterization in the geometry's data structures.
parname	String	s	Parameter name.
reversedir	on | off	off	Reverse sweep direction.
rtol	double	1e-4	Relative tolerance.
scale	String	1	Scale factor for cross section.
smooth	boolean	true	Smooth edge connections.
twist	String	0	Twist angle for cross section.
twistcomp	on | off	on	Twist compensation.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.

The expressions in scale and twist can contain functions defined in the model. If the definition of such a function is changed, the swept object is not automatically rebuilt. Use model.component(*<ctag>*).geom(*<tag>*).feature(*<ftag>*).importData() to rebuild the swept object after such a change.

If includefinal is off, input objects are automatically removed in the Finalize (Form Union/Assembly) operation if they are completely used by this feature. Objects used in face are considered completely used if they

contain a single face. Objects used in `edge` are considered completely used if they contain no faces and all their edges are included in `edge`. If an object is considered completely used by one property but not completely used by another property, the object is not removed in the Finalize operation. If `includefinal` is `on`, input objects are not removed in the Finalize operation.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

In COMSOL Multiphysics 4.2a and earlier versions, the positive sweep direction was defined as the curve direction instead of the edge direction.

EXAMPLE

Create a half torus about the *y*-axis using a sweep operation:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("wp1","WorkPlane");
g.feature("wp1").geom().create("c1","Circle");
g.create("pc1","ParametricCurve");
g.create("swe1","Sweep");
g.feature("pc1").set("parmax","pi");
g.feature("pc1").set("coord",new String[]{"(cos(s)-1)*3","0","sin(s)*3"});
g.feature("swe1").selection("face").set("wp1.c1", new int[]{1});
g.feature("swe1").selection("edge").set("pc1(1)",new int[]{1});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('wp1','WorkPlane');
g.feature('wp1').geom.create('c1','Circle');
g.create('pc1','ParametricCurve');
g.create('swe1','Sweep');
g.feature('pc1').set('parmax','pi');
g.feature('pc1').set('coord',{'(cos(s)-1)*3','0','sin(s)*3'});
g.feature('swe1').selection('face').set('wp1.c1', 1);
g.feature('swe1').selection('edge').set('pc1(1)', 1);
g.run;
```

SEE ALSO

`Extrude`, `Helix`, `Revolve`, `WorkPlane`

Tangent

Create a tangent line segment to one or two 2D edges.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"Tangent");
model.component(<ctag>).geom(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Tangent")` to create a line segment tangent to two edges or tangent to one edge with a fixed endpoint. The following properties are available:

TABLE 3-103: VALID PROPERTY/VALUE PAIRS FOR TANGENT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`edge`	Selection		Edge in an geometry object to find tangent to.
`start`	double	`0.5`	Start guess for parameter value of point of tangency.
`type`	`edge` | `point` | `coord`	`edge`	Type of tangent.
`selresult`	`on` | `off`	`off`	Create selections of all resulting objects.
`selresultshow`	`all` | `obj` | `bnd` | `edg` | `pnt` | `off`	`bnd`	Show selections, if `selresult` is `on`, in physics, materials, and so on; in part instances; or in 3D from a plane geometry. `obj` is not available in a component's geometry. `dom`, `bnd`, and `edg` are not available in all features.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

If `type` is `edge` a common tangent line to two edges are constructed. Then, the following additional properties are available:

TABLE 3-104: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`edge2`	Selection		Second edge in some geometry object to find tangent to.
`start2`	double	`0.5`	Start guess for parameter value of point of tangency.

If `type` is `point` a tangent line through a given point is constructed. Then, the following additional property is available:

TABLE 3-105: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`point`	Selection		Point in some geometry object.

If `type` is `coord` a tangent line through a point with given coordinates are constructed. Then, the following additional property is available:

TABLE 3-106: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`coord`	double[]	`{0,0}`	Coordinates.

If a tangent cannot be found, a tangent to some adjacent edge is constructed, if possible.

For information about the `selresult` and `contributeto` properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(gname).create(fname,"tangent")` creates a `Tangent` feature.

The following properties are no longer supported:

TABLE 3-107: OBSOLETE PROPERTY/VALUE PAIRS

PROPERTY NAME	PROPERTY VALUE	DEFAULT	DESCRIPTION
`edim1`	0 | 1	geometry dependent	Starting point element dimension: 0 for vertex, 1 for edge.
`edim2`	0 | 1	geometry dependent	Ending point element dimension: 0 for vertex, 1 for edge.

TABLE 3-107: OBSOLETE PROPERTY/VALUE PAIRS

PROPERTY NAME	PROPERTY VALUE	DEFAULT	DESCRIPTION
dom1	integer	1	Starting point entity number.
dom2	integer	1	Ending point entity number.
out	cell array of Strings	{}	Additional output data.
start1	double	0.5	Starting point parameter value on specified edge.

EXAMPLE

The following sequence generates a tangent from the unit circle to the point (2, 0):

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("c1","Circle");
g.run("c1");
g.create("tan1","Tangent");
g.feature("tan1").set("type","coord");
g.feature("tan1").selection("edge").set("c1",3);
g.feature("tan1").set("coord","2 0");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('c1','Circle');
g.run('c1');
g.create('tan1','Tangent');
g.feature('tan1').set('type','coord');
g.feature('tan1').selection('edge').set('c1',3);
g.feature('tan1').set('coord','2 0');
g.run;
```

The following sequence generates a common tangent between two circles:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",2);
g.create("c1","Circle");
g.create("c2","Circle");
g.feature("c2").set("pos", "2 2");
g.run("c2");
g.create("tan1","Tangent");
g.feature("tan1").selection("edge").set("c1",4);
g.feature("tan1").selection("edge2").set("c2",4);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',2);
g.create('c1','Circle');
g.create('c2','Circle');
g.feature('c2').set('pos', '2 2');
g.run('c2');
g.create('tan1','Tangent');
g.feature('tan1').selection('edge').set('c1',4);
g.feature('tan1').selection('edge2').set('c2',4);
g.run;
```

SEE ALSO

BezierPolygon

Tetrahedron

Create a solid or surface tetrahedron in 3D.

SYNTAX

```
model.component(<ctag>).geom(<tag>)create(<ftag>,"Tetrahedron");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).geom(<tag>).create(<ftag>,"Tetrahedron")` to create a tetrahedron. The following properties are available:

TABLE 3-108: VALID PROPERTY/VALUE PAIR FOR TETRAHEDRON

PROPERTY NAME	PROPERTY VALUE	DEFAULT	DESCRIPTION
color	none | custom | integer between 1 and the number of colors in the current theme	none	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the customcolor property. Coloring is only available when selresult in active.
customcolor	RGB-triplet	Next available theme color	The color to use. Active when color is set to custom.
p	double[3][4]	{{0,0,1,0}, {0,1,0,0}, {0,0,0,1}}	Corner coordinates.
type	solid | surface	solid	Object type.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

`model.component(<ctag>).geom(<tag>).create(<ftag>,"tetrahedron3")` creates a solid tetrahedron.

`model.component(<ctag>).geom(<tag>).create(<ftag>,"tetrahedron2")` creates a surface tetrahedron.

EXAMPLE

The following commands generate a solid tetrahedron object:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
```

```
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("t1","Tetrahedron");
g.feature("t1").set("p", new double[][]{{0,0,1,0},{0,0.8,1,0},{0,0.1,0,0.2}});
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('t1','Tetrahedron');
g.feature('t1').set('p', [[0,0,1,0];[0,0.8,1,0];[0,0.1,0,0.2]]);
g.run;
```

SEE ALSO

`Hexahedron`, `Pyramid`

Torus

Create a solid or surface torus in 3D.

SYNTAX

`model.component(`*<ctag>*`).geom(`*<tag>*`).create(`*<ftag>*`,"Torus");`
`model.component(`*<ctag>*`).geom(`*<tag>*`).feature(`*<ftag>*`).set(`*property*`,`*<value>*`);`
`model.component(`*<ctag>*`).geom(`*<tag>*`).feature(`*<ftag>*`).get`*Type*`(`*property*`);`

DESCRIPTION

Use `model.component(`*<ctag>*`).geom(`*<tag>*`).create(`*<ftag>*`,"Torus")` to create a torus. The following properties are available:

TABLE 3-109: VALID PROPERTY/VALUE PAIRS FOR TORUS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`angle`	double	360	Revolution angle.
`axis`	double[]	`{0,0,1}`	Direction of the revolution axis. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`axistype`	`x` | `y` | `z` | `cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property. Coloring is only available when `selresult` in active.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`intfaces`	on | `off`	`off`	Create cross section faces inside the torus.
`pos`	double[]	`{0,0,0}`	Center coordinates.
`rmaj`	double	1	Directrix radius.
`rmin`	double	`0.5`	Generatrix radius.
`rot`	double	0	Rotational angle about `axis`.
`type`	`solid` | `surface`	`solid`	Object type.
`selresult`	on | `off`	`off`	Create selections of all resulting objects.

TABLE 3-109: VALID PROPERTY/VALUE PAIRS FOR TORUS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selresultshow	all | obj | dom | bnd | edg | pnt | off	dom	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.
contributeto	String	none	Tag of cumulative selection to contribute to.
workplanesrc	this | Part Instance feature	this	Part Instance feature to take the work plane from.
workplane	xyplane | Work plane feature	xyplane	Work Plane feature that defines the coordinate system. The default, xyplane, is the global Cartesian coordinate system.

For information about the selresult and contributeto properties, see Selections of Geometric Entities.

COMPATIBILITY

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"torus3") creates a solid torus.

model.component(*<ctag>*).geom(*<tag>*).create(*<ftag>*,"torus2") creates a surface torus.

The following properties are also available:

TABLE 3-110: VALID PROPERTY/VALUE PAIRS FOR TORUS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ax2	double[]	{0,0}	Alias for axis when axistype is spherical.
ax3	double[]	{0,0,1}	Alias for axis when axistype is cartesian.
x, y, z	double	0	Alias for pos.

The property const is no longer available.

EXAMPLE

The following sequence generates a surface torus and a solid torus:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("t2","Torus");
g.feature("t2").set("type","surface");
g.feature("t2").set("rmaj",2);
g.feature("t2").set("rmin",1);

g.create("t3","Torus");
g.feature("t3").set("rmaj",10);
g.feature("t3").set("rmin",2);
g.feature("t3").set("pos","0,0,-100");
g.feature("t3").set("axis","1,1,1");
g.feature("t3").set("rot",60);
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('t2','Torus');
g.feature('t2').set('type','surface');
g.feature('t2').set('rmaj',2);
g.feature('t2').set('rmin',1);
```

```
g.create('t3','Torus');
g.feature('t3').set('rmaj',10);
g.feature('t3').set('rmin',2);
g.feature('t3').set('pos','0,0,-100');
g.feature('t3').set('axis','1,1,1');
g.feature('t3').set('rot',60);
g.run;
```

SEE ALSO

Cylinder

UnionSelection, IntersectionSelection, DifferenceSelection, ComplementSelection

Combine selections of entities or objects using a Boolean operation.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"UnionSelection");
model.component(<ctag>).geom(<tag>).create(<ftag>,"IntersectionSelection");
model.component(<ctag>).geom(<tag>).create(<ftag>,"DifferenceSelection");
model.component(<ctag>).geom(<tag>).create(<ftag>,"ComplementSelection");
model.component(<ctag>).geom(<tag>).feature().set(property,<value>);
model.component(<ctag>).geom(<tag>).feature().getType(property);
```

DESCRIPTION

Use UnionSelection to get all entities/objects that belong to at least one of the input selections. Use IntersectionSelection to get all entities/objects that belong to all input selections. Use DifferenceSelection to get all entities/objects that belong some of the `add` selections, but do not belong to any of the `subtract` selections. Use ComplementSelection to get all entities/objects of the given dimension that do not belong to any input selection.

For DifferenceSelection, the following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`add`	String[]	`{}`	Tags of selections to add.
`color`	`none` | `custom` | integer between 1 and the number of colors in the current theme	`none`	The color of the selection, either given as an integer indicating a color in the color theme, or as a custom color in the `customcolor` property.
`customcolor`	RGB-triplet	Next available theme color	The color to use. Active when `color` is set to `custom`.
`entitydim`	`-1` | `0` | `1` | `2` | `3`	space dimension	Dimension of entities to select. -1 means Object.
`subtract`	String[]	`{}`	Tags of selections to subtract.
`selkeep`	`on` | `off`	`on`	Keep the selection within the geometry sequence.
`selshow`	`on` | `off`	`on`	Show selection in physics, materials, and so on; in part instances; or in 3D from a plane geometry.
`contributeto`	String	`none`	Tag of cumulative selection to contribute to.

For the other selections, the following properties are available:

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`entitydim`	`-1` | `0` | `1` | `2` | `3`	space dimension	Dimension of entities to select. -1 means Object.
`input`	String[]	`{}`	Tags of input selections.
`selkeep`	`on` | `off`	`on`	Keep the selection within the geometry sequence.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selshow	If the level is not Object, the allowed values are on | off. If the level is Object, the allowed values are all | obj | dom | bnd | edg | pnt | off.	If the level is not Object, the default value is on. If the level is Object, the default value is all in a component's geometry, obj in a part, and dom in a work plane's Plane Geometry.	Show selection in physics, materials, and so on; in part instances; or in 3D from a plane geometry. obj is not available in a component's geometry.
contributeto	String	none	Tag of cumulative selection to contribute to.

See Selections of Geometric Entities for general information about selections.

EXAMPLE

In an array of blocks, select all vertices whose distance to the origin is between 2.5 and 3.5. This results in 22 vertices in 7 different objects.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
g.create("blk1", "Block");
g.create("arr1", "Array");
g.feature("arr1").selection("input").set("blk1");
g.feature("arr1").set("size", new int[]{3,3,1});
g.feature("arr1").set("displ", new double[]{1.5,1.5,0});
g.run("arr1");
g.create("ballsel1","BallSelection");
g.feature("ballsel1").set("entitydim", 0);
g.feature("ballsel1").set("r", 3.5);
g.feature().duplicate("ballsel2","ballsel1");
g.feature("ballsel2").set("r", 2.5);
g.create("difsel1", "DifferenceSelection");
g.feature("difsel1").set("entitydim", 0);
g.feature("difsel1").set("add", new String[]{"ballsel1"});
g.feature("difsel1").set("subtract", new String[]{"ballsel2"});
g.run("difsel1");
String[] obj = g.selection("difsel1").objects();
int nVtx = 0;
for (int i=0; i<obj.length; ++i)
  nVtx += g.selection("difsel1").entities(obj[i],0).length;
// obj.length = 7, nVtx = 22
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
g.create('blk1', 'Block');
g.create('arr1', 'Array');
g.feature('arr1').selection('input').set('blk1');
g.feature('arr1').set('size', [3,3,1]);
g.feature('arr1').set('displ', [1.5,1.5,0]);
g.run('arr1');
g.create('ballsel1','BallSelection');
g.feature('ballsel1').set('entitydim', 0);
g.feature('ballsel1').set('r', 3.5);
g.feature.duplicate('ballsel2','ballsel1');
g.feature('ballsel2').set('r', 2.5);
g.create('difsel1', 'DifferenceSelection');
```

```
g.feature('difsel1').set('entitydim', 0);
g.feature('difsel1').set('add', {'ballsel1'});
g.feature('difsel1').set('subtract', {'ballsel2'});
g.run('difsel1');
obj = g.selection('difsel1').objects;
nVtx = 0;
for i=1:length(obj)
  nVtx = nVtx + length(g.selection('difsel1').entities(obj(i),0));
end
% length(obj) = 7, nVtx = 22
```

SEE ALSO

AdjacentSelection, BallSelection, BoxSelection, CylinderSelection, Disk Selection, ExplicitSelection

WorkPlane

Create a work plane in 3D for drawing 2D objects that can be extruded, revolved, or embedded.

SYNTAX

```
model.component(<ctag>).geom(<tag>).create(<ftag>,"WorkPlane");
model.component(<ctag>).geom(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).geom(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).geom(<tag>).feature(<ftag>).geom().geomSequenceMethod
model.component(<ctag>).geom(<tag>).feature(<ftag>).geom().feature();
```

DESCRIPTION

A work plane embeds 2D objects in 3D. The sections below describe how to define the location of the work plane and how to create 2D objects in it. You can also use a work plane in the CrossSection and Partition features. In that case, you do not need to draw anything in the work plane.

Unite Objects

There is an option to unite all objects in the work plane before using the 2D geometry in 3D. Uniting all objects can improve the handling of the 2D geometry when extruding it, for example. You can control the union of 2D objects using the following properties:

TABLE 3-111: VALID PROPERTIES, UNITE OBJECTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
absrepairtol	double	See below	Absolute repair tolerance.
repairtol	double	See below	Relative repair tolerance, relative to size of union of inputs.
repairtoltype	auto | relative | absolute	See below	Repair tolerance type: automatic, relative, or absolute.
unite	on | off	off	Unite objects.

The tolerance settings are active when unite is set to on. The default values for the repair tolerance is taken from the geometry sequence's default repair tolerance.

Visualization

To specify the in-plane visualization of the 3D geometry and activate the ability to draw directly on the work plane in 3D, use the following properties:

TABLE 3-112: VALID PROPERTIES, VISUALIZATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
showcoincident	on | off	on	Show coincident 3D geometry.
showintersection	on | off	on	Show intersection of 3D geometry.

TABLE 3-112: VALID PROPERTIES, VISUALIZATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
showprojection	on | off	on	Show projection of 3D geometry.
workplane3d	on | off	of	Draw on work plane in 3D.

Defining the Location of the Work Plane

A work plane has a local coordinate system that is orthonormal and positively oriented (right-handed). The work plane coincides with the *xy*-plane in the local coordinate system. The following properties control how the work plane is defined.

TABLE 3-113: VALID PROPERTIES, LOCATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
planetype	quick | faceparallel | edgeparallel | edgeangle | circleperpendicular | vertices | coordinates | transformed	quick	Type of data defining the work plane.
contributeto	String	none	Tag of cumulative selection to contribute to.

For information about the selresult and contributeto properties, see Selections of Geometric Entities. Note that in a work plane's Plane Geometry, the selresultshow and selindividualshow properties are not available.

Depending on planetype, additional properties are available.

Quick

This creates a work plane parallel to one of the global coordinate planes.

TABLE 3-114: VALID PROPERTIES, QUICK

PROPERTY	VALUE	DEFAULT	DESCRIPTION
quickplane	xy | yz | zx | yx | zy | xz	xy	Coordinate plane.
quickx	double	0	x-coordinate for work plane (used when plane is yz or zy).
quicky	double	0	y-coordinate for work plane (used when plane is xz or zx).
quickz	double	0	z-coordinate for work plane (used when plane is xy or yx).
quickoffsettype	distance | vertex	distance	Type of offset specification.
offsetvertex	Selection		Vertex for offset.
quickorigin	global | vertexproj	global	Origin of local coordinate system.
originvertex	Selection		Vertex for origin.
quickaxis	natural | vertexproj	natural	Local x-axis.
axisvertex	Selection		Vertex for axis.
displ	double[2]	{0,0}	Displacement of local coordinate system.
rot	double	0	Rotation angle of local coordinate system.

Face Parallel

This creates a work plane that is parallel to a planar face in a geometry object

TABLE 3-115: VALID PROPERTIES, FACE PARALLEL

PROPERTY	VALUE	DEFAULT	DESCRIPTION
face	Selection		Planar face.
offset	double	0	Signed offset in the direction of the local z-axis.

TABLE 3-115: VALID PROPERTIES, FACE PARALLEL

PROPERTY	VALUE	DEFAULT	DESCRIPTION
reverse	on | off	off	Reverse direction of local z-axis.
offsettype	distance | vertex	distance	Type of offset specification.
offsetvertex	Selection		Vertex for offset.
origin	facecenter | boxcorner | vertexproj	facecenter	Origin of local coordinate system.
originvertex	Selection		Vertex for origin.
faceparallel axis	s1 | s2 | vertexproj	s1	Local x-axis.
axisvertex	Selection		Vertex for axis.
displ	double[2]	{0,0}	Displacement of local coordinate system.
rot	double	0	Rotation angle of local coordinate system.

Edge Parallel

This creates a work plane that is parallel to a planar edge in a geometry object.

TABLE 3-116: VALID PROPERTIES, FACE PARALLEL

PROPERTY	VALUE	DEFAULT	DESCRIPTION
edge	Selection		Planar edge.
offset	double	0	Signed offset in the direction of the local z-axis.
origin	edgecenter | boxcorner	edgecenter	Origin of local coordinate system.
reverse	on | off	off	Reverse direction of local z-axis.
offsettype	distance | vertex	distance	Type of offset specification.
offsetvertex	Selection		Vertex for offset.
edgeparallel origin	startvertex | endvertex | vertexproj	startvertex	Origin of local coordinate system.
originvertex	Selection		Vertex for origin.
edgeparallel axis	tangent | vertexproj	tangent	Local x-axis.
axisvertex	Selection		Vertex for axis.
displ	double[2]	{0,0}	Displacement of local coordinate system.
rot	double	0	Rotation angle of local coordinate system.

Edge Angle

This creates a work plane through a straight edge of a geometry object. The work plane makes a given angle with the tangent plane of a face in the same geometry object. The face must be adjacent to the edge, and its tangent plane must be the same at all points on the edge. The origin of the local coordinate system coincides with the start vertex (if `reverse` is `off`) or end vertex (if `reverse` is `on`) of the edge. The direction of the local *x*-axis coincides with the direction of the edge (if `reverse` is `off`) or its opposite (if `reverse` is `on`). If the property `angle` is zero, the direction of the local *y*-axis points into the face. In general, the local coordinate system is rotated by `angle` about the local *x*-axis.

TABLE 3-117: VALID PROPERTIES, EDGE ANGLE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
angle	double	0	Angle between face and work plane.
edge	Selection		Straight edge.
adjface	Selection		Face adjacent to edge in the same object.
reverse	on | off	off	Reverse direction of local x-axis.

TABLE 3-117: VALID PROPERTIES, EDGE ANGLE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
displ	double[2]	{0,0}	Displacement of local coordinate system.
rot	double	0	Rotation angle of local coordinate system.

Circle Perpendicular

This creates a work plane that is perpendicular to a given circular edge. The origin of the local coordinate system is at the circle's center. By default, the local *x*-axis goes through the edge's start vertex. Thus, if the geometry is rotationally symmetric, the symmetry axis coincides with the local *y*-axis.

TABLE 3-118: VALID PROPERTIES, CIRCLE PERPENDICULAR

PROPERTY	VALUE	DEFAULT	DESCRIPTION
circedge	Selection	empty	Circular edge.
circpoint	startvertex | endvertex | othervertex	startvertex	Point on plane.
circvertex	Selection		Vertex on plane.
circoffset	double	0	Offset angle.
reverse	on | off	off	Reverse direction of local x-axis.
displ	double[2]	{0,0}	Displacement of local coordinate system.
rot	double	0	Rotation angle of local coordinate system.

Vertices

This creates a work plane parallel to a plane through three vertices v1, v2, and v3. When offset=0, the origin of the local coordinate system coincides with the first vertex v1. The *x*-axis of the local coordinate system is in the direction v2-v1. The direction of the local *z*-axis is given by the cross product (v2-v1)x(v3-v1) or its opposite (if reverse is on).

TABLE 3-119: VALID PROPERTIES, VERTICES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
offset	double	0	Signed offset in the direction of the local z-axis.
reverse	on | off	off	Reverse direction of local z-axis.
vertex1	Selection		First vertex.
vertex2	Selection		Second vertex.
vertex3	Selection		Third vertex.
displ	double[2]	{0,0}	Displacement of local coordinate system.
rot	double	0	Rotation angle of local coordinate system.

Coordinates

This creates a work plane through three points p1, p2, and p3. The origin of the local coordinate system coincides with the first point p1. The *x*-axis of the local coordinate system is in the direction p2-p1. The direction of the local *z*-axis is given by the cross product (p2-p1)x(p3-p1).

TABLE 3-120: VALID PROPERTY, COORDINATES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
genpoints	double[3][3]	{{0,0,0},{1,0,0},{0,1,0}}	Points.

genpoints[n][i] is the *i*th coordinate of the *n*th point.

Transformed

This creates a work plane as a transformation of another work plane, using a displacement and a rotation.

TABLE 3-121: VALID PROPERTIES, TRANSFORMED

PROPERTY	VALUE	DEFAULT	DESCRIPTION
workplanesrc	String	this	Tag of PartInstance feature to take work plane from, or this to take work plane from this sequence.
workplane	String	xyplane	Tag of input work plane, or xyplane.
transdispl	double[3]	{0,0,0}	Displacement in local coordinate system.
transaxistype	x | y | z | cartesian | spherical	z	Type of rotation axis.
transaxis	double[]	{0,0,0}	Rotation axis in local coordinate system. Vector has length 3 if axistype is cartesian, and length 2 if axistype is spherical.
transrot	double	0	Rotation angle.

Part Instances

In a part instance, the following property is available:

TABLE 3-122: VALID PROPERTY IN PART INSTANCES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
showworkplane	on | off	on	Show work plane in part instances. This property is only available if the work plane is in a geometry part.

Selections of Resulting Entities

For selections of resulting entities, the following properties are available:

TABLE 3-123: VALID PROPERTIES FOR SELECTIONS OF RESULTING ENTITIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
selplaneshow	on | off	off	Show selections from Plane Geometry in physics or part instances.
selresult	on | off	off	Create selections of all resulting objects.
selresultshow	all | obj | bnd | edg | pnt | off	bnd	Show selections, if selresult is on, of resulting objects in physics, materials, and so on, or in part instances. obj is not available in a component's geometry. dom, bnd, and edg are not available in all features.

Creating 2D Objects in the Work Plane

The work plane owns a geometry sequence that contains the features that define the 2D objects you draw in the work plane. You access this geometry sequence by

```
model.component(<ctag>).geom(<tag>).feature(<ftag>).geom()
```

where *<ftag>* is the name of the work plane feature. You can add geometry features in this 2D sequence as usual.

COMPATIBILITY

The plane type circularedge from earlier versions is still valid as an alternative to its replacement circleperpendicular, and the plane type general from earlier versions is still valid as an alternative to its replacement coordinates.

EXAMPLE

Create a work plane with a rectangle. When the work plane is built, the rectangle is embedded in the space of the 3D sequence:

Code for Use with Java

```
Model model = ModelUtil.create("Model1");
```

```
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1",3);
g.create("wp1","WorkPlane");
g.feature("wp1").set("quickplane","yz");
g.feature("wp1").geom().create("r1","Rectangle");
g.feature("wp1").geom().feature("r1").set("pos", "1 1");
g.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model1');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1',3);
g.create('wp1','WorkPlane');
g.feature('wp1').set('quickplane','yz');
g.feature('wp1').geom.create('r1','Rectangle');
g.feature('wp1').geom.feature('r1').set('pos', '1 1');
g.run;
```

SEE ALSO

CrossSection, Extrude, Partition, Revolve, Sweep

4

Mesh

Details include reference information about the mesh commands and utility methods.

In this chapter:

About Mesh Commands

The following list includes the mesh commands that are documented in this chapter (listed in alphabetical order):

- Adapt
- Ball
- BndLayer
- BndLayerProp
- Box
- Convert
- CopyEdge
- CopyFace
- CopyDomain
- Copy
- CornerRefinement
- CreateVertex
- Cylinder
- Delete
- DeleteEntities
- DetectFaces
- Distribution
- Edge
- EdgeGroup
- EdgeMap
- FreeQuad
- FreeTet
- FreeTri
- Import
- JoinEntities
- LogicalExpression
- Map
- OnePointMap
- Point
- Reference
- Refine
- Scale
- Size
- SizeExpression
- Sweep
- TwoPointMap

- Operation Features
- Attribute Features
- Features for Imported Meshes

Operation Features

Table 4-1 is an overview of the features that create or modify the mesh corresponding to a geometry.

TABLE 4-1: MESH OPERATION FEATURES

FEATURE TYPE	LOCALIZED TYPE DESCRIPTION IN GUI	DEFAULT NAME IN GUI
BndLayer	Boundary Layers	bl
Convert	Convert	conv
Copy	Copy	copy
CopyEdge	Copy Edge	cpe
CopyFace	Copy Face	cpf
CopyDomain	Copy Domain	cpd
Delete	Delete	del
Edge	Edge	edg

TABLE 4-1: MESH OPERATION FEATURES

FEATURE TYPE	LOCALIZED TYPE DESCRIPTION IN GUI	DEFAULT NAME IN GUI
FreeQuad	Free Quad	fq
FreeTet	Free Tetrahedral	ftet
FreeTri	Free Triangle	ftri
Map	Mapped	map
Reference	Reference	rf
Refine	Refine	ref
Sweep	Swept	swe

Attribute Features

Table 4-2 is an overview of the features that contain properties used by operation features to build the mesh.

TABLE 4-2: MESH ATTRIBUTE FEATURES

FEATURE TYPE	LOCALIZED TYPE DESCRIPTION IN GUI	DEFAULT NAME IN GUI
Adapt	Mesh Adaptation	ada
BndLayerProp	Boundary Layer Properties	blp
CornerRefinement	Corner Refinement	cr
Distribution	Distribution	dis
EdgeGroup	Edge Groups	eg
EdgeMap	Edge Map	em
OnePointMap	One-Point Map	pm
Scale	Scale	sca
Size	Size	size
SizeExpression	Size Expression	se
TwoPointMap	Two-Point Map	ppm

Features for Imported Meshes

Table 4-3 is an overview of the features that operate on imported meshes.

TABLE 4-3: FEATURES FOR IMPORTED MESHES

FEATURE TYPE	LOCALIZED TYPE DESCRIPTION IN GUI	DEFAULT NAME IN GUI
Ball	Ball	ball
Box	Box	box
CreateVertex	Create Vertex	vtx
Cylinder	Cylinder	cyl
DeleteEntities	Delete Entities	dele
DetectFaces	Detect Faces	detf
Import	Import	imp
JoinEntities	Join Entities	join
LogicalExpression	Logical Expression	le

Working with a Meshing Sequence

This section describes how to build meshes using Java® methods. A *mesh* is defined by a *meshing sequence* consisting of *mesh features*. A meshing feature is either an *attribute feature* or an *operation feature*. Each operation feature modifies the mesh when you *build* the feature using properties defined by attribute features.

An attribute feature is defined on a geometric entity selection and has a set of properties. Running an attribute feature does not change the mesh, but affects the subsequent operation features in the sequence. For example, the `FreeTet` operation feature, that creates a tetrahedral mesh, uses properties from the `Distribution`, `Scale`, and `Size` attribute features, that define the size and distribution of the mesh elements. You can add an attribute feature directly to the meshing sequence, this is referred to as a *global attribute feature*, or add it to an operation feature, this is referred to as a *local attribute feature*. Properties defined in local attribute features of an operation feature overrides corresponding properties defined in preceding global feature properties (on the same selection).

An operation features makes operations on the mesh as defined by the meshing sequence. Some operation features, like `FreeTet` and `Sweep` *generate* new mesh. Other operation features, like `Refine` and `Convert` *modify* existing mesh.

In this section:

Meshing in the *COMSOL Multiphysics Reference Manual*

Adding a Meshing Sequence

To add a new meshing sequence to a model object `model`, enter

```
model.component(<ctag>).mesh().create(<mtag>,<gtag>);
```

where `mTag` is the mesh's tag (an identifier of your choice) and `gTag` is the tag of the associated geometry. If you want to import a mesh, you must specify an empty geometry sequence; the geometry is then defined by the mesh.

The syntax that includes the component level, such as `model.component(<ctag>).mesh()...` is the default and is used throughout this chapter. To use the earlier `model.mesh()...` syntax, clear the **Use component syntax** check box on the **Methods** page in the **Preferences** dialog box.

Adding a Mesh Feature

To add a feature to a mesh with tag *<tag>*, enter

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,ftype);
```

where *<ftag>* is the feature's tag (an identifier of your choice), and *ftype* is the feature's type. Feature types are capitalized and case-sensitive (for example, `FreeTet`).

When you add a feature, it is inserted after the *current feature*. You can get the tag of the current feature type by entering

```
String ftag = model.component(<ctag>).mesh(<tag>).current();
```

If `ftag` is the empty string, the current feature is the beginning of the meshing sequence, that is, the empty state before all features. Adding a meshing feature, it automatically becomes current, but it is not built automatically.

For some operation features it is possible to add attribute features. To add an attribute feature to an operation feature, enter

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype);
```

where *<ftag1>* is the attribute feature's tag (an identifier of your choice), and *ftype* is the attribute feature's type.

All properties in a new feature get a default value.

Editing a Mesh Feature

To change a property value in a feature, enter

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
```

where *property* is a property name and *<value>* is a property value.

All numeric properties can be given either as a numeric value or as a string expression that can contain parameters defined in `model.param()`. When building the feature, the string expressions are evaluated using the current values of the parameters.

To get the value of a property, enter one of the following, depending on the property type:

```
double d = model.component(<ctag>).mesh(<tag>).feature(<ftag>).getDouble(property);
String s = model.component(<ctag>).mesh(<tag>).feature(<ftag>).getString(property);
double[] da = model.component(<ctag>).mesh(<mtag>).feature(<ftag>).
              getDoubleArray(property);
String[] sa = model.component(<ctag>).mesh(<tag>).feature(<ftag>).
              getStringArray(property);
```

If you request a numerical value for a string property, it is evaluated using the current values of the parameters in `model.param()`.

Building Mesh Features

To modify the mesh, you must *build* an operation feature. Enter

```
model.component(<ctag>).mesh(<tag>).run(<ftag>);
```

to build the feature *<ftag>* and all its preceding features (the features are built in the order from the first to the last). When the build has completed, the feature *<ftag>* becomes the current feature.

To build all features, enter

```
model.component(<ctag>).mesh(<tag>).run();
```

Using Mesh Parts

For a description of mesh parts, see Using Mesh Parts in the *COMSOL Multiphysics Reference Manual*.

A mesh part is defined by a model component of `MeshComponent` type (a *mesh component*). A mesh component contains a single meshing sequence and a geometry that defines the dimension, selections, and geometrical properties such as the length and angular unit. When you work with a Mesh Part node in the user interface, you can modify the meshing sequence of the mesh component. When working with the API it is important to be aware of the corresponding mesh component and its geometry.

To create a mesh part, enter

```
model.modelNode().create(<mcomptag>, "MeshComponent");
model.geom().create(<mgeomtag>, sDim);
model.mesh().create(<tag>, <mgeomtag>);
```

where *<mcomptag>* is the tag of the mesh component, *<mgeomtag>* is the tag of the geometry, `sDim` is its space dimension (1, 2, or 3), and *<tag>* is the mesh part's tag.

Use `model.component(`*<ctag>*`).geom(`*<mgeomtag>*`)` to access the geometry properties, such as length units (see `model.geom(`*<tag>*`)`).

To work with the mesh part, use `model.mesh(`*<tag>*`)`, see the sections above in Working with a Meshing Sequence and Table 4-3, Features for Imported Meshes, for details.

For using a mesh part in a model component, see Import Mesh Part or Meshing Sequence under Geometry Commands to create a geometry from the part, or Import under Mesh Commands to use the resulting mesh as an imported mesh.

To remove a mesh part, use `model.modelNode().remove(`*<mcomptag>*`);`

Feature Status

The *status* of a feature can be one of the following:

- *Built*. This means that the none of the feature's properties have changed since the feature was last built, and the features of the input objects are all built. The feature can contain warning messages.
- *Edited*. This means that some of the feature's properties have changed since the feature was last built.
- *Needs rebuild*. This means that any of the preceding features is edited.
- *Error*. This means that the feature contains an error message.
- *Warning*. This means that the feature contains a warning message.

You can examine the status of a feature by entering

```
boolean built = model.component(<ctag>).mesh(<tag>).feature(<ftag>).isBuilt();
boolean edited = model.component(<ctag>).mesh(<tag>).feature(<ftag>).isEdited();
boolean hasError = model.component(<ctag>).mesh(<tag>).feature(<ftag>).hasError();
boolean hasWarning = model.component(<ctag>).mesh(<tag>).feature(<ftag>).hasWarning();
boolean needsRebuild = !(built || edited || hasError || hasWarning);
```

Deleting Mesh Features

To delete a feature, enter

```
model.component(<ctag>).mesh(<tag>).feature().remove(<ftag>);
```

Disabling Mesh Features

To disable a feature, enter

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).active(false);
```

To enable a disabled feature, enter

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).active(true);
```

You can get the enabled/disabled status of a feature by entering

```
boolean isEnabled = model.component(<ctag>).mesh(<tag>).feature(<ftag>).active();
```

Clearing Meshes

To clear the mesh of a sequence, enter

```
model.component(<ctag>).mesh(<tag>).clearMesh();
```

To clear the mesh and remove all features in a sequence, enter

```
model.component(<ctag>).mesh(<tag>).feature().clear();
```

To clear all meshes for all geometries in a model, enter

```
model.component(<ctag>).mesh().clearMeshes();
```

Units

The meshing sequence uses the same base unit system as the geometry sequence. The string versions of setters and getters support units and unit conversion using the standard machinery.

Selections

Most mesh features have selections, to specify where they operate. To access a feature's selection, use the syntax

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
```

To specify the entire geometry, write

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().allgeom();
```

To specify all geometric entities in dimension *<dim>*, write

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().geom(<dim>).all();
```

To specify the geometric entities that remains to be meshed when the feature is about to be built, use

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().remaining();
```

It is not possible to retrieve the geometric entities of this selection, unless the feature is built.

If `entities` is an integer array of geometric entities in dimension `dim`, use the following syntax to select these entities

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().geom(dim).set(entities);
```

For example, to selection domain 1 and 2 in a 3D geometry, write

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().geom(3).
      set(new int[]{1,2});
```

To add the geometric entities specified in the integer array *<entities>* in dimension *<dim>* to the selection, write

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().geom(<dim>).
      add(<entities>);
```

To remove the geometric entities specified in the integer array *<entities>* in dimension *<dim>* from the selection, write

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().geom(<dim>).
      remove(<entities>);
```

To clear the selection in dimension *<dim>*, write

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection().geom(<dim>).clear();
```

Some features have more than one selection, for example `sweep`, where it is possible to specify `source` and `destination` faces. Use the following syntax to access these selections.

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection(<property>);
```

Thus, to specify boundary 5 as source face on the sweep feature `swe1`, write

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection("sourceface").
      geom(2).set(5);
```

Physics-Controlled Meshing

When a physics-controlled sequence is built, a sequence of ordinary meshing features is created. This sequence can be customized by editing these features. However, do not assume the existence of a certain feature in a Java program designed to run with future versions of COMSOL Multiphysics. The actual contents of the sequence might change.

A physics-controlled meshing sequence examines the physics to automatically determine size attributes and sequence operations needed to create a mesh adapted to the problem. The physics-controlled sequence is based on heuristics and knowledge built-in by application experts. It is not adapted by numerical error estimates — that type of adaptation is provided by mesh adaptation in the solver sequence.

When a mesh is built or a problem solved, the physics-controlled sequence is updated to match the currently active physics. If the sequence is in any other state than physics-controlled, it is not updated or modified before it is built.

By default, a meshing sequence is in the physics-controlled state. If you manually add a feature to the sequence or edit a feature, the sequence automatically switches to the user-controlled state. It is also possible to explicitly switch to user-controlled state by entering

```
model.component(<ctag>).mesh(<tag>).automatic(false);
```

To switch back to physics-controlled mesh, enter

```
model.component(<ctag>).mesh(<tag>).automatic(true);
```

The current sequence is then modified or overwritten next time the sequence is built or the problem is solved.

Use `model.component(<ctag>).mesh(<tag>).isAutomatic()` to determine in which state the sequence is.

You can adjust the overall size of a physics-induced mesh by using the method

```
model.component(<ctag>).mesh(<tag>).autoMeshSize(<size>);
```

The value 5 of *<size>* corresponds to the default size, the values 4, 3, 2, and 1 give you an increasingly finer mesh, whereas the values 6, 7, 8, and 9 give you a coarser mesh. The method `model.component(<ctag>).mesh(<tag>).autoMeshSize()` returns the current size adjustment.

Mesh Sequence Methods for Physics Contributing to the Mesh Control Suggestions

The following methods are available for specifying or checking which physics interfaces and other features that contribute to the mesh control suggestions for a physics-controlled mesh:

The Boolean method `contribute`: `MeshSequence contribute(String physics, boolean state)`, where `physics` is the tag of a physics interface or multiphysics interfaces, and the Boolean `state` is `true` if the physics is contributing and `false` if it is not contributing. To specify a multiphysics interface, use a syntax like `multiphysics/emh1`. Similarly, `physics/ht` is allowed for a physics interface but `ht` is sufficient (for a Heat Transfer interface). In addition, common features can be contributing. To specify a common feature, use the following syntax `common/<feature tag>`, where the right part represents the tag for the common feature.

The Boolean method `contributing`: `boolean contributing(String physics)`, where `physics` is the tag of a physics interface or multiphysics interfaces, and the `contributing` method returns `true` if that physics is contributing; otherwise, it returns `false`.

The following code shows some examples of how to use these methods:

```
model.mesh("mesh1").contribute("ht", false);
model.mesh("mesh1").contribute("multiphysics/emh1", true);
```

```
boolean isActivated = model.mesh("mesh1").contributing("ht");
```

Adaptively Refined Meshes

A meshing sequence can represent an adaptively refined mesh controlled by an Adaptation study feature. The following method is available to return the tag of the study and study feature with adaptation that controls the meshing sequence:

```
model.component(<ctag>).mesh(<tag>).adaptationStudyFeature();
```

If no such study exists, this method returns an empty string.

To specify the study feature with adaptation that controls the meshing sequence, use

```
model.component(<ctag>).mesh(<tag>).adaptationStudyFeature(<studytag>)
```

where *<studytag>* is a path of tags to the Adaptation study feature. Use an empty string to disable study control.

Use the following

Information and Statistics

In this section:

Statistics

Use the `stat()` method on the meshing sequence to determine the number of elements of different types and the quality of elements. Use the `info()` method to obtain topological information, the number of geometric entities, and so forth. When importing mesh, use `infoCurrent()` to obtain topological information about the current (last built) mesh feature, and `info()` to obtain this information about the finalized mesh. See Geometry Object Information Methods for a list of available methods.

The `stat()` method returns an object with a collection of methods that can be queried for statistical information about the current mesh. There is also a selection,

```
model.component(<ctag>).mesh(<tag>).stat().selection()
```

which is used to select geometric entities for which the statistics is calculated. The default selection is the entire geometry. The methods described below also exist directly on the meshing sequence. These methods always return statistics for the entire geometry.

Statistics can be requested per element type. The type is given as a string, denoted *type*, and the possible types are listed in the following table.

TABLE 4-4: ELEMENT TYPES

STRING	ELEMENT	ELEMENT DIMENSION
`vtx`	Vertex element	0
`edg`	Edge element	1
`tri`	Triangular element	2
`quad`	Quadrilateral element	2
`tet`	Tetrahedral element	3
`pyr`	Pyramid element	3
`prism`	Prism element	3
`hex`	Hexahedral element	3
`all`	All elements of maximal dimension in the selection	

The parameter string `all` gives statistics for all elements with the same dimension as the maximal dimension of the current selection. For example, if the entire geometry is selected in 2D, the parameter `all` provides combined statistics for triangular and quadrilateral elements.

To specify the mesh quality measure to use, use the `setQualityMeasure` method. For example,

```
model.component(<ctag>).mesh(<tag>).stat().setQualityMeasure("maxangle")
```

To get the current mesh quality measure, use the `getQualityMeasure` method:

```
String model.component(<ctag>).mesh(<tag>).stat().getQualityMeasure()
```

The following mesh quality measures are available:

TABLE 4-5: MESH QUALITY MEASURES

NAME	DESCRIPTION
`skewness`	Skewness. This measure is based on a calculation of the mesh elements' equiangular skew.
`maxangle`	Maximum angle. This measure is based on the largest angle in the element.
`volcircum`	Volume versus circumradius. This measure is based on a quotient of the element volume and the radius of the circumscribed sphere (or circle) of the element.
`vollength`	Volume versus length. This measure is based on a quotient of element edge lengths and element volume.
`condition`	Condition number. This measure is based on the element dimension divided by the condition number (in the Frobenius norm) of the matrix transforming the element to a reference element.
`growth`	Neighbor growth rate. This measure is based on a mesh element growth rate calculation.
`custom`	A custom mesh quality expression.

- Geometry Object Information
- Selections

Number and Types of Elements

To determine the number of elements of a certain type, use

```
int model.component(<ctag>).mesh(<tag>).stat().getNumElem(type);
```

To get the number of elements of all types, use

```
int model.component(<ctag>).mesh(<tag>).stat().getNumElem();
```

To determine the element types, use

```
String[] model.component(<ctag>).mesh(<tag>).stat().getTypes();
```

If the current selection is not the entire geometry, only elements and types in the current selection is returned. You can also use the methods

```
int model.component(<ctag>).mesh(<tag>).getNumElem(type);
int model.component(<ctag>).mesh(<tag>).getNumElem();
String[] model.component(<ctag>).mesh(<tag>).getTypes();
```

to obtain information about the entire geometry.

To check whether the mesh contains any second-order element, use

```
boolean model.component(<ctag>).mesh(<tag>).hasSecondOrderElements();
```

Quality of Elements

COMSOL Multiphysics includes several different mesh quality measures. The absolute value of the mesh element quality is always between 0 and 1, where 0.0 represents a degenerated element and 1.0 represents the best possible element. A negative value means a contradiction to the COMSOL Multiphysics numbering convention for mesh element vertices (see Mesh Element Numbering Conventions), and the element is then referred to as an *inverted element*. The following mesh quality measures are available:

- The *skewness* (`skewness`), which is based on the mesh elements' equiangular skew.

- The *maximum angle* (`maxangle`), which is based on the largest angle in the element. If no angle is larger than the largest angle of the corresponding optimal element, the quality is one; otherwise, the measure shows how much larger the angle is. This quality measure is insensitive to element anisotropy.
- The *volume versus circumradius* (`volcircum`), which is the default quality measure, is based on the ratios of the inscribed and circumscribed circles' or spheres' radii for the simplex corresponding to each corner of the element. If the simplex cannot be clearly determined (an apex of the pyramid, for example), the corresponding corner is excluded from the consideration.
- The *volume versus length* (`vollength`), which is based on a quotient of element edge lengths and element volume. This quality measure is primarily sensitive to anisotropy.
- The *condition number* (`condition`), which is based on the element dimension divided by the condition number (in the Frobenius norm) of the matrix transforming the element to a reference element.
- The *growth rate* (`growth`), which is based on the mesh elements' local (anisotropic) growth rate.

There is also a *custom* quality measure (`custom`), which is based on a user-defined expression for the mesh element quality.

To retrieve the minimal quality, use

```
double model.component(<ctag>).mesh(<tag>).stat().getMinQuality(type);
double model.component(<ctag>).mesh(<tag>).stat().getMinQuality();
```

To retrieve the mean quality, use

```
double model.component(<ctag>).mesh(<tag>).stat().getMeanQuality(type);
double model.component(<ctag>).mesh(<tag>).stat().getMeanQuality();
```

To calculate a distribution of qualities, use the `getQualityDistr` method.

```
int[] model.component(<ctag>).mesh(<tag>).stat().getQualityDistr(type, <size>);
int[] model.component(<ctag>).mesh(<tag>).stat().getQualityDistr(<size>);
```

The size parameter is a positive integer determining how detailed the distribution is and equals the size of the output array. The distribution can by used to plot a histogram of the element quality. For example, if size equals 10, the first entry in the returned array is the number of elements with quality less than 0.1, and the last entry is the number of elements with quality better than 0.9.

The following methods are available directly on the sequence and provide mesh quality statistics, using the volume versus circumradius quality measure, for the entire geometry:

```
double model.component(<ctag>).mesh(<tag>).getMinQuality(type);
double model.component(<ctag>).mesh(<tag>).getMinQuality();
double model.component(<ctag>).mesh(<tag>).getMeanQuality(type);
double model.component(<ctag>).mesh(<tag>).getMeanQuality();
int[] model.component(<ctag>).mesh(<tag>).getQualityDistr(type, <size>);
int[] model.component(<ctag>).mesh(<tag>).getQualityDistr(<size>);
```

The following methods are available for retrieving and specifying the mesh quality measure, respectively:

```
String model.component(<ctag>).mesh(<tag>).getQualityMeasure();
model.component(<ctag>).mesh(<tag>).setQualityMeasure(String measure);
```

Volume of Elements and Mesh

To determine minimum element volume, area, or length of a certain type, use the method `getMinVolume`:

```
double model.component(<ctag>).mesh(<tag>).stat().getMinVolume(type);
double model.component(<ctag>).mesh(<tag>).stat().getMinVolume();
```

To determine maximum element volume, area, or length of a certain type, use the method `getMaxVolume`:

```
double model.component(<ctag>).mesh(<tag>).stat().getMaxVolume(type);
```

```
double model.component(<ctag>).mesh(<tag>).stat().getMaxVolume();
```

To determine the volume, area, or length of the mesh, use the method `getVolume`:

```
double model.component(<ctag>).mesh(<tag>).stat().getVolume(type);
double model.component(<ctag>).mesh(<tag>).stat().getVolume();
```

The following methods are available directly on the sequence, and provide volume information about the entire geometry:

```
double model.component(<ctag>).mesh(<tag>).getMinVolume(type);
double model.component(<ctag>).mesh(<tag>).getMinVolume();
double model.component(<ctag>).mesh(<tag>).getMaxVolume(type);
double model.component(<ctag>).mesh(<tag>).getMaxVolume();
double model.component(<ctag>).mesh(<tag>).getVolume(type);
double model.component(<ctag>).mesh(<tag>).getVolume();
```

Growth Rate in Mesh

The growth rate value is a local measure greater than or equal to 1 indicating the maximum element size growth rate between two neighboring elements.

To retrieve the maximal growth rate value for a selection, use

```
double model.component(<ctag>).mesh(<tag>).stat().getMaxGrowthRate();
```

To retrieve the average growth rate for a selection, use

```
double model.component(<ctag>).mesh(<tag>).stat().getMeanGrowthRate();
```

The following methods are available directly on the sequence, and provide statistics for the entire geometry:

```
double model.component(<ctag>).mesh(<tag>).getMaxGrowthRate();
double model.component(<ctag>).mesh(<tag>).getMeanGrowthRate();
```

Mesh Status

You can check if the entire selected geometry has a mesh by calling the `isComplete` method.

```
boolean model.component(<ctag>).mesh(<tag>).stat().isComplete();
```

To check if the entire geometry is meshed, use

```
boolean model.component(<ctag>).mesh(<tag>).isComplete();
```

You can also check if the selected geometry has an empty mesh by calling the `isEmpty` method.

```
boolean model.component(<ctag>).mesh(<tag>).stat().isEmpty();
```

To check if the entire geometry has an empty mesh, use

```
boolean model.component(<ctag>).mesh(<tag>).isEmpty();
```

Getting and Setting Mesh Data

The data in the mesh object can be accessed and manipulated via *getters and setters*. You can get vertex coordinates, elements, and for each element the number of its geometric entity. The element matrix consists of indexes into the vertex list. The entity list contains the entity number of each element. There is one element matrix and one entity number list for each type.

Accessing Mesh Data

To get the number of mesh vertices, use

```
int model.component(<ctag>).mesh(<tag>).getNumVertex();
```

To get the coordinates of the mesh vertices, use

```
double[][] model.component(<ctag>).mesh(<tag>).getVertex();
```

which gives you a matrix where each column corresponds to a mesh vertex.

To get the element types in the mesh, use

```
String[] model.component(<ctag>).mesh(<tag>).getTypes();
```

The following table lists the possible types. See Mesh Element Numbering Conventions for an explanation of each type.

STRING	ELEMENT	DIMENSION	NUMBER OF NODES
vtx	Vertex element	0	1
edg	Edge element	1	2
tri	Triangular element	2	3
quad	Quadrilateral element	2	4
tet	Tetrahedral element	3	4
pyr	Pyramid element	3	5
prism	Prism element	3	6
hex	Hexahedral element	3	8

To get the number of elements of a specific type, use

```
int model.component(<ctag>).mesh(<tag>).getNumElem(type);
```

To get the elements for a specific type, use

```
int[][] model.component(<ctag>).mesh(<tag>).getElem(type);
```

which gives you a matrix where each column contains the mesh vertex indices of an element's corners.

To get the geometric entity number for the elements of a specific type, use

```
int[] model.component(<ctag>).mesh(<tag>).getElemEntity(type);
```

To return the tags of imported mesh selections, use

```
String[] outputSelection();
```

The tag for the corresponding selection feature can then be derived by adding component tag and feature tag in front of the mesh selection tag. For example, if a mesh selection feature is imported by a feature `imp1` in component

comp1, and its tag (returned by the function outputSelection()) is foo, the tag of the selection feature is comp1_imp1_foo.

Information and Statistics

Setting or Modifying Mesh Data

You can modify the mesh object of a meshing sequence via the data() method. Using this method you access a temporary object (MeshData) storing mesh data. When you use the data() method the first time the MeshData object is empty. You can fill it with mesh data by using various set methods or by transferring mesh data from the mesh of the meshing sequence. Call the method data().createMesh to construct a complete mesh from the MeshData object and store it in the meshing sequence. If the geometry is not empty, the new mesh is checked to ensure that it matches the geometry. Thus, to create an arbitrary mesh, you need to create an empty geometry sequence and a corresponding empty meshing sequence and construct the mesh on the empty meshing sequence.

To set the mesh vertices, use

```
model.component(<ctag>).mesh(<tag>).data().setVertex(double[][]);
```

where each column of the input matrix contains the coordinates of a mesh vertex.

To set the elements of a specific type, use

```
model.component(<ctag>).mesh(<tag>).data().setElem(type, int[][]);
```

where each column of input element matrix contains the mesh vertex indices of an element's corners.

If you want to specify the geometric entity number for the elements of a specific type, use

```
model.component(<ctag>).mesh(<tag>).data().setElemEntity(type, int[]);
```

The MeshData object has the same access methods as the meshing sequence.

```
int model.component(<ctag>).mesh(<tag>.data().getNumVertex();
double[][] model.component(<ctag>).mesh(<tag>).data().getVertex();
String[] model.component(<ctag>).mesh(<tag>).data().getTypes();
int model.component(<ctag>).mesh(<tag>).data().getNumElem(type);
int[][] model.component(<ctag>).mesh(<tag>).data().getElem(type);
int[] model.component(<ctag>).mesh(<tag>).data().getElemEntity(type);
```

Accessing Mesh Data

It is also possible to fill the MeshData object with mesh data from the mesh of a meshing sequence. To transfer the mesh from the current meshing sequence into the MeshData object, use

```
model.component(<ctag>).mesh(<tag>).data().transferMesh();
```

To transfer the mesh from another meshing sequence, specified by *mtag*, into the MeshData object, use

```
model.component(<ctag>).mesh(<tag>).data().transferMesh(mtag);
```

To clear the MeshData object, use

```
model.component(<ctag>).mesh(<tag>).data().clearData();
```

To create a complete mesh from the MeshData object and store it in the sequence, use

```
model.component(<ctag>).mesh(<tag>).data().createMesh();
```

This method uses several properties when creating a complete mesh from the specified mesh data. To set a property, use

```
model.component(<ctag>).mesh(<tag>).data().set(property, <value>);
```

To get a property, use

```
model.component(<ctag>).mesh(<tag>).data().getType(property);
```

The following properties are available.

TABLE 4-6: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	2D	3D	DESCRIPTION
extrangle	double	0.6 degrees		√	Maximum angle between boundary element normal and extrusion plane that causes the element to be a part the extruded face if possible.
faceangle	double	360 degrees		√	Maximum angle between any two boundary elements in the same face.
facecleanup	double	0.01		√	Avoid creating small faces. Faces with an area less than Facecleanup * the mean face area, are merged with adjacent faces.
facecurv	double	10 degrees		√	Maximum relative angle deviation between any two boundary elements in the same face.
minareacurv	double	1		√	Minimum relative area of face to be considered as a face with constant curvature.
minareaextr	double	0.05		√	Minimum relative area of face to be considered extruded.
minareaeplane	double	0.005	√	√	Minimum relative area of face to be considered planar.
neighangle	double	20 degrees	√	√	Maximum angle between a boundary element and a neighbor that causes the elements to be part of the same boundary domain if possible.
planarangle	double	0.6 degrees	√	√	Maximum angle between boundary element normal and a neighbor that causes the element to be a part the planar face if possible

EXAMPLES OF SETTING OR MODIFYING MESH DATA

The following examples create a triangular mesh on a square, extracts the vertices and the triangles. Then the vertices are transformed and inserted into a new meshing sequence.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");

model.component("comp1").geom().create("geom1", 2);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

// Create a rectangle and a mesh
model.component("comp1").geom("geom1").create("r1", "Rectangle");
m.create("ftri1", "FreeTri");
m.run();

double[][] vtx = m.getVertex();
int[][] tri = m.getElem("tri");

// Transform x coordinates
for (int k=0; k<vtx[0].length; k++)
  vtx[0][k] *= 0.5;

// Create a new geometry and mesh
```

```
model.component("comp1").geom().create("geom2", 2);
MeshSequence m2 = model.component("comp1").mesh().create("mesh2", "geom2");

// Insert vertices and triangles and create mesh
m2.data().setElem("tri", tri);
m2.data().setVertex(vtx);
m2.data().createMesh();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');

model.component('comp1').geom.create('geom1', 2);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

% Create a rectangle and a mesh
model.component('comp1').geom('geom1').create('r1', 'Rectangle');
m.create('ftri1', 'FreeTri');
m.run;

vtx = m.getVertex;
tri = m.getElem('tri');

% Transform x coordinates
vtx(1,:) = vtx(1,:)*0.5;

% Create a new geometry and mesh
model.component('comp1').geom.create('geom2', 2);
m2 = model.component('comp1').mesh.create('mesh2', 'geom2');

% Insert vertices and triangles and create mesh
m2.data.setElem('tri', tri);
m2.data.setVertex(vtx);
m2.data.createMesh;
```

Block Versions

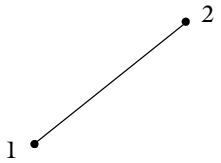
Since the amount of available Java memory might be limited, there are block versions of the mesh setters and getters, which sets or gets a subset of the data. The getters take a *position* argument, which specifies the first item to get, and a *number* argument, which specifies the number of items to get. The setters takes only the position argument; the number of items is determined by the size of the provided data. When working with the setters, remember that it is more efficient to set the data at the last position first, since sufficient space in then allocated directly and no copying and reallocation is needed.

```
double[][] model.component(<ctag>).mesh(<tag>).getVertex(int position, int number);
int[][] model.component(<ctag>).mesh(<tag>).getElem(type, int position, int number);
int[] model.component(<ctag>).mesh(<tag>).getGeomEntity(type, int position, int number);

model.component(<ctag>).mesh(<tag>).data().setVertex(double[][], int position);
model.component(<ctag>).mesh(<tag>).data().setElem(type, int[][], int position);
model.component(<ctag>).mesh(<tag>).data().setGeomEntity(type, int[], int position);

double[][] model.component(<ctag>).mesh(<tag>).data().getVertex(int position, int number);
int[][] model.component(<ctag>).mesh(<tag>).data().getElem(type, int position, int number);
int[] model.component(<ctag>).mesh(<tag>).data().getGeomEntity(type, int position,
            int number);
```

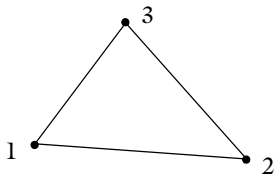
Mesh Element Numbering Conventions

The (local) numbering of the corners of a mesh element is defined according to the following.

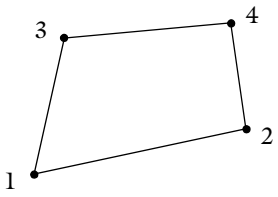
Edge element (`edg`):



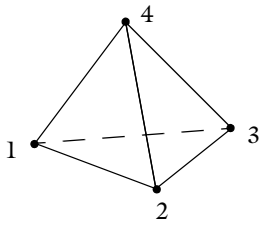
Triangular element (`tri`):



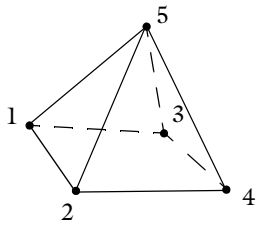
Quadrilateral element (`quad`):



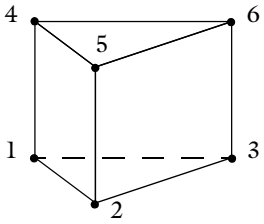
Tetrahedral element (`tet`):



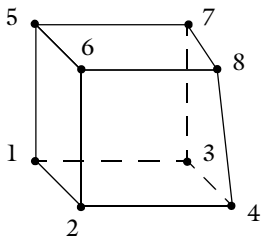
Pyramid element (`pyr`):



Prism element (`prism`):



Hexahedral element (`hex`):



Errors and Warnings

COMSOL Multiphysics treats problems encountered when building a meshing feature in two different ways depending on if it is possible to avoid the problem and continue the operation or if the operation must be stopped.

See also Errors and Warnings in the *General Commands* chapter.

Continuing Operations

In most cases when you build a mesh feature and problems are detected on some geometric entities, those entities and adjacent entities are left unprocessed. The operation continues meshing the remaining entities and stores information about the encountered problems in the feature. A feature that encountered this type of problems during the build gets an error status. If you build several mesh features in a sequence, the build is not stopped by a feature that fails to process some of its entities. However, some errors are considered as fatal and therefore stop the build process. Failure to process one or more entities in some operation will always result in a thrown exception when all specified features are built, even if the build process was not stopped directly.

The information on the encountered problems for a feature with warning status is contained in `MeshError` and `MeshWarning` features stored in the feature. There is one `MeshError` feature for each geometric entity that failed to be meshed and one `MeshWarning` feature for each dimension where there exists an entity that could not be meshed due to failures meshing any of its adjacent entities.

Use the `continue` property to control whether any of the previously listed meshing features should avoid encountered problems and continue to mesh or if it should stop at the first encountered problem.

Stopping Operations

When you build a feature other than any of the `BndLayer`, `FreeTri`, `FreeQuad`, `FreeTet`, `Map`, or `Sweep` features, the operation always stops if a problem is encountered. This means that no changes are made to the mesh. The feature gets an error status and if it is part of a sequence build the build stops and the preceding feature becomes the current feature. Information on the error is contained in a `MeshError` feature stored in the feature.

The MeshError Feature

A `MeshError` feature contains an error message and can be equipped with a selection defining the failed entity, or a coordinate value specifying a position related to the error. It can also be equipped with details about the error. A `MeshError` feature can have a children feature of `MeshError` type that contains low-level error information. This means that an error can be represented by a stack of `MeshError` features that reflects the stack trace of the error.

The MeshWarning Feature

One `MeshWarning` feature is generated for each dimension where there are entities that cannot be meshed due to previous errors. For example, if there are edges that fail to be meshed for a `FreeTet` feature operating on the entire geometry there is one `MeshWarning` feature for the adjacent faces and one `MeshWarning` feature for the adjacent domains.

The `MeshWarning` feature contains a selection defining the entities that could not be meshed and a message describing the cause for this.

Exporting Meshes to Files

Exporting Mesh to a File

To export a mesh to a file, enter

```
model.mesh(<tag>).export(<filename>);
```

where *<filename>* is a string. The file can be any of the following formats.

TABLE 4-7: VALID FILE FORMATS

FILE FORMAT	NOTE	FILE EXTENSIONS
COMSOL Multiphysics Binary		`.mphbin`
COMSOL Multiphysics Text		`.mphtxt`
NASTRAN file		`.nas`, `.bdf`, `.nastran`, `.dat`
STL Binary (3D)	1	`.stl`
STL Text (3D)	1	`.stl`

[1] Use model.mesh(*<tag>*).export().set("stlformat",*<format>*) to specify the STL file format ("*binary*" or "*text*")

Exporting Mesh to a COMSOL Multiphysics File

To specify the dimensions of the elements to export or to choose to include or exclude the geometric entity information, enter

```
model.mesh(<tag>).export().set(<property>,<value>);
```

The following table lists the available properties:

TABLE 4-8: AVAILABLE COMSOL MESH EXPORT PROPERTIES AND THEIR VALID VALUES.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`domelem`	`on` | `off`	`on`	Specify if domain elements are exported.
`bndelem`	`on` | `off`	`on`	Specify if boundary elements are exported.
`edgelem`	`on` | `off`	`on`	Specify if edge elements are exported (3D only).
`vtxelem`	`on` | `off`	`on`	Specify if vertex elements are exported (2D and 3D only).
`geominfo`	`on` | `off`	`on`	Specify if geometric entity information for each element is exported.
`selection`	`on` | `off`	`off`	Specify if mesh selections are exported.

Exporting Mesh to a NASTRAN® File

To specify the dimensions of the elements to export, to choose to include or exclude the geometric entity information, or to set the file field format or element order, enter

```
model.component(<ctag>).mesh(<tag>).export().set(<property>,<value>);
```

The following table lists the available properties:

TABLE 4-9: AVAILABLE NASTRAN MESH EXPORT PROPERTIES AND THEIR VALID VALUES.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`solidelem`	`on` | `off`	`on`	Specify if domain elements are exported.
`shellelem`	`on` | `off`	`off`	Specify if boundary elements are exported (3D only).
`geominfo_nastran`	`on` | `off`	`on`	Specify if geometric entity information for each element is exported.

TABLE 4-9: AVAILABLE NASTRAN MESH EXPORT PROPERTIES AND THEIR VALID VALUES.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`fieldformat`	`small` | `large` | `free`	`small`	Specify file field format.
`linear`	`on` | `off`	`off`	Specify if elements are exported as linear or second-order (quadratic) elements.

Mesh Commands

The following list includes the available commands for creating and modifying meshes (listed in alphabetical order):

- Adapt
- Ball
- BndLayer
- BndLayerProp
- Box
- Convert
- CopyEdge
- CopyFace
- CopyDomain
- Copy
- CornerRefinement
- CreateVertex
- Cylinder
- Delete
- DeleteEntities
- DetectFaces
- Distribution
- Edge
- EdgeGroup
- EdgeMap
- FreeQuad
- FreeTet
- FreeTri
- Import
- JoinEntities
- LogicalExpression
- Map
- OnePointMap
- Point
- Reference
- Refine
- Scale
- Size
- Sweep
- TwoPointMap

Adapt

Set up an adaptive mesh refinement.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Adapt");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Adapt")` to set up a mesh adaptation based on some expressions and criteria. The adaptive mesh refinement feature is also available for imported mesh sequences.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify geometric entities to perform adaptive mesh refinement in. If you do not specify the selection, the feature operates on the entire geometry.

To use an anisotropic metric for the type of expression to base the adaptive mesh refinement on, use the following code for a 2D anisotropic expression in the local mesh size `h`:

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set("method", "modify");
model.component(<ctag>).mesh(<tag>).feature("ada1").set("exprtype", "metric");
```

```
model.component(<ctag>).mesh(<tag>).feature("ada1").
   set("metric", new String[][]{{"2/h", "0"}, {"0", "1/h"}});
```

The following properties are available.

TABLE 4-10: AVAILABLE PROPERTIES FOR ADAPT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapsolnum	Integer array (positive values)	1	Solution number indices, determining which solutions in a parametric or eigenvalue simulation to use for the adaptation.
allowcoarsening	on | off	on	Controls if the mesh can be coarsened by the general modification method (method set to modify).
elementspar	Positive scalar		Controls refinement if elselect = elements.
elselect	globalmin | worst | elements		Method to select elements to refine.
errorexpr	String		Error expression.
exprtype	size | error | metric	size	Type of expression for the adaptive mesh generation: an absolute size, an error expression, or (2D and 3D) an anisotropic metric.
globalminparam	Positive scalar		Controls refinement if elselect = globalmin.
horder	Double array	0	Error orders (see below).
method	modify | regular | longest	longest	The refinement method for mesh adaptation (general mesh modification, regular refinement, or longest edge refinement)
metric	2-by-2 (2D) or 3-by-3 (3D) symmetric string matrix	{{"1/h", "0"}, {"0", "1/h"}}	
selection	first | last | all | manual	last	Solution selection: the first or last solution, a sum of the selection, or manual, using weights and solution number indices in adapsolnum.
sizeexpr	String		Mesh size expression.
solution	String		The solution defining the mesh adaptation.
weights	Double array (positive values)	1.0	Weight for each selected solution.
worstpar	Positive scalar		Controls refinement if elselect = worst.

SEE ALSO

Refine, SizeExpression

Ball

Split geometric entities of an imported mesh by a ball.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Ball");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Ball")` to split geometric entities of an imported 2D or 3D mesh by an element set defined by a ball.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify geometric entities to split. If you do not specify the selection, the feature operates on the entire geometry.

The following properties are available:

TABLE 4-11: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
posx	double	0	Center, first coordinate.
posy	double	0	Center, second coordinate.
posz	double	0	Center, third coordinate.
r	double	1	Radius.
condition	allvertices | somevertex	allvertices	Condition for inclusion of an element.

SEE ALSO

Import, Box, Cylinder, DetectFaces, LogicalExpression

BndLayer

Create a boundary layer mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"BndLayer");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"BndLayerProp");
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"BndLayer")` to create a boundary layer mesh in 2D or 3D.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain selection. If you do not specify the selection, the feature operates on all domains.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"BndLayerProp")` to add a `BndLayerProp` attribute feature defining the locations and properties of the boundary layers.

The feature reads properties from the `BndLayerProp` attribute feature.

The following properties are available:

TABLE 4-12: AVAILABLE PROPERTIES FOR BNDLAYER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
continue	on | off	on	When enabled, the mesher does not stop if there is an error.
sharpcorners	none | split | trim	split	Specifies the handling of sharp corners in 2D and sharp edges in 3D.
splitangle	double	240[deg]	Minimum angle between boundary layer boundaries to introduce a boundary layer split.
splitdivangle	double	100[deg]	Maximum angle per split.
trimmaxangle	double	50[deg]	Maximum angle between boundary layer boundaries for boundary layer trimming.
trimminangle	double	240[deg]	Minimum angle between boundary layer boundaries for boundary layer trimming.
layerdec	integer	2	Maximum difference in number of boundary layers between neighboring points on boundary layer boundaries.
smoothtransition	on | off	on	Specifies if the operation smooths the transition to interior mesh.
smoothmaxiter	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
smoothmaxdepth	integer	16 in 2D, 6 in 3D	Specifies the maximum element smoothing depth.

EXAMPLES

Insert boundary layers to an existing mesh containing both quadrilateral elements and triangular elements.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("sq1", "Square");
g.create("sq2", "Square");
g.feature("sq2").setIndex("pos", "1", 0);
g.create("c1", "Circle");
g.feature("c1").set("r", "0.2");
g.feature("c1").setIndex("pos", "1.5", 0);
g.feature("c1").setIndex("pos", "0.5", 1);
g.create("co1", "Compose");
g.feature("co1").selection("input").init().set(new String[]{"c1", "sq1", "sq2"});
g.feature("co1").set("formula", "sq1+sq2-c1");
g.run();

m.create("map1", "Map");
m.feature("map1").selection().geom("geom1", 2);
m.feature("map1").selection().set(new int[]{1});
m.create("ftri1", "FreeTri");
m.create("bl1", "BndLayer");
m.feature("bl1").create("blp", "BndLayerProp");
m.feature("bl1").feature("blp").selection().set(new int[]{2, 3, 5, 6, 8, 9, 10, 11});
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
```

```
m = model.component('comp1').mesh.create('mesh1', 'geom1');
g.create('sq1', 'Square');
g.create('sq2', 'Square');
g.feature('sq2').setIndex('pos', '1', 0);
g.create('c1', 'Circle');
g.feature('c1').set('r', '0.2');
g.feature('c1').setIndex('pos', '1.5', 0);
g.feature('c1').setIndex('pos', '0.5', 1);
g.create('co1', 'Compose');
g.feature('co1').selection('input').init.set({'c1', 'sq1', 'sq2'});
g.feature('co1').set('formula', 'sq1+sq2-c1');
g.run;

m.create('map1', 'Map');
m.feature('map1').selection.geom('geom1', 2);
m.feature('map1').selection.set(1);
m.create('ftri1', 'FreeTri');
m.create('bl1', 'BndLayer');
m.feature('bl1').create('blp', 'BndLayerProp');
m.feature('bl1').feature('blp').selection.set([2, 3, 5, 6, 8, 9, 10, 11]);
m.run;
```

Create a boundary layer mesh consisting of prism elements along the boundary layer boundaries and tetrahedral elements in the interior:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.feature("blk1").setIndex("size", "10", 0);
g.feature("blk1").setIndex("size", "5", 1);
g.feature("blk1").setIndex("size", "5", 2);
g.create("sph1", "Sphere");
g.feature("sph1").setIndex("pos", "3", 0);
g.feature("sph1").setIndex("pos", "2.5", 1);
g.feature("sph1").setIndex("pos", "2.5", 2);
g.create("dif1", "Difference");
g.feature("dif1").selection("input").init().set(new String[]{"blk1"});
g.feature("dif1").selection("input2").init().set(new String[]{"sph1"});
g.run();

m.create("ftet1", "FreeTet");
m.create("bl1", "BndLayer");
m.feature("bl1").create("blp", "BndLayerProp");
m.feature("bl1").feature("blp").selection().
  set(new int[]{2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13});
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.feature('blk1').setIndex('size', '10', 0);
g.feature('blk1').setIndex('size', '5', 1);
g.feature('blk1').setIndex('size', '5', 2);
g.create('sph1', 'Sphere');
g.feature('sph1').setIndex('pos', '3', 0);
g.feature('sph1').setIndex('pos', '2.5', 1);
```

```
g.feature('sph1').setIndex('pos', '2.5', 2);
g.create('dif1', 'Difference');
g.feature('dif1').selection('input').init.set({'blk1'});
g.feature('dif1').selection('input2').init.set({'sph1'});
g.run;

m.create('ftet1', 'FreeTet');
m.create('bl1', 'BndLayer');
m.feature('bl1').create('blp', 'BndLayerProp');
m.feature('bl1').feature('blp').selection.set(2:13);
m.run;
```

SEE ALSO

BndLayerProp, Map, Sweep

BndLayerProp

Set the boundary layer meshing properties.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"BndLayerProp");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).
      set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"BndLayerProp")` to define boundary layer properties for the `BndLayer` feature *<ftag>*.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection()` to specify the boundary selection. If you do not specify the selection, it is empty.

The following properties are available:

TABLE 4-13: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`blhminfact`	string | double	1	Factor used to adjust the default thickness
`blhmin`	string | double		Manual initial boundary layer thickness
`blnlayers`	string | integer	8	Number of boundary layers
`blstretch`	string | double	`1.2`	Boundary layer stretching factor
`const`	String array of property/ value pairs	`Empty`	Parameters to use in the expressions.
`inittype`	`blhminfact` | `blhmin`	`blhminfact`	Selects whether blhmin or blhminfact is used.

Use the properties `blhmin`, `blstretch`, and `blnlayers` to specify the distribution of the boundary layers. `blhmin` specifies the thickness of the initial boundary layer, `blstretch` a stretching factor, and `blnlayers` the number of boundary layers. This means that the thickness of the mth boundary layer (m=1 to blnlayers) is $\text{blstretch}^{(m-1)}\text{blhmin}$. The number of boundary layers and the thickness of the boundary layers might be automatically reduced in thin regions.

It is also possible to specify the thickness of the initial layer by using the `blhminfact` property. Then, the thickness of the first layer is 1/20 of the local domain element height. Use the `blhminfact` property to specify a scaling factor that multiplies this default size.

The property `inittype` determines which of `blhminfact` or `blhmin` that is used. You do not need to set it explicitly because the feature automatically changes it when you set one of `blhmin` or `blhminfact`.

The values of `blhmin`, `blhminfact`, and `blstretch` are positive real scalars, or strings that evaluate to positive real scalars, given the evaluation context provided by the property `const`.

The value of `blnlayers` is a positive integer scalar, or a string that evaluates to a positive integer, given the evaluation context provided by the property `const`.

SEE ALSO

`BndLayer`, `Scale`, `Size`

Box

Split geometric entities of an imported mesh by a box.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Box");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Box")` to split geometric entities of an imported 2D or 3D mesh by an element set defined by a box.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify geometric entities to split. If you do not specify the selection, the feature operates on the entire geometry.

The following properties are available:

TABLE 4-14: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`xmin`	double	`-inf`	Minimum x-coordinate of box
`xmax`	double	`inf`	Maximum x-coordinate of box
`ymin`	double	`-inf`	Minimum y-coordinate of box
`ymax`	double	`inf`	Maximum y-coordinate of box
`zmin`	double	`-inf`	Minimum z-coordinate of box
`zmax`	double	`inf`	Maximum z-coordinate of box
`condition`	`allvertices` | `somevertex`	`allvertices`	Condition for inclusion of an element

SEE ALSO

`Import`, `Ball`, `Cylinder`, `DetectFaces`, `LogicalExpression`

Convert

Convert a mesh to a simplex mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Convert");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Convert")` to convert non-simplex elements in a 2D or 3D mesh to simplex elements, that is, triangles and tetrahedra. The convert feature is also available for imported mesh sequences.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain or face selection. If you do not specify the selection the feature converts all quadrilateral, pyramidal, prismatic, and hexahedral elements in the mesh.

The following properties are available:

TABLE 4-15: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`splitmethod`	`diagonal` | `center`	`diagonal`	Split method for quadrilateral and hexahedral elements.

Use the property `splitmethod` to specify how to split quadrilateral and hexahedral elements into triangular and tetrahedral elements, respectively. Use the `diagonal` option to split each quadrilateral element into two triangular elements and each hexahedral element into five tetrahedral element. Use the `center` option to split each quadrilateral element into four triangular elements and each hexahedral element into 28 tetrahedral elements. The conversion also affects quadrilateral elements on the boundaries of the specified domains in 3D, which are converted into two triangular elements (when the option `diagonal` is used) or four triangular elements (when the option `center` is used).

EXAMPLES

Create a mapped quad mesh on a unit rectangle and convert each quadrilateral element into four triangular elements:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("r1", "Rectangle");
g.run();

m.create("map1", "Map");
m.create("conv1", "Convert");
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('r1', 'Rectangle');
g.run;

m.create('map1', 'Map');
m.create('conv1', 'Convert');
m.run;
```

Create a prism mesh and then convert each prism into three tetrahedral elements:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
```

```
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.run();

m.create("ftri1", "FreeTri");
m.feature("ftri1").selection().set(new int[]{1});
m.create("swe1", "Sweep");
m.create("conv1", "Convert");
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.run;

m.create('ftri1', 'FreeTri');
m.feature('ftri1').selection().set(1);
m.create('swe1', 'Sweep');
m.create('conv1', 'Convert');
m.run;
```

SEE ALSO

`BndLayer`, `Map`, `Refine`, `Sweep`

CopyEdge

Copy an edge mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"CopyEdge");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"CopyEdge")` to copy mesh between edges in a 2D or 3D geometry.

The following properties are available:

TABLE 4-16: AVAILABLE PROPERTIES FOR COPYEDGE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`direction`	`auto` | `same` | `opposite`	auto	Direction of the copied mesh.
`copymethod`	`auto` | `singlecopy` | `arraycopy`	auto	Type of copy operation.
`source`	Selection	Empty	Source edges.
`destination`	Selection	Empty	Destination edges.
`smoothcontrol`	`on` | `off`	on	Specifies if the operation smooths the mesh across removed control entities.
`smoothmaxiter`	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
`smoothmaxdepth`	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.

Use the properties `source` and `destination` to specify the source and destination edges. The copymethod property determines if many-to-one or many-to-many copying is used. The `direction` property controls the orientation of the copied mesh, and is relative the direction of the source edge with smallest number and the direction of the destination edge.

Copying a mesh is only possible if the destination edge is not adjacent to a meshed domain. The copy feature overwrites any existing mesh on the destination edge.

EXAMPLE

Mesh Edge 1 and copy the mesh to Edges 2, 3, and 4.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("sq1", "Square");
g.run();

m.create("edg1", "Edge");
m.feature("edg1").selection().set(new int[]{1});
m.create("cpe1", "CopyEdge");
m.feature("cpe1").selection("source").set(new int[]{1});
m.feature("cpe1").selection("destination").set(new int[]{2, 3, 4});
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('sq1', 'Square');
g.run;

m.create('edg1', 'Edge');
m.feature('edg1').selection().set(1);
m.create('cpe1', 'CopyEdge');
m.feature('cpe1').selection('source').set(1);
m.feature('cpe1').selection('destination').set(2:4);
m.run;
```

SEE ALSO

`CopyFace`, `CopyDomain`, `Copy`

CopyFace

Copy a face mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"CopyFace");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,maptype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"CopyFace")` to copy mesh between faces in a 3D geometry.

If you want to specify the orientation of the source mesh on the destination, use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,maptype)` to add an `EdgeMap`, `OnePointMap`, or `TwoPointMap` attribute feature.

The following properties are available:

TABLE 4-17: AVAILABLE PROPERTIES FOR COPYFACE

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`copymethod`	`auto` | `singlecopy` | `arraycopy`	auto	Type of copy operation.
`source`	Selection	Empty	Source boundaries.
`destination`	Selection	Empty	Destination boundary.
`smoothcontrol`	`on` | `off`	on	Specifies if the operation smooths the mesh across removed control entities.
`smoothmaxiter`	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
`smoothmaxdepth`	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.

Use the properties `source` and `destination` to specify the source and destination boundaries. The copymethod property determines if many-to-one or many-to-many copying is used.

EXAMPLE

Mesh Face 1 of a block and copy the mesh to the opposite Face 6.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
MeshSequence m= model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.run();

m.create("ftri1", "FreeTri");
m.feature("ftri1").selection().set(new int[]{1});
m.create("cpf1", "CopyFace");
m.feature("cpf1").selection("source").set(new int[]{1});
m.feature("cpf1").selection("destination").set(new int[]{6});
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.run;

m.create('ftri1', 'FreeTri');
m.feature('ftri1').selection().set(1);
m.create('cpf1', 'CopyFace');
m.feature('cpf1').selection('source').set(1);
m.feature('cpf1').selection('destination').set(6);
m.run;
```

SEE ALSO

`CopyEdge`, `CopyDomain`, `Copy`, `EdgeMap`, `OnePointMap`, `TwoPointMap`

CopyDomain

Copy a domain mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"CopyDomain");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,maptype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"CopyDomain")` to copy mesh between domains in a 2D or 3D geometry.

If you want to specify the orientation of the source mesh on the destination, use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,maptype)` to add an `EdgeMap`, `OnePointMap`, or `TwoPointMap` attribute feature.

The following properties are available:

TABLE 4-18: AVAILABLE PROPERTIES FOR COPYDOMAIN

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`copymethod`	`auto` | `singlecopy` | `arraycopy`	auto	Type of copy operation.
`source`	Selection	Empty	Source domains.
`destination`	Selection	Empty	Destination domains.
`smoothcontrol`	`on` | `off`	`on`	Specifies if the operation smooths the mesh across removed control entities.
`smoothmaxiter`	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
`smoothmaxdepth`	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.

Use the properties `source` and `destination` to specify the source and destination boundaries. The `copymethod` property determines if many-to-one or many-to-many copying is used.

EXAMPLE

Mesh block 1 and copy the mesh to the block 2.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.create("blk2", "Block");
g.feature("blk2").setIndex("pos", "2", 0);
g.run();

m.create("ftet1", "FreeTet");
m.feature("ftet1").selection().set(new int[]{1});
m.create("cpd1", "CopyDomain");
m.feature("cpd1").selection("source").set(new int[]{1});
m.feature("cpd1").selection("destination").set(new int[]{2});
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
```

```
g = model.component('comp1').geom.create('geom1', 3);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.create('blk2', 'Block');
g.feature('blk2').setIndex('pos', '2', 0);
g.run;

m.create('ftet1', 'FreeTet');
m.feature('ftet1').selection().set(1);
m.create('cpd1', 'CopyDomain');
m.feature('cpd1').selection('source').set(1);
m.feature('cpd1').selection('destination').set(2);
m.run;
```

SEE ALSO

CopyEdge, CopyFace, Copy, EdgeMap, OnePointMap, TwoPointMap

Copy

Copy a mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Copy");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,maptype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Copy")` to copy a mesh between meshing sequences. Any meshing sequence can be used as the source of the operation, whereas the destination sequence cannot contain an imported mesh. The dimension of the source sequence must be less than or equal to the dimension of the destination sequence.

The following properties are available (for 1D meshes, only the `mesh` property is available):

TABLE 4-19: AVAILABLE PROPERTIES FOR COPY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`mesh`	String | none	Native sequence (none in 1D)	Specifies the source mesh.
`copymethod`	`auto` | `singlecopy` | `arraycopy`	auto	Type of copy operation.
`dimension`	`all`, 1, 2, or 3 (in 3D)	2 in 2D, 3 in 3D	Specifies the dimension for the operation. `all` means that the entire mesh should be copied.
`source`	Selection	Empty	Specifies the selection of source entities.
`buildsource`	on | `off`	`off`	Build source mesh automatically.
`destination`	Selection	Empty	Specifies the selection of destination entities.
`smoothcontrol`	on | `off`	`on`	Specifies if the operation smooths the mesh across removed control entities.
`smoothmaxiter`	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
`smoothmaxdepth`	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.

Use the properties `source` and `destination` to specify the geometric entities of the source and destination (except when the dimension is set to copy the entire geometry). The `copymethod` property determines if many-to-one or many-to-many copying is used.

EXAMPLE

The following example shows how to use the Copy feature with a modified geometry from an imported mesh:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence geom1 = model.component("comp1").geom().create("geom1", 2);
geom1.create("c1", "Circle");
MeshSequence mesh1 = model.component("comp1").mesh().create("mesh1", "geom1");
mesh1.run();

model.component().create("comp2");
GeomSequence geom2 = model.component("comp2").geom().create("geom2", 2);
GeomFeature imp1 = geom2.create("imp1", "Import");
imp1.set("type", "mesh");
imp1.set("mesh", "mesh1");
GeomFeature r1 = geom2.create("r1", "Rectangle");
r1.set("size", new String[]{"3", "3"});
r1.set("base", "center");

MeshSequence mesh2 = model.component("comp2").mesh().create("mesh2", "geom2");
MeshFeature copy1 = mesh2.create("copy1", "Copy");
copy1.set("mesh", "mesh1");
copy1.set("dimension", 2);
copy1.selection("source").set(1);
copy1.selection("destination").set(2);
mesh2.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
geom1 = model.component('comp1').geom.create('geom1', 2);
geom1.create('c1', 'Circle');
mesh1 = model.component('comp1').mesh.create('mesh1', 'geom1');
mesh1.run;

model.component.create('comp2');
geom2 = model.component('comp2').geom.create('geom2', 2);
imp1 = geom2.create('imp1', 'Import');
imp1.set('type', 'mesh');
imp1.set('mesh', 'mesh1');
r1 = geom2.create('r1', 'Rectangle');
r1.set('size', {'3', '3'});
r1.set('base', 'center');

mesh2 = model.component('comp2').mesh.create('mesh2', 'geom2');
copy1 = mesh2.create('copy1', 'Copy');
copy1.set('mesh', 'mesh1');
copy1.set('dimension', 2);
copy1.selection('source').set(1);
copy1.selection('destination').set(2);
mesh2.run;
```

SEE ALSO

`CopyEdge`, `CopyFace`, `CopyDomain`

CornerRefinement

Decrease element size at sharp corners.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"CornerRefinement");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).vmesh(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"CornerRefinement");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).
  set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"CornerRefinement")` to decrease the element size defined in the sequence at vertices in 2D and edges in 3D that define a sharp corner. Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"CornerRefinement")` to decrease the element size for the feature *<ftag>* that can be any of the types `Edge`, `FreeQuad`, `FreeTri`, or `FreeTet`.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` or `model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection()` to specify the domain selection. If you do not specify any selection, the feature is defined on the entire geometry.

The following properties are available:

TABLE 4-20: VALID PROPERTIES

NAME	VALUE	DEFAULT	DESCRIPTION
`boundary`	Selection		Boundary selection.
`minangle`	double	`240 [deg]`	Minimum angle between two boundaries (sharp corner) for decreasing the element size.
`refinement`	double	`0.25 in 2D, 0.35 in 3D`	Factor multiplying the element size at sharp corners. The valid range is (0 1].

CreateVertex

Create an additional vertex in an imported mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"CreateVertex");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"CreateVertex")` to create an additional vertex in the mesh point closest to a specified position.

The following properties are available:

TABLE 4-21: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
x	double	0	x-coordinate.
y	double	0	y-coordinate.
z	double	0	z-coordinate.

SEE ALSO

`Import`

Cylinder

Split geometric entities of an imported mesh by a cylinder.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Cylinder");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Cylinder")` to split geometric entities of an imported 3D mesh by an element set defined by a cylinder.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify geometric entities to split. If you do not specify the selection, the feature operates on the entire geometry.

The following properties are available:

TABLE 4-22: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`r`	double	`1`	Radius of the cylinder.
`top`	double	`inf`	Coordinate of upper boundary circle in local coordinate system.
`bottom`	double	`-inf`	Coordinate of lower boundary circle in local coordinate system.
`pos`	double[]	`{0,0,0}`	Position of the cylinder.
`axistype`	`x` | `y` | `z` | `Cartesian` | `spherical`	`z`	Coordinate system used for axis. The value is synchronized with `axis`.
`axis`	double[]	`{0,0,1}`	Direction of the axis. Vector has length 3 if `axistype` is `cartesian`, and length 2 if `axistype` is `spherical`.
`condition`	`allvertices` | `somevertex`	`allvertices`	Condition for inclusion of an element.

SEE ALSO

`Import`, `Ball`, `Box`, `DetectFaces`, `LogicalExpression`

Delete

Delete elements from mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Delete");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Delete")` to delete elements from the mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the geometric entity selection. Allowed selections are meshed geometric entities of any dimension and the entire geometry, which can be partially meshed.

The following properties are available:

TABLE 4-23: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
deladj	on | off	on	Specifies if elements belonging to adjacent domains of lower dimensions are deleted as well.

Deleting elements corresponding to a specific domain, all elements on adjacent domains of higher dimension are deleted as well.

EXAMPLE

Create a mesh of a 2D geometry with 3 domains. First, delete the elements belonging to Domain 3 only. Then delete the elements belonging to Domain 1 and all adjacent domains of lower dimensions that can be deleted. At last, delete the edge elements belonging to Edge 1. The elements belonging to the adjacent domain (Domain 2) are deleted as well.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
MeshSequence m= model.component("comp1").mesh().create("mesh1", "geom1");

g.create("R1", "Rectangle");
g.create("C1", "Circle");
g.run();

m.create("ftri1", "FreeTri");

m.create("del1","Delete");
m.feature("del1").selection().geom(2).set(3);
m.feature("del1").set("deladj","off");

m.create("del2","Delete");
m.feature("del2").selection().geom(2).set(1);
m.feature("del2").set("deladj","on");

m.create("del3","Delete");
m.feature("del3").selection().geom(1).set(1);

m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
m = model.component('comp1').mesh.create('mesh1', 'geom1');
```

```
g.create('R1', 'Rectangle');
g.create('C1', 'Circle');
g.run;

m.create('ftri1', 'FreeTri');

m.create('del1','Delete');
m.feature('del1').selection().geom(2).set(3);
m.feature('del1').set('deladj','off');

m.create('del2','Delete');
m.feature('del2').selection().geom(2).set(1);
m.feature('del2').set('deladj','on');

m.create('del3','Delete');
m.feature('del3').selection().geom(1).set(1);

m.run;
```

SEE ALSO

FreeTet, Map, Sweep

DeleteEntities

Delete geometric entities from an imported mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"DeleteEntities");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"DeleteEntities")` to delete geometric entities from an imported 2D or 3D mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify geometric entities to delete.

The following property is available:

TABLE 4-24: AVAILABLE PROPERTY FOR DELETEENTITIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
deleteadj	Boolean	true	Specifies if the operation removes lower dimensional adjacent entities.

SEE ALSO

Import, JoinEntities

DetectFaces

Split geometric boundary entities by detecting faces in the mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"DetectFaces");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"DetectFaces")` to split geometric boundary entities of an imported 3D mesh by detecting shapes in the mesh that are likely to constitute faces.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the boundary entities to split. If you do not specify the selection, it is left empty.

The following properties are available:

TABLE 4-25: VALID PROPERTY/VALUE PAIRS FOR DETECTFACES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`detectadjfillets`	`on` | `off`	`on`	Whether to detect cylindrical faces adjacent to the detected planar faces.
`detectfacesplanar`	`on` | `off`	`on`	Whether to detect planar faces.
`facemaxangle`	double	40 degrees	Maximum tolerated angle between neighboring boundary elements in the same face.
`planarfacemaxangle`	double	0.6 degrees	Maximum tolerated angle between neighboring boundary elements in the same planar face.
`planarfaceminareafraction`	double	0.005	Minimum relative area for a planar face to be created.

SEE ALSO

`Import`, `Ball`, `Box`, `Cylinder`, `LogicalExpression`

Distribution

Mesh element distribution properties.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Distribution");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"Distribution");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).
      set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Distribution")` to specify element distribution properties in the sequence. Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"Distribution")` to specify element distribution properties for the feature `<ftag>` that can be any of the types `Edge`, `FreeQuad`, `FreeTri`, `FreeTet`, `Map`, or `Sweep`.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` or `model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection()` to specify the edge or domain selection.

You can specify a mesh element distribution in three different ways: by specifying the number of elements only, by specifying the number of elements together with properties determining the distribution of the elements, or by specifying the element distribution explicitly. The property `type` determines which of the three alternatives you want to use. However, you need not set `type` manually since it is automatically updated when you set a property from one of the three groups below.

The following group of properties are available:

TABLE 4-26: AVAILABLE PROPERTIES WHEN TYPE IS NUMBER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
numelem	integer	5	Number of elements.

Use the property `numelem` to specify the number of elements, but let the algorithm determine a suitable distribution, taking geometry and surrounding mesh into account.

TABLE 4-27: AVAILABLE PROPERTIES WHEN TYPE IS EXPLICIT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
explicit	double[]	{0, 1}	Specifies the relative placement of vertices along the edge.
reverse	on | off	off	Reverse the direction of the explicit distribution.

Use the `explicit` property to specify an explicit element distribution. The value of this property is an array with increasing values starting at 0.

TABLE 4-28: AVAILABLE PROPERTIES WHEN TYPE IS PREDEFINED

PROPERTY	VALUE	DEFAULT	DESCRIPTION
elemcount	integer	5	Number of elements.
elemratio	double	1	Specifies the ratio in size between the last element and first element along the edge.
method	arithmetic | geometric	arithmetic	Specifies if the element distribution is an arithmetic or a geometric sequence.
reverse	on | off	off	Specifies if the distribution is defined in the opposite edge direction for the edge in the selection with lowest index.
symmetric	on | off	off	Specifies if the distribution is made symmetric.

When the type is `predefined`, the distribution as calculated from the parameters given above.

This `Distribution` feature can be assigned to edges in 2D and 3D, domains in 3D or the entire geometry. The `FreeTet`, `FreeTri`, `FreeQuad`, `Edge`, and `Map` features use this property on when defined on edges, the `Sweep` feature uses this property defined on domains.

SEE ALSO

`Scale`, `Size`

Edge

Create an edge mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Edge");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Edge")` to create an edge mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the edge selection. If you do not specify a selection, the feature creates a mesh on the remaining entities in 1D. In 3D and 2D, the default selection is empty.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype)` to add `Size` or `Distribution` attribute features.

The following properties are available:

TABLE 4-29: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`smoothcontrol`	`on` | `off`	`on`	Specifies if the operation smooths the mesh across removed control entities.
`smoothmaxiter`	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
`smoothmaxdepth`	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.

SEE ALSO

`Distribution`, `Point`, `Size`

EdgeGroup

Define edge groups for mapped meshes.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"EdgeGroup");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"EdgeGroup")` to define edge groups for the `Map` feature `<ftag>`.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection()` to specify the domain.

The following properties are available:

TABLE 4-30: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`edge1`	Selection		First group of edges.
`edge2`	Selection		Second group of edge.
`edge3`	Selection		Third group of edge.
`edge4`	Selection		Fourth group of edge.

The value of each property is an edge selection that combines edges to defines a logical side of the corresponding domain (in 2D) or boundary (in 3D). No specific ordering of the edges is required.

SEE ALSO

`Distribution`, `Map`, `Size`

EdgeMap

Specify an edge map for a face copy or a domain copy operation.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag1>,"EdgeMap");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).
      set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"EdgeMap")` to define an edge mapping for `CopyFace` or `CopyDomain` feature *<ftag>*.

The following properties are available:

TABLE 4-31: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
direction	auto | same | opposite	auto	The direction of dstedge relative srcedge.
dstedge	Selection		Edge on destination face/domain.
srcedge	Selection		Edge on source face/domain.

Use the `EdgeMap` feature if you need to control how the source and destination faces/domains are matched in a copy face or a copy domain mesh operation. When this feature is present, the source mesh is transformed so that `srcedge` is mapped onto `dstedge`. The relative orientation of the edges is specified by the direction property.

EXAMPLE

Create a block and then mesh Face 1 with a fine mesh on Edge 1. Copy this mesh to face 6 and ensure that the fine mesh of Edge 1 ends up on Edge 12.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
MeshSequence m= model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.run();

m.create("ftri1", "FreeTri");
m.feature("ftri1").selection().set(new int[]{1});
m.feature("ftri1").create("size1", "Size");
m.feature("ftri1").feature("size1").selection().geom("geom1", 1).set(new int[]{1});
m.feature("ftri1").feature("size1").set("hmax", "0.01");

m.create("cpf1", "CopyFace");
m.feature("cpf1").selection("source").set(new int[]{1});
m.feature("cpf1").selection("destination").set(new int[]{6});
m.feature("cpf1").create("em1", "EdgeMap");
m.feature("cpf1").feature("em1").selection("dstedge").set(new int[]{1});
m.feature("cpf1").feature("em1").selection("dstedge").set(new int[]{12});

m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.run;
```

```
m.create('ftri1', 'FreeTri');
m.feature('ftri1').selection().set(1);
m.feature('ftri1').create('size1', 'Size');
m.feature('ftri1').feature('size1').selection().geom('geom1', 1).set(1);
m.feature('ftri1').feature('size1').set('hmax', '0.01');

m.create('cpf1', 'CopyFace');
m.feature('cpf1').selection('source').set(1);
m.feature('cpf1').selection('destination').set(6);
m.feature('cpf1').create('em1', 'EdgeMap');
m.feature('cpf1').feature('em1').selection('dstedge').set(1);
m.feature('cpf1').feature('em1').selection('dstedge').set(12);

m.run;
```

SEE ALSO

CopyFace, CopyDomain, OnePointMap, TwoPointMap

FreeQuad

Create an unstructured quadrilateral mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"FreeQuad");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"FreeQuad")` to create an unstructured quadrilateral mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain (boundary in 3D) selection. If you do not specify any selection the feature creates a mesh on the remaining geometric entities in 2D. In 3D, the default selection is empty.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype)` to add `Size` or `Distribution` attribute features.

The following properties are available:

TABLE 4-32: AVAILABLE PROPERTIES FOR FREEQUAD

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`continue`	`on` | `off`	`on`	When enabled, the mesher does not stop if there is an error.
`method`	`auto` | `legacy52` | `legacy52a`	`auto` in new models; `legacy52a` in migrated models	The free quad meshing algorithm to use.
`smoothcontrol`	`on` | `off`	`on`	Specifies if the operation smooths the mesh across removed control entities.
`smoothmaxdepth`	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.
`smoothmaxiter`	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
`xscale`	double	1	Scale geometry in x direction before meshing.

TABLE 4-32: AVAILABLE PROPERTIES FOR FREEQUAD

PROPERTY	VALUE	DEFAULT	DESCRIPTION
yscale	double	1	Scale geometry in y direction before meshing.
zscale	double	1	Scale geometry in z direction before meshing.

See the FreeTet feature for more information on the properties.

This feature uses the same attribute feature as the FreeTet feature.

COMPATIBILITY

See FreeTet.

SEE ALSO

Distribution, FreeTri, Size

FreeTet

Create a free tetrahedral mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"FreeTet");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>)create(<ftag1>,ftype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"FreeTet")` to create an unstructured tetrahedral mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain selection. If you do not specify any selection the feature creates a mesh on the remaining geometric entities.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype)` to add Size or Distribution attribute features.

The following properties are available:

TABLE 4-33: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
continue	on | off	on	When enabled, the mesher does not stop if there is an error.
method	auto | del | dellegacy52	auto	Delaunay meshing algorithm to use.
optlevel	basic | medium | high	basic	Optimization level for the mesh element quality.
optcurved	on | off	off	Avoid inverted curved mesh elements.
optlarge	on | off	off	Avoid too large mesh elements.
optsmall	on | off	off	Avoid too small mesh elements.
smoothcontrol	on | off	on	Specifies if the operation smooths the mesh across removed control entities.
smoothmaxiter	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
smoothmaxdepth	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.
xscale	double	1	Scale geometry in x direction before meshing.

TABLE 4-33: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
yscale	double	1	Scale geometry in y direction before meshing.
zscale	double	1	Scale geometry in z direction before meshing.

If `continue` is `on`, the mesher does not stop if it encounters an error. Instead, it continues to mesh remaining entities. Before finishing, all errors are collected and reported as feature problems. You can use the output to visually examine the partial mesh; this can help you understand what the problems are and how they can be fixed.

The `method` property determines the Delaunay tessellation algorithm to use. The default is `auto`, which makes the `FreeTet` mesh generator determine the best algorithm for each domain. The `del1` Delaunay algorithm is the Delaunay algorithm used in earlier COMSOL versions. The `del2` Delaunay algorithm is an alternative version of the algorithm, which under some conditions can modify the boundary mesh to simplify the meshing.

The properties `xscale`, `yscale`, and `zscale` specify scalar factors in each axis direction that the geometry is scaled by before meshing. The resulting mesh is then scaled back to fit the original geometry. The values of other properties correspond to the scaled geometry. By default, no scaling is done.

The following attribute features are used:

TABLE 4-34: ATTRIBUTE FEATURES USED

FEATURE	REMARKS
Distribution	Used when defined on edges.
Scale	Scales Size and Distribution.
Size	All properties are used.

SEE ALSO

`Distribution`, `FreeTri`, `Size`

FreeTri

Create an unstructured triangular mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"FreeTri");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"FreeTri")` to create an unstructured triangular mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain (boundary in 3D) selection. If you do not specify any selection the feature creates a mesh on the remaining geometric entities in 2D. In 3D, the default selection is empty.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype)` to add `Size` or `Distribution` attribute features.

The following properties are available:

TABLE 4-35: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
continue	on | off	on	When enabled, the mesher does not stop if there is an error.
method	auto | af | del	auto	Triangulation method.
xscale	double	1	Scale geometry in x direction before meshing.
yscale	double	1	Scale geometry in y direction before meshing.
zscale	double	1	Scale geometry in z direction before meshing.
smoothcontrol	on | off	on	Specifies if the operation smooths the mesh across removed control entities.
smoothmaxiter	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
smoothmaxdepth	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.

Use the property `method` to specify the method used to triangulate domains in 2D and faces in 3D. A Delaunay based method is used if the property is set to `del` and an advancing front method is used if the property is set to `af`. If `method` is set to `auto`, the program tries to choose the best method for each geometric entity.

COMPATIBILITY

See `FreeTet`.

SEE ALSO

`Distribution`, `FreeTet`, `FreeQuad`, `Size`

Import

Import mesh from a file or from another meshing sequence. You can import a mesh from a COMSOL Multiphysics native file. In 3D you can also import meshes from NASTRAN, STL, or VRML files. In 2D you can also import 2D meshes from NASTRAN (the third coordinate must then be the same for all mesh points).

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Import");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).importData();
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Import")` to import a mesh into a sequence without a corresponding geometry. It is only possible to use this feature when the geometry sequence is empty. If the sequence already contains a mesh, the imported mesh is added to the existing mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).importData()` to import the file again.

The following mesh formats are supported:

FORMAT	FILE EXTENSION
COMSOL Multiphysics text file	.mphtxt
COMSOL Multiphysics binary file	.mphbin
NASTRAN file	.nas | .bdf | .dat

The following properties are available:

TABLE 4-36: AVAILABLE PROPERTIES FOR THE MESH IMPORT

PROPERTY	VALUES	DEFAULT	DESCRIPTION
allowshellpartition	on | off	on	Specifies whether the boundary entities that are defined based on the data in the file can be split into smaller parts.
data	all | mesh	all	Specifies the data to import from the NASTRAN file.
facepartition	auto | minimal | detectfaces | manual	auto	Boundary partitioning algorithm. detectfaces is only available in 3D, and manual is only available in 2D.
filename	String		The filename.
linearelem	on | off	off	Specifies if the elements in the COMSOL Multiphysics file or NASTRAN file are imported as linear elements. Available in 2D and 3D.
materialsplit	on | off	on	Specifies if material data in the NASTRAN file is used to determine the domain partitioning of the domain elements.
selcreation	on | off	on	Specifies whether selections corresponding to the groups of domain and boundary elements in the NASTRAN file should be created.
selection	on | off	on	Import mesh selections from a COMSOL Multiphysics file.
sequence	String		Meshing sequence name.
source	file | sequence | native | nastran | stlvrml	file	Source for the import.
stltolabs	Positive scalar	1e-8	Absolute tolerance for STL import, when stltoltype is set to absolute.
stltolrel	Positive scalar, 1.0 or smaller	1e-8	Relative tolerance for STL import, when stltoltype is set to relative.
stltoltype	auto | relative | absolute	auto	STL file import tolerance type: automatic, relative, or absolute.

The properties stltolabs, stltolrel, and stltoltype are only used for import of STL files.

The properties linearelem, materialsplit, and data are only used for import of NASTRAN files. The properties selcreation and allowshellpartition are only used when materialsplit is on.

linearelem specifies if the elements in the NASTRAN or COMSOL Multiphysics file are imported as linear elements. If the value is on all imported elements are linear. Otherwise, the order of the imported elements is determined from the order of the elements in the file. The default value is off.

materialsplit determines if material data in the file is used (if available) to determine the domain partitioning of the domain elements. If the value is off all domain elements in the imported mesh belongs to the same domain if possible. The default value is off.

If you set facepartition to minimal, the operation keeps the original partition from the file (if any), adding minimal partitioning in order to satisfy topological requirements.

If you set `facepartition` to `manual`, you can use the following properties. If you set any of these properties without setting `facepartition` to `manual`, the operation automatically switches `facepartition` to `manual`.

TABLE 4-37: VALID PROPERTY/VALUE PAIRS FOR FACEPARTITION = MANUAL

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`faceangle`	double	360 degrees	Maximum angle between any two boundary elements in the same face.
`minareaplane`	double	0.005	Minimum relative area of face to be considered planar.
`neighangle`	double	40 degrees	Maximum angle between a boundary element and a neighbor that causes the elements to be part of the same boundary domain if possible.
`planar`	on | `off`	on	Detect planar faces.
`planarangle`	double	0.6 degrees	Maximum angle between boundary element normal and a neighbor that causes the element to be a part the planar face if possible.

The following properties are available in 3D when `facepartition` is set to `detectfaces`:

TABLE 4-38: VALID PROPERTY/VALUE PAIRS FOR FACEPARTITION = DETECTFACES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`detectadjfillets`	on | `off`	on	Whether to detect cylindrical faces adjacent to the detected planar faces.
`detectedgesplanar`	on | `off`	on	Whether to detect planar edges.
`detectedgesstraight`	on | `off`	on	Whether to detect straight edges.
`detectfacesplanar`	on | `off`	on	Whether to detect planar faces.
`edgemaxangle`	double	60 degrees	Maximum angle between an edge element and a neighbor for the two elements to belong to the same edge.
`facemaxangle`	double	40 degrees	Maximum tolerated angle between neighboring boundary elements in the same face.
`minlengthtype`	`auto` | `relative` | `absolute`	`auto`	Minimum edge length type: automatic, relative, or absolute.
`minrellength`	double	0.01	Minimum relative edge length, relative to size of geometry, if `minlengthtype` = `relative`.
`minabslength`	double	0	Minimum absolute edge length, if `minlengthtype` = `absolute`.
`planaredgeparam`	double	0.5	Parameter for planar edge detection (0–1).
`planarfacemaxangle`	double	0.6 degrees	Maximum tolerated angle between neighboring boundary elements in the same planar face.
`planarfaceminareafraction`	double	0.005	Minimum relative area for a planar face to be created.
`straightedgeparam`	double	0.5	Parameter for straight edge detection (0–1).

The table below specifies the supported NASTRAN bulk data entries.

BULK DATA ENTRY			
CBAR	CORD2C	CQUAD4	GRID
CHEXA	CORD2R	CQUAD8	MAT1
CORD1C	CORD2S	CTETRA	MAT10

BULK DATA ENTRY			
CORD1R	CPENTA	CTRIA3	PSHELL
CORD1S	CPYRAM	CTRIA6	PSOLID

The NASTRAN bulk data format uses reduced second-order elements; that is, the center node on quadrilateral mesh faces (`quadNode`) and the center node of hexahedral elements (`hexNode`) are missing. Importing a NASTRAN mesh with second-order elements, COMSOL Multiphysics interpolates the coordinates of these missing node points from the surrounding node points using the following formulas: `quadNode = 0.5*quadEdgeNodes - 0.25*quadCornerNodes`, where `quadEdgeNodes` is the sum of the coordinates of the surrounding 4 edge nodes and `quadCornerNodes` is the sum of the coordinates of the surrounding 4 corner nodes, and `hexNode = 0.25*hexEdgeNodes-0.25*hexCornerNodes`, where `hexEdgeNodes` is the sum of the coordinates of the surrounding 12 edge nodes and `hexCornerNodes` is the sum of the coordinates of the surrounding 8 corner nodes.

The `Import` feature does not handle NASTRAN files in free field format where the data fields are separated by blanks.

COMPATIBILITY

The `elemsplit` property from earlier versions is no longer available from version 5.3.

For 3D meshing sequences, the setting `manual` of the property `facepartition` in the mesh Import feature, as well as all the properties associated with this setting, are deprecated as of COMSOL 5.1 and may be removed in a future version. In COMSOL 5.1, these properties are still available with unchanged behavior for backward compatibility.

SEE ALSO

`Ball`, `Box`, `CreateVertex`, `DeleteEntities`, `DetectFaces`, `JoinEntities`, `LogicalExpression`

JoinEntities

Join geometric entities of an imported mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"JoinEntities");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"JoinEntities")` to join adjacent geometric entities of an imported 2D or 3D mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify geometric entities to join.

The following properties are available:

TABLE 4-39: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`joinadj`	Boolean	`true`	Specifies if the operation joins lower dimensional adjacent entities.

SEE ALSO

`Import`, `DeleteEntities`

LogicalExpression

Split geometric entities of an imported mesh by specifying a logical expression.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"LogicalExpression");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"LogicalExpression")` to split entities of an imported mesh by specifying an element set based on a logical expression.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the geometric entities for which you want to define an element selection. If you do not specify the selection, the feature operates on the entire geometry.

The following properties are available:

TABLE 4-40: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`expression`	String	1	Logical expression,, where the valid variables are: `x`, `y`, `z`, `istri`, `isquad`, `istet`, `ispyr`, `isprism`, and `ishex`.
`condition`	`allvertices` | `somevertex`	`allvertices`	Condition for inclusion of an element.

SEE ALSO

`Import`, `Ball`, `Box`, `Cylinder`, `DetectFaces`

Map

Create a structured (mapped) quadrilateral mesh. The mapped mesher maps a regular grid defined on a logical unit square onto each domain. The mapping method is based on transfinite interpolation.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Map");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Map")` to create a structured quadrilateral mesh.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain (boundary in 3D) selection. If you do not specify any selection the feature creates a mesh on the remaining domains in 2D. In 3D, the default selection is empty.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype)` to add a `Size`, `Distribution`, or `EdgeGroup` attribute feature.

The following properties are available:

TABLE 4-41: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adjustedgdistr	on | off	off	When enabled, the mapped mesher adjusts evenly distributed edge mesh.
continue	on | off	on	When enabled, the mesher does not stop if there is an error.
interpmethod	auto | transfinite2D | transfinite3D	auto	Interpolation method (3D meshes only).
smoothcontrol	on | off	on	Specifies if the operation smooths the mesh across removed control entities.
smoothmaxiter	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
smoothmaxdepth	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.

The following attribute features are used:

TABLE 4-42: ATTRIBUTE FEATURES USED

FEATURE	REMARKS
EdgeGroup	Defined on the domain/face to be meshed.
Distribution	Used when defined on edges.
Scale	Scales Size and Distribution.
Size	Defined on domain/face. Uses only hauto and hmax.

SEE ALSO

Distribution, FreeTri

OnePointMap

Specify a one-point map for a face copy or a domain copy operation.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"OnePointMap");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"OnePointMap")` to define a one-point map for `CopyFace` or `CopyDomain` feature *<ftag>*.

The following properties are available:

TABLE 4-43: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
srcpoint1	Selection		Point on source face/domain.
dstpoint1	Selection		Point on destination face/domain.

Use the `OnePointMap` feature if you need to control how the source and destination faces/domains are matched in a copy face or a copy domain mesh operation. When this feature is present, the source mesh is transformed so that `srcpoint1` is mapped to `dstpoint1`.

EXAMPLE

Create a block and mesh face 4 with a fine mesh near point 8. Copy this mesh onto face 3 and ensure that the fine mesh near point 8 ends up near point 3:

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.run();

m.create("ftri1", "FreeTri");
m.feature("ftri1").selection().set(new int[]{4});
m.feature("ftri1").create("size1", "Size");
m.feature("ftri1").feature("size1").selection().geom("geom1", 0).set(new int[]{8});
m.feature("ftri1").feature("size1").set("hmax", "0.01");
m.create("cpf1", "CopyFace");
m.feature("cpf1").selection("source").geom("geom1", 2).set(new int[]{4});
m.feature("cpf1").selection("destination").geom("geom1", 2).set(new int[]{3});
m.feature("cpf1").create("pm1", "OnePointMap");
m.feature("cpf1").feature("pm1").selection("srcpoint1").set(new int[]{8});
m.feature("cpf1").feature("pm1").selection("dstpoint1").set(new int[]{3});
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom().create('geom1', 3);
m = model.component('comp1').mesh().create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.run();

m.create('ftri1', 'FreeTri');
m.feature('ftri1').selection().set(4);
m.feature('ftri1').create('size1', 'Size');
m.feature('ftri1').feature('size1').selection().geom('geom1', 0).set(8);
m.feature('ftri1').feature('size1').set('hmax', '0.01');
m.create('cpf1', 'CopyFace');
m.feature('cpf1').selection('source').geom('geom1', 2).set(4);
m.feature('cpf1').selection('destination').geom('geom1', 2).set(3);
m.feature('cpf1').create('pm1', 'OnePointMap');
m.feature('cpf1').feature('pm1').selection('srcpoint1').set(8);
m.feature('cpf1').feature('pm1').selection('dstpoint1').set(3);
m.run();
```

SEE ALSO

`CopyFace`, `CopyDomain`, `EdgeMap`, `TwoPointMap`

Point

Create a point mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Point");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Point")` to mesh geometry vertices.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the point selection. If you do not specify any selection the feature creates a mesh on the remaining points.

SEE ALSO

Edge

Reference

Refer to another meshing sequence.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Reference");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).expand();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Reference")` to refer to another meshing sequence. Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype)` to add `Scale` attribute features.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).expand()` to replace the reference with a copy of the referred sequence, where the attributes have been scaled with the scale attribute features of the reference.

The following properties are available:

TABLE 4-44: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
sequence	String		Tag of referred sequence.

Use the `sequence` property to specify another meshing sequence on the same geometry. When running the feature, all features of the specified sequence are run in the current context.

It is not allowed to introduce circular references.

EXAMPLE

Create a mixed mesh with quads and triangles on a geometry. Create a second meshing sequence with a `scale` feature and a reference to the first meshing sequence. The result is a coarser version of the first mesh.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
MeshSequence m1 = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("sq1", "Square");
g.create("sq2", "Square");
g.feature("sq2").set("size", "0.5");
g.run();

m1.create("map1", "Map");
m1.feature("map1").selection().geom("geom1", 2).set(new int[]{1});
m1.create("ftri1", "FreeTri");
m1.feature("ftri1").selection().geom("geom1", 2).set(new int[]{2});
m1.run();
```

```
MeshSequence m2 = model.mesh().create("mesh2", "geom1");
m2.create("sca1", "Scale");
m2.feature("sca1").set("scale", "2");
m2.create("rf1", "Reference");
m2.feature("rf1").set("sequence", "mesh1");
m2.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
m1 = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('sq1', 'Square');
g.create('sq2', 'Square');
g.feature('sq2').set('size', '0.5');
g.run();

m1.create('map1', 'Map');
m1.feature('map1').selection().geom('geom1', 2).set(1);
m1.create('ftri1', 'FreeTri');
m1.feature('ftri1').selection().geom('geom1', 2).set(2);
m1.run();

m2 = model.mesh().create('mesh2', 'geom1');
m2.create('sca1', 'Scale');
m2.feature('sca1').set('scale', '2');
m2.create('rf1', 'Reference');
m2.feature('rf1').set('sequence', 'mesh1');
m2.run();
```

SEE ALSO

Scale

Refine

Refine a mesh.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Refine");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Refine")` to refine the mesh. The mesh refinement feature is also available for imported mesh sequences.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain selection. The default selection is the entire geometry, meaning that all elements in the mesh are refined.

The following properties are available:

TABLE 4-45: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
boxcoord	on | off	off	Use coordinates of a bounding box to determine the elements to refine.
rmethod	longest | regular	see below	Refinement method.

TABLE 4-45: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
numrefine	int or int[]	1	Number of refinements.
xmax, xmin, ymax, ymin, zmax, zmin	double		Coordinates of bounding box.

Use the boxcoord property to refine elements inside a bounding box. To define the bounding box, set the properties xmin, xmax, ymin, ymax, zmax, and zmin on the feature, where (xmin,ymin,zmin) defines the lower-left corner, and (xmax,ymax,zmax) defines the upper-right corner of the bounding box. The elements that have all its corner points in the bounding box are refined once. boxcoord is automatically set to on if one of the coordinates are set.

The default refinement method in 2D is regular refinement, where all edges of the element are bisected. Longest edge refinement, where the longest edge of each specified element is bisected, can be selected by giving longest as rmethod. Using regular as rmethod results in regular refinement. Some elements outside of the specified set can also be refined due to propagation.

In 3D, the default refinement method is longest. If the mesh contains nonsimplex elements, consider using regular refinement instead because this method preserves the structure of the mesh.

In 1D, regular refinement, where each element is divided into two elements of the same shape, is always used.

By default, all elements are refined once. The numrefine property specifies how many times the elements is refined.

EXAMPLE

Mesh two squares with free mesh. Refine the mesh on sq2 once and refine the elements inside a box in sq1 twice.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g = model.component("comp1").geom().create("geom1", 2);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("sq1", "Square");
g.create("sq2", "Square");
g.feature("sq2").setIndex("pos", "1", 0);
g.run();

m.create("ftri1", "FreeTri");
m.create("ref1", "Refine");
m.feature("ref1").selection().geom("geom1", 2).set(new int[]{2});
m.create("ref2", "Refine");
m.feature("ref2").set("xmin", "0.2");
m.feature("ref2").set("xmax", "0.8");
m.feature("ref2").set("ymin", "0.2");
m.feature("ref2").set("ymax", "0.6");
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component().create('comp1');
g = model.component('comp1').geom.create('geom1', 2);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('sq1', 'Square');
g.create('sq2', 'Square');
g.feature('sq2').setIndex('pos', '1', 0);
g.run;

m.create('ftri1', 'FreeTri');
m.create('ref1', 'Refine');
```

```
m.feature('ref1').selection().geom('geom1', 2).set(2);
m.create('ref2', 'Refine');
m.feature('ref2').set('xmin', '0.2');
m.feature('ref2').set('xmax', '0.8');
m.feature('ref2').set('ymin', '0.2');
m.feature('ref2').set('ymax', '0.6');
m.run();
```

SEE ALSO

Adapt, Convert

Scale

Scale mesh size properties.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Scale");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"Scale");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).
      set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Scale")` to scale size properties defined in the sequence and use `model.mesh(<tag>).feature(<ftag>).create(<ftag1>,"Scale")` to scale size properties defined in the sequence referred to by the `Reference` feature *<ftag>*.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` or `model.mesh(<tag>).component(<ctag>).feature(<ftag>).feature(<ftag1>).selection()` to specify the geometric entity selection or the entire geometry (which is default).

The following properties are available:

TABLE 4-46: FEATURE PROPERTIES DEFINED

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`scale`	double	1	Scale factor.

`Scale` is a positive number. The feature scales mesh size properties, distribution properties, and boundary layer properties affecting mesh elements generated by features following the scale feature. The scale feature also affects size properties defined by `Size`, `Distribution`, and `BndLayerProp` features occurring later in the sequence.

A scale less than 1 gives smaller (more) elements; a scale greater than 1 gives larger (fewer) elements. The scale feature has no effect on any mesh generated earlier in the sequence.

If two or more scale features exist on the same selection, the resulting scale on that selection is the product of the given scales.

EXAMPLE

Create a block and mesh it with 10-by-10-by-10 hexahedra. Setting `scale` to 2 gives you a block with 5-by-5-by-5 hexahedra and setting the scale to 0.5 gives you a block with 20-by-20-by-20 hexahedra.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
```

```
GeomSequence g = model.component("comp1").geom().create("geom1", 3);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.run();

m.create("sca1", "Scale");
m.create("map1", "Map");
m.feature("map1").selection().set(new int[]{1});
m.create("swe1", "Sweep");
m.run();

m.feature("sca1").set("scale", "2");
m.run();

m.feature("sca1").set("scale", "0.5");
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.run;

m.create('sca1', 'Scale');
m.create('map1', 'Map');
m.feature('map1').selection().set(1);
m.create('swe1', 'Sweep');
m.run;

m.feature('sca1').set('scale', '2');
m.run;

m.feature('sca1').set('scale', '0.5');
m.run;
```

SEE ALSO

BndLayerProp, Distribution, Size

Size

Specify mesh size properties.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Size");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"Size");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).
      set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Size")` to specify element size properties in the sequence. Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"Size")`

to specify element size properties for the feature *<ftag>* that can be any of the types `Edge`, `FreeQuad`, `FreeTri`, `FreeTet`, `Map`, or `Sweep`.

Use `model.component(`*<ctag>*`).mesh(`*<tag>*`).feature(`*<ftag>*`).selection()` or `model.component(`*<ctag>*`).mesh(`*<tag>*`).feature(`*<ftag>*`).feature(`*<ftag1>*`).selection()` to specify the geometric entity selection. If you do not specify any selection the size feature is defined on all geometric entities. The selection is not available for the *default size feature*, tagged `size`.

The following properties are available:

TABLE 4-47: FEATURE PROPERTIES DEFINED

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`custom`	`on` | `off`	`off`	Setting custom to on deactivates all mesh parameters.
`hauto`	double	`5`	Automatic settings for all mesh parameters.
`hcurve`	double	`0.3` | `0.6`	Curvature mesh size.
`hcurveactive`	`on` | `off`	`on`	Specifies if hcurve is used.
`hgrad`	double	`1.3` | `1.5`	Element growth rate.
`hgradactive`	`on` | `off`	`on`	Specifies if hgrad is used.
`hmax`	double	geometry dependent	Maximum element size.
`hmaxactive`	`on` | `off`	on	Specifies if hmax is used.
`hmin`	double	geometry dependent	Minimum element size.
`hminactive`	`on` | `off`	`on`	Specifies if hmin is used.
`hnarrow`	double	`0.5`	Resolution of narrow regions.
`hnarrowactive`	`on` | `off`	`on`	Specifies if hnarrow is used.
`table`	`cfd` | `default` | `plasma` | `semi`	`default`	Specifies for which physics the element size is calibrated.

The properties with names ending in active are not available for the default size feature.

The property `table` specifies the physics for which the element size is calibrated.

`Hauto` is a positive scalar. This value is used to set several mesh parameters in order to get a mesh of desired size. Smaller values of `hauto` generate finer meshes with more elements. The integers between 1 and 9 has a special interpretation; they correspond to the mesh settings **Normal**, **Fine**, **Coarse**, and so forth in COMSOL Multiphysics. The value 5 correspond to **Normal**. When you set the property `hauto`, all other properties are set to their default value, according to the following tables (for `table` set to `default`). Other noninteger values provide mesh parameters that are interpolated from the values in the tables.

TABLE 4-48: MESH PARAMETERS SET BY THE PROPERTY HAUTO IN 2D (FOR DEFAULT TABLE)

HAUTO	HMAXFACT	HCURVE	HGRAD	HMINFACT	HNARROW
1	0.01	0.2	1.1	2e-5	1
2	0.02	0.25	1.2	7.5e-5	1
3	0.037	0.25	1.25	1.25e-4	1
4	0.053	0.3	1.3	3e-4	1
5	0.067	0.3	1.3	3e-4	1
6	0.1	0.4	1.4	0.002	1

TABLE 4-48: MESH PARAMETERS SET BY THE PROPERTY HAUTO IN 2D (FOR DEFAULT TABLE)

HAUTO	HMAXFACT	HCURVE	HGRAD	HMINFACT	HNARROW
7	0.13	0.6	1.5	0.006	1
8	0.2	0.8	1.8	0.016	1
9	0.33	1	2	0.05	0.9

TABLE 4-49: MESH PARAMETERS SET BY THE PROPERTY HAUTO IN 3D (FOR DEFAULT TABLE)

HAUTO	HMAXFACT	HCURVE	HGRAD	HMINFACT	HNARROW
1	0.02	0.2	1.3	2e-4	1
2	0.035	0.3	1.35	0.0015	0.85
3	0.055	0.4	1.4	0.004	0.7
4	0.08	0.5	1.45	0.01	0.6
5	0.1	0.6	1.5	0.018	0.5
6	0.15	0.7	1.6	0.028	0.4
7	0.19	0.8	1.7	0.04	0.3
8	0.3	0.9	1.85	0.054	0.2
9	0.5	1	2	0.07	0.1

The property `hcurve` is a real value that relates the mesh size to the curvature of the geometry boundaries. The Gaussian radius of curvature is multiplied by the `hcurve` factor to obtain the mesh size along the boundary. The specified `hcurve` is only used if `hcurveactive` is `on`, otherwise `hcurve` is taken from a preceding size feature in the sequence. In the default size feature, tagged `size`, `hcurve` is always active and there is no `hcurveactive` property.

The property `hgrad` tells how fast the element size — measured as the length of the longest edge of the element — can grow from a region with small elements to a region with larger elements. If two elements lie one unit length apart, the difference in element size can be at most `hgrad`. The specified `hgrad` is only used if `hgradactive` is `on`, otherwise `hgrad` is taken from a preceding size feature in the sequence. In the default size feature, `hgrad` is always active and there is no `hcurvegrad` property.

The `hmax` parameter controls the size of the elements in the mesh. The algorithm aims at creating a mesh where no element size exceeds `hmax`. The default `hmax` value is `hmaxfact * maxdist`, where `maxdist` is the longest axis parallel distance in the geometry. The specified `hmax` is only used if `hmaxactive` is `on`, otherwise `hmax` is taken from a preceding size feature in the sequence. In the default size feature, `hmax` is always active and there is no `hmaxactive` property.

You can use `hmin` to control the minimum size of the elements. The main purpose of this parameter is to prevent the generation of many small elements near small curved parts of the geometry. The default `hmin` value is `hminfact * maxdist`, where `maxdist` is the longest axis parallel distance in the geometry. The specified `hmin` is only used if `hminactive` is `on`, otherwise `hmin` is taken from a preceding size feature in the sequence. In the default size feature, `hmin` is always active and there is no `hminactive` property.

The `hnarrow` parameter controls the size of the elements in narrow regions. Increasing values of this property decrease the size of the elements in narrow regions. If the value of `hnarrow` is less than one, elements that are anisotropic in size might be generated in narrow regions. The specified `hnarrow` is only used if `hnarrowactive` is `on`, otherwise `hnarrow` is taken from a preceding size feature in the sequence. In the default size feature, `hnarrow` is always active and there is no `hnarrowactive` property.

The values of `hauto`, `hcurve`, `hgrad`, `hmax`, `hmin`, and `hnarrow` are positive real scalars, or strings that evaluate to positive real scalars, given the evaluation context provided by `model.param()`.

It is not possible to specify coarser size settings on the boundary of a domain than on the domain. The finer settings on the domain is inherited by its boundaries and, in 3D, edges. A warning is issued when settings are overwritten by inheritance. If you need to create coarser mesh on a boundary, you should first mesh the boundary then add the finer size settings on the domain and a corresponding free mesh operation.

SEE ALSO

`Distribution`, `Scale`, `SizeExpression`

SizeExpression

Specify a mesh size expression.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"SizeExpression");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"SizeExpression");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).
      set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).getType(property);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"SizeExpression")` to specify a mesh element size expression in the sequence. Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"SizeExpression")` to specify an element size expression for the feature `<ftag>` that can be any of the types `Edge`, `FreeQuad`, `FreeTri`, or `FreeTet`.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` or `model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection()` to specify the geometric entity selection. If you do not specify any selection, the size expression feature is defined on all geometric entities.

You can use `mesh.feature(<ftag>).importData()` to reevaluate the size expression, taking an updated model into account.

The following properties are available.

TABLE 4-50: FEATURE PROPERTIES FOR SIZEEXPRESSION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`adapsolnum`	Array of integers>0	1	Solution number indices.
`cellsize`	Positive scalar	Geometry bounding box size / 25	Grid cell size.
`elementspar`	Positive scalar		Controls refinement if `elselect` = `elements`.
`elselect`	`globalmin` | `worst` | `elements`		Method to select elements to refine.
`errorexpr`	String		Error expression.
`exprtype`	`size` | `error`	`size`	Type of expression for the adaptive mesh generation: an absolute size or an error expression.

TABLE 4-50: FEATURE PROPERTIES FOR SIZEEXPRESSION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`evaltype`	`grid` | `solution` | `initialexpression`	`grid`	Specification of mesh to evaluate on.
`globalminparam`	Positive scalar		Controls refinement if `elselect` = `globalmin`.
`gridtype`	`cellresolution` | `cellsize`	`cellresolution`	Grid specification.
`hmeshgrad`	Scalar, 1.0 or greater	`1.4`	Maximum size field growth rate (1.4 means that the mesh can grow by 40%, for example).
`horder`	Double array	0	Error orders (see below).
`mesh`	`auto` | tag of other mesh	auto	Mesh for evaluation when `evaltype` is `initialcondition`.
`numcell`	Integer	25	Number of cells per dimension.
`selection`	`first` | `last` | `all` | `manual`	`last`	Solution selection: the first or last solution, all solutions, or manual, using `weights` and solution number indices in `adapsolnum`.
`sizeexpr`	String	Geometry bounding box size	Size expression to evaluate for the mesh size.
`solution`	String		The solution defining the mesh adaptation.
`studystep`	`none` | tag path to study step	none	The study step to use. Available when `evaltype` is `initialcondition`.
`updatecondition`	A parameter name		Name of a parameter used to trigger an update.
`weights`	Double[] (positive values)	1.0	Weight for each selected solution.
`worstpar`	Positive scalar		Controls refinement if `elselect` = `worst`.

For the `horder` property, its value is automatically calculated in the adaptation algorithm. It is used only when the Element selection method is set to Rough global minimum.

SEE ALSO

`Adapt`, `Distribution`, `Scale`, `Size`

Sweep

Create a swept mesh in 3D by sweeping the mesh from the source face along the domain to an opposite destination face.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).create(<ftag>,"Sweep");
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection();
model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).set(property,<value>);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).getType(property);
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype);
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).create(<ftag>,"Sweep")` to create a swept mesh in 3D.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the domain selection. If you do not specify any selection the feature creates a mesh on the remaining domains.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,ftype)` to add a `Size` or `Distribution` attribute feature.

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).selection()` to specify the 3D domain selection. If you do not specify any selection the feature creates a mesh on the remaining domains.

The following properties are available:

TABLE 4-51: AVAILABLE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`continue`	`on` | `off`	`on`	When enabled, the mesher does not stop if there is an error.
`facemethod`	`tri` | `quad` | `quadlegacy52` | `quadlegacy52a`	`quad` for new models; `quadlegacy52a` for migrated models	Face meshing method.
`smoothcontrol`	`on` | `off`	`on`	Specifies if the operation smooths the mesh across removed control entities.
`smoothmaxiter`	integer	8 in 2D, 4 in 3D	Specifies the number of smoothing iterations.
`smoothmaxdepth`	integer	8 in 2D, 4 in 3D	Specifies the maximum element smoothing depth.
`sourceface`	Selection		Source faces selection.
`sweeppath`	String	`auto`	Sweep path.
`targetface`	Selection		Destination face selection.
`targetmesh`	String	`auto`	Destination mesh method.

Use the property `sourceface` and `targetface` to specify the source faces and the destination faces of the sweep, respectively. For domains in the feature selection where none of the surrounding faces are specified as either a source or a destination face, the software automatically tries to determine these faces.

Use the property `sweeppath` if you want to specify the shape of the sweep path. The string is either `auto`, `straight`, `circular`, or `general`. `straight` means that all interior mesh points are located on straight lines between the corresponding source and destination points. `circular` means that all interior mesh points are located on circular arcs between the corresponding source and destination points. `general` means that the positions of the interior mesh points are determined by a general interpolation procedure. `auto`, which is default, means that the sweeping algorithm automatically tries to determine if the sweep path is straight or circular. If this is the case `sweeppath` is set to `straight` or `circular`, respectively. Otherwise, `sweeppath` is set to `general`.

Any source face that is not meshed, is meshed automatically. The property `facemethod` controls which face meshing method is used:

- If `facemethod` is `quad`, you get quadrilateral face mesh and therefore hexahedral domain mesh.
- If `facemehtod` is `tri`, you get triangular face mesh and prism elements in the domain.

Use the property `targetmesh` if you want to specify the method to be used for transferring the source mesh to the destination. The string is either `auto`, `rigid`, `morph`, or `project`. `rigid` means that the destination mesh is created by a rigid transformation of the source mesh, `morph` means that the destination mesh is created from the source mesh by a morphing technique, and `project` means that the destination mesh is created from the source mesh by a projection technique. The value `auto`, which is the default, means that the sweeping algorithm automatically tries to determine a suitable method for creating the destination mesh.

The following attribute features are used:

TABLE 4-52: ATTRIBUTE FEATURES USED

FEATURE	REMARKS
Distribution	Used when defined on domains.
Scale	Scales Size and Distribution.
Size	Defined on domain.

If a Distribution feature is defined on a domain, it is used to determine the distribution of element layer in the sweep direction. Otherwise, if hauto or hmax is specified, equidistant element layers are generated.

SEE ALSO

Distribution, FreeQuad, FreeTri, Map

TwoPointMap

Specify a two-point map for a face copy or a domain copy operation.

SYNTAX

```
model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"TwoPointMap")
model.component(<ctag>).mesh(<tag>).feature(<ftag>).feature(<ftag1>).selection(property)
```

DESCRIPTION

Use `model.component(<ctag>).mesh(<tag>).feature(<ftag>).create(<ftag1>,"TwoPointMap")` to define a two-point map for the CopyFace or CopyDomain feature *<ftag>*.

The following properties are available:

TABLE 4-53: AVAILABLE PROPERTIES

PROPERTY	VALUE	DESCRIPTION
srcpoint1	Selection	First point on source face/domain.
srcpoint2	Selection	Second point on source face/domain.
dstpoint1	Selection	First point on destination face/domain.
dstpoint2	Selection	Second point on destination face/domain.

Use the TwoPointMap feature if you need to control how the source and destination faces/domains are matched in a copy face or a copy domain mesh operation. When this feature is present, the source mesh is transformed so that srcpoint1 is mapped to dstpoint1 and srcpoint2 is mapped to dstpoint2.

EXAMPLE

Create a block and mesh face 2. Copy this mesh onto the opposite face 5 and ensure that point 6 is mapped to point 4 and point 5 is mapped to Point 8.

Code for Use with Java

```
Model model = ModelUtil.create("Model");
model.component().create("comp1");
GeomSequence g= model.component("comp1").geom().create("geom1", 3);
MeshSequence m = model.component("comp1").mesh().create("mesh1", "geom1");

g.create("blk1", "Block");
g.run();

m.create("ftri1", "FreeTri");
m.feature("ftri1").selection().set(new int[]{2});
m.feature("ftri1").create("size1", "Size");
```

```
m.feature("ftri1").feature("size1").selection().geom("geom1", 1).set(new int[]{9});
m.feature("ftri1").feature("size1").set("hmax", "0.01");
m.create("cpf1", "CopyFace");
m.feature("cpf1").selection("source").geom("geom1", 2).set(new int[]{2});
m.feature("cpf1").selection("destination").geom("geom1", 2).set(new int[]{5});
m.feature("cpf1").create("ppm1", "TwoPointMap");
m.feature("cpf1").feature("ppm1").selection("srcpoint1").set(new int[]{6});
m.feature("cpf1").feature("ppm1").selection("dstpoint1").set(new int[]{4});
m.feature("cpf1").feature("ppm1").selection("srcpoint2").set(new int[]{5});
m.feature("cpf1").feature("ppm1").selection("dstpoint2").set(new int[]{8});
m.run();
```

Code for Use with MATLAB

```
model = ModelUtil.create('Model');
model.component.create('comp1');
g = model.component('comp1').geom.create('geom1', 3);
m = model.component('comp1').mesh.create('mesh1', 'geom1');

g.create('blk1', 'Block');
g.run;

m.create('ftri1', 'FreeTri');
m.feature('ftri1').selection().set(2);
m.feature('ftri1').create('size1', 'Size');
m.feature('ftri1').feature('size1').selection().geom('geom1', 1).set(9);
m.feature('ftri1').feature('size1').set('hmax', '0.01');
m.create('cpf1', 'CopyFace');
m.feature('cpf1').selection('source').geom('geom1', 2).set(2);
m.feature('cpf1').selection('destination').geom('geom1', 2).set(5);
m.feature('cpf1').create('ppm1', 'TwoPointMap');
m.feature('cpf1').feature('ppm1').selection('srcpoint1').set(6);
m.feature('cpf1').feature('ppm1').selection('dstpoint1').set(4);
m.feature('cpf1').feature('ppm1').selection('srcpoint2').set(5);
m.feature('cpf1').feature('ppm1').selection('dstpoint2').set(8);
m.run;
```

SEE ALSO

CopyFace, CopyDomain, EdgeMap, OnePointMap

5

Elements and Shape Function Programming

This chapter contains reference information for using the API available for the shape functions (elements) in COMSOL Multiphysics. See also `model.shape()` in the *General Commands* chapter for details about the syntax for specifying shape functions. For an overview of the elements and shape functions, see Elements and Shape Functions in the *COMSOL Multiphysics Reference Manual*.

Shape Functions and Element Types

This section describes the available shape functions (element types) with their properties and syntax examples.

Shape Function Types (Elements)

THE LAGRANGE ELEMENT (SHLAG)

Specify Lagrange elements in the `model.shape` field of the model object. The constructor of the Lagrange shape function is `shlag`. The following properties are allowed:

TABLE 5-1: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHLAG SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	Variable name		Base variable name
`order`	Positive integer		Basis function order
`sorder`	Positive integer	Determined by `frame`	Geometry shape order

It is not possible to abbreviate the property names, and you must write them in lowercase letters enclosed in quotation marks. For example:

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shlag");
model.shape("shu").feature("f1").set("order",2);
model.shape("shu").feature("f1").set("basename","u");
```

The Lagrange element defines the following variables. Denote `basename` with u, and let x and y denote (not necessarily distinct) spatial coordinates. The variables are (sdim = space dimension and edim = mesh element dimension):

- u
- ux, meaning the derivative of u with respect to x, defined on edim = sdim
- uxy, meaning a second derivative, defined on edim = sdim
- uTx, the tangential derivative variable, meaning the x-component of the tangential projection of the gradient, defined on edim < sdim
- $uTxy$, meaning xy-component of the tangential projection of the second derivative, defined when edim < sdim

When calculating the derivatives, the global spatial coordinates are expressed as polynomials of degree (at most) `sorder` in the local coordinates.

THE NODAL SERENDIPITY ELEMENT (SHNSERP)

Specify serendipity shape functions in the `model.shape` field of the model object. The constructor of the serendipity shape function is `shnserp`. The following properties are allowed:

TABLE 5-2: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHNSERP SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	Variable name		Base variable name
`order`	Integer, 2–4		Basis function order
`sorder`	Positive integer	Determined by `frame`	Geometry shape order

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shnserp");
```

```
model.shape("shu").feature("f1").set("order",3);
model.shape("shu").feature("f1").set("basename","u");
```

The nodal serendipity element defines the following field variables. Denote `basename` with u, and let x and y denote (not necessarily distinct) spatial coordinates. The variables are (sdim = space dimension and edim = mesh element dimension):

- u
- ux, meaning the derivative of u with respect to x, defined when edim = sdim or edim=0
- uxy, meaning a second derivative, defined when edim = sdim
- uTx, the tangential derivative variable, meaning the x-component of the tangential projection of the gradient, defined when 0 < edim < sdim
- $uTxy$, meaning xy-component of the tangential projection of the second derivative, defined when edim < sdim

When calculating the derivatives, the global spatial coordinates are expressed as polynomials of degree (at most) `sorder` in the local coordinates.

THE ARGYRIS ELEMENT (SHARG_2_5)

Specify Argyris shape functions in the `model.shape` field of the model object. The constructor of the Argyris shape function is `sharg_2_5`. The following properties are allowed:

TABLE 5-3: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHARG SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	Variable name		Base variable name

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","sharg_2_5");
model.shape("shu").feature("f1").set("basename","u");
```

The Argyris element defines the following degrees of freedom (where u is the base name and x and y are the spatial coordinate names):

- u at corners
- ux and uy at corners, meaning derivatives of u
- uxx, uxy, and uyy at corners, meaning second derivatives
- un at side midpoints, meaning a normal derivative. The direction of the normal is to the right if moving along an edge from a corner with lower mesh vertex number to a corner with higher number

The Argyris element defines the following field variables (where sdim = space dimension = 2 and edim = mesh element dimension):

- u
- ux, meaning the derivative of u with respect to x
- uxy, meaning a second derivative, defined for edim = sdim and edim = 0
- $uxTy$, the tangential derivative variable, meaning the y-component of the tangential projection of the gradient of ux, defined for 0 < edim < sdim

When calculating the derivatives, the global spatial coordinates are always expressed with shape order 1 in the Argyris element.

THE HERMITE ELEMENT (SHHERM)

Specify Hermite shape functions in the `model.shape` field of the model object. The constructor of the Hermite shape function is `shherm`. The following properties are allowed:

TABLE 5-4: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHHERM SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	Variable name		Base variable name
`order`	Integer >= 3		Basis function order
`sorder`	Positive integer	Determined by `frame`	Geometry shape order

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shherm");
model.shape("shu").feature("f1").set("order",3);
model.shape("shu").feature("f1").set("basename","u");
```

The Hermite element defines the following degrees of freedom:

- The value of the variable `basename` at each Lagrange node point that is not adjacent to a corner of the mesh element.
- The values of the first derivatives of `basename` with respect to the global spatial coordinates at each corner of the mesh element. The names of these derivatives are formed by appending the spatial coordinate names to `basename`.

The Hermite element defines the following field variables. Denote `basename` with u, and let x and y denote (not necessarily distinct) spatial coordinates. The variables are (sdim = space dimension and edim = mesh element dimension):

- u
- ux, meaning the derivative of u with respect to x, defined when edim = sdim or edim=0
- uxy, meaning a second derivative, defined when edim = sdim
- uTx, the tangential derivative variable, meaning the x-component of the tangential projection of the gradient, defined when 0 < edim < sdim
- $uTxy$, meaning xy-component of the tangential projection of the second derivative, defined when edim < sdim

When calculating the derivatives, the global spatial coordinates are expressed as polynomials of degree (at most) `sorder` in the local coordinates.

BUBBLE ELEMENTS (SHBUB)

Specify bubble shape functions in the `model.shape` field of the model object. The constructor of a bubble shape function is `shbub`. The following properties are allowed:

TABLE 5-5: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHBUB SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	variable name		Base variable name
`mdim`	nonnegative integer	`sdim`	Dimension of the mesh elements on which the bubble exist
`sorder`	positive integer	Determined by `frame`	Geometry shape order

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shbub");
model.shape("shu").feature("f1").set("mdim",2);
```

```
model.shape("shu").feature("f1").set("basename","u");
```

The bubble element has a single degree of freedom, `basename`, at the midpoint of the mesh element.

The bubble element defines the following field variables. Denote `basename` with u, and let x and y denote (not necessarily distinct) spatial coordinates. The variables are (sdim = space dimension and edim = mesh element dimension):

- u, defined when edim ≤ mdim, $u = 0$ if edim < mdim.
- ux, meaning the derivative of u with respect to x, defined when edim = mdim = sdim.
- $u\mathtt{T}x$, the tangential derivative variable, meaning the x-component of the tangential projection of the gradient, defined when mdim < sdim and edim ≤ mdim. $u\mathtt{T}x = 0$ if edim < mdim.
- $u\mathtt{T}xy$, meaning the xy-component of the tangential projection of the second derivative, defined when mdim < sdim and edim ≤ mdim. $u\mathtt{T}xy = 0$ if edim < mdim.

THE CURL ELEMENT (SHCURL)

Specify curl shape functions in the `model.shape` field of the model object. The constructor of the curl shape function is `shcurl`. The following properties are allowed:

TABLE 5-6: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHCURL SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`fieldname`	string		Field name
`compnames`	string array	derived from fieldname	Names of vector field components
`dofbasename`	string	See below	Base name of degrees of freedom
`dcompnames`	string array	See below	Names of the anti-symmetrized components of the gradient of the vector field
`order`	integer		Basis function order
`sorder`	positive integer	Determined by `frame`	Geometry shape order

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shcurl");
model.shape("shu").feature("f1").set("fieldname","E");
model.shape("shu").feature("f1").set("order",2);
model.shape("shu").feature("f1").set("compnames",new String[]{"Ex","Ey"});
model.shape("shu").feature("f1").set("dofbasename","tE");
```

The default for `compnames` is `fieldname` concatenated with the spatial coordinate names. The default for `dofbasename` is `t`*`allcomponents`*, where *`allcomponents`* is the concatenation of the names in `compnames`.

The property `dcompnames` lists the names of the component of the antisymmetric matrix

$$dA_{ij} = \frac{\partial A_j}{\partial x_i} - \frac{\partial A_i}{\partial x_j},$$

where A_i are the vector field components and x_i are the spatial coordinates. The components are listed in row order. If a name is the empty string, the field variable corresponding to that component is not defined. If you have provided `compnames`, the default for the entries in `dcompnames` is `compnames(j) sdimnames(i) compnames(i) sdimnames(j)` for off-diagonal elements. If only `fieldname` has been given, the default for the entries are `dfieldname sdimnames(i)sdimnames(j)`. Diagonal elements are not defined per defaults. For example, `shcurl('order',3,'fieldname','A','dcompnames', {'','','curlAy','curlAz','','','curlAx',''})`.

The curl element defines the following degrees of freedom: `dofbasename` d c, where $d = 1$ for DOFs in the interior of an edge, $d = 2$ for DOFs in the interior of a surface, and so forth, and c is a number between 0 and $d - 1$.

The curl element defines the following field variables (where comp is a component name from `compnames`, and dcomp is a component from `dcompnames`, sdim = space dimension and edim = mesh element dimension):

- comp, meaning a component of the vector, defined when edim = sdim.
- `t`comp, meaning one component of the tangential projection of the vector onto the mesh element, defined when edim < sdim.
- comp$x$, meaning the derivative of a component of the vector with respect to global spatial coordinate x, defined when edim = sdim.
- `tcompT`x, the tangential derivative variable, meaning the x component of the projection of the gradient of `t`comp onto the mesh element, defined when edim < sdim. Here, x is the name of a spatial coordinate.
- dcomp, meaning a component of the anti-symmetrized gradient, defined when edim = sdim.
- `td`comp, meaning one component of the tangential projection of the anti-symmetrized gradient onto the mesh element, defined when edim < sdim.

For performance reasons, use dcomp in expressions involving the curl rather than writing it as the difference of two gradient components.

For the computation of components, the global spatial coordinates are expressed as polynomials of degree (at most) `sorder` in the local coordinates.

DISCONTINUOUS ELEMENTS (SHDISC AND SHHWDISC)

Specify discontinuous shape functions in the `model.shape` field of the model object. The constructor of the discontinuous shape functions is either `shdisc` or `shhwdisc`. The difference between these two is that the latter has optimal placement of degrees of freedom on triangle and tetrahedral meshes with respect to certain interpolation error estimates, whereas the former are available on all types of mesh elements with arbitrary polynomial order k. However, the available numerical integration formulas usually limits the usefulness to $k \leq 5$ ($k \leq 4$ for tetrahedral meshes). The following properties are allowed:

TABLE 5-7: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHDISC SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	variable name		Base variable name
`order`	integer		Basis function order
`mdim`	nonnegative integer	`sdim`	Dimension of the mesh elements where the discontinuous element exists
`sorder`	positive integer	Determined by `frame`	Geometry shape order

The `shhwdisc` shape function has the same properties as `shdisc`, except that the mesh element dimension `mdim` cannot be set; it is instead assumed equal to `sdim`. That is, `shhwdisc` shape functions are only usable on the top dimension of the geometry.

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("sh1","frame1");
model.shape("sh1").create("f1","shdisc");
model.shape("sh1").feature("f1").set("order",2);
model.shape("sh1").feature("f1").set("basename","u");
```

The discontinuous element defines the following field variables. Denote `basename` with u, and let x denote the spatial coordinates. The variables are (edim is the mesh element dimension):

- u, defined when edim = mdim.

- ux, meaning the derivative of u with respect to x, defined when edim = mdim = sdim.
- uTx, the tangential derivative variable, meaning the derivative of u with respect to x, defined when edim = mdim < sdim.

DENSITY ELEMENTS (SHDENS)

Specify density shape functions in the `model.shape` field of the model object. The constructor of the density shape function is `shdens`. The following properties are allowed:

TABLE 5-8: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHDENS SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	variable name		Base variable name
`order`	integer		Basis function order
`sorder`	positive integer	Determined by `frame`	Geometry shape order

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shdens");
model.shape("shu").feature("f1").set("order",2);
model.shape("shu").feature("f1").set("basename","u");
```

The density element defines the following field variables. Denote `basename` with u, and let x denote the spatial coordinates. The variables are (edim is the mesh element dimension):

- u, defined when edim = sdim.
- ux, meaning the derivative of u with respect to x, defined when edim = sdim.

GAUSS POINT DATA ELEMENTS (SHGP)

Specify Gauss point data shape functions in the `model.shape` field of the model object. The constructor of the density shape function is `shgp`. The following properties are allowed:

TABLE 5-9: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHGP SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`basename`	variable name		Base variable name
`order`	integer		Basis function order
`mdim`	integer		Element dimension
`valuetype`	`real|complex`	`complex`	Value type in case of using split representation of complex variables[a]

a. The value type is ignored when split representation of complex variables is not used.

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks. The following code creates a Gauss point data shape function declaring the degree of freedom u at integration points of order 4 in three-dimensional mesh elements.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shgp");
model.shape("shu").feature("f1").set("order",4);
model.shape("shu").feature("f1").set("basename","u");
model.shape("shu").feature("f1").set("mdim","3");
```

The Gauss point data element defines the following field variables. Denote `basename` with u and let edim be the evaluation dimension:

- u, defined when edim <= mdim.

DIVERGENCE ELEMENTS (SHDIV)

Syntax for Divergence Elements (shdiv)

Specify divergence shape functions in the `model.shape` field of the model object. The constructor of the divergence shape function is `shdiv`. The following properties are allowed:

TABLE 5-10: VALID PROPERTY NAME/VALUE PAIRS FOR THE SHDIV SHAPE FUNCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`fieldname`	variable name		Name of vector field
`compnames`	string array	Derived from fieldname	Names of vector field components
`dofbasename`	string	see below	Base name of degrees of freedom
`divname`	string	see below	Name of divergence field
`order`	integer	1	Basis function order
`sorder`	positive integer	Determined by `frame`	Geometry shape order

The property names cannot be abbreviated and must be written in lowercase letters enclosed in quotation marks.

```
model.shape().create("shu","f");
model.shape("shu").create("f1","shdiv");
model.shape("shu").feature("f1").set("order",2);
model.shape("shu").feature("f1").set("compnames",new String[]{"Bx","By"});
model.shape("shu").feature("f1").set("dofbasename","nB");
```

The default for `compnames` is `fieldname` concatenated with the spatial coordinate names. The default for `dofbasename` is `n`*`allcomponents`*, where *`allcomponents`* is the concatenation of the names in `compnames`.

The vector element defines the following degrees of freedom: `dofbasename` on element boundaries, and `dofbasename` sdim c, $c = 0, \ldots,$ sdim $- 1$ for DOFs in the interior.

The divergence element defines the following field variables (where comp is a component name from `compnames`, divname is the `divname`, sdim = space dimension and edim = mesh element dimension):

- comp, meaning a component of the vector, defined when edim = sdim.
- `n`comp, meaning one component of the projection of the vector onto the normal of mesh element, defined when edim = sdim – 1.
- comp$x$, meaning the derivative of a component of the vector with respect to global spatial coordinate x, defined when edim = sdim.
- `n`comp`T`x, the tangential derivative variable, meaning the x component of the projection of the gradient of `n`comp onto the mesh element, defined when edim < sdim. Here, x is the name of a spatial coordinate. `n`comp`T`x = 0.
- divname, means the divergence of the vector field.

For performance reasons, prefer using divname in expressions involving the divergence rather than writing it as the sum of sdim gradient components.

For the computation of components, the global spatial coordinates are expressed as polynomials of degree (at most) `sorder` in the local coordinates.

6

Solvers and Study Steps

This chapter contains reference information about the solver command and utility commands for producing and handling solutions. Information about study steps is also included.

In this chapter:

About Solver Commands

The following sections describe the solver commands:

- Features Producing and Manipulating Solutions
- Features with Solver Settings
- Solution Object Information Methods
- Solution Feature Information Methods
- Studies and Solvers in the *COMSOL Multiphysics Reference Manual*

Features Producing and Manipulating Solutions

Table 6-1 is an overview of the available features for producing and handle solution objects.

TABLE 6-1: SOLUTION OBJECT FEATURES

FEATURE	PURPOSE
`Assemble`	Assembles and stores the matrices generated during assembly
`AWE`	Solve parametric problem with asymptotic waveform evaluation
`CombineSolution`	Combine solutions by concatenation or summation
`CopySolution`	Copy solution
`Eigenvalue`	Solve eigenvalue problem
`EigenvalueParam`	Solve parametric eigenvalue problem
`FFT`	Perform a forward or inverse fast Fourier transform (FFT or IFFT)
`InputMatrix`	Input matrices or vectors (for example, load vectors or stiffness matrices) to a solver
`Modal`	Solve time-dependent or parametric problem with modal analysis
`Optimization`	Solve optimization problem
`PlugFlow`	Solve stationary plug flow problem
`StateSpace`	Assembles and stores matrices that describe a model as a dynamic system
`Stationary`	Solve stationary problem
`StudyStep`	Specifies which problem to compile
`Time`	Solve time-dependent problem with implicit time stepping
`TimeDiscrete`	Solve time-dependent problem with user's own time stepping
`TimeExplicit`	Solve time-dependent problem with explicit time stepping
`Variables`	Handle variables solved for (initial values, scaling) and not solved for (prescribed values)

Features with Solver Settings

Table 6-2 is an overview of the available features for solver settings.

TABLE 6-2: SOLVER SETTING FEATURES

FEATURE	SETTINGS HANDLED
`Adaption`	Adaptation subfeature (created by the study step)
`Advanced`	Advanced general settings
`AutoRemesh`	Automatically remesh deformed geometries
`ControlField`	Control fields (a set of control variables)

TABLE 6-2: SOLVER SETTING FEATURES

FEATURE	SETTINGS HANDLED
`ControlState`	Set of global control variables
`Field`	Fields (a set of dependent variables)
`FullyCoupled`	Fully coupled nonlinear solution approach
`Lower Limit`	Lower limits.
`Lumped Step`	Lumped steps.
`Parametric`	Parameter stepping
`Previous Solution`	Previous solution solvers
`Segregated`	Segregated nonlinear solution approach
`SegregatedStep`	Segregated steps
`Sensitivity`	Sensitivity analysis
`StatAcceleration`	Stationary acceleration
`StopCondition`	Stop conditions
`TimeAdaption`	Time-dependent adaptive mesh refinement
See `Linear` for the following:	
`Direct`	Direct linear system solvers
`DirectPreconditioner`	Direct linear system solvers as preconditioners
`DomainDecomposition`	Domain decomposition solver
`HierarchicalLU`	Hierarchical LU linear system preconditioner (for BEM)
`IncompleteLU`	Incomplete factorization preconditioners
`Iterative`	Iterative linear system solvers
`Jacobi`	Jacobi linear system preconditioners
`KrylovPreconditioner`	Krylov linear system preconditioners
`SchurKrylovPreconditioner`	Krylov linear system preconditioners for a Schur solver
`Multigrid`	Multigrid linear system preconditioners
`SCGS`	SCGS linear system preconditioners
`SOR`	SOR linear system preconditioners
`SORGauge`	SOR Gauge linear system preconditioners
`SORLine`	SOR Line linear system preconditioners
`SORVector`	SOR Vector linear system preconditioners
`State`	Sets of global dependent variables
`Vanka`	Vanka linear system preconditioners

Solution Object Information Methods

The following tables are an overview of the solution object information methods.

GENERAL INFORMATION

TABLE 6-3: GENERAL SOLUTION INFORMATION METHODS

METHOD	DESCRIPTION
`getType`	Get solution type
`getSize`	Get number of dynamic solutions and length of solution vector
`getSizeMulti`	Get number of local solution objects and total number of solutions
`getMesh`	Get mesh name associated with solution and geometry
`getNU`	Get number of solutions of a certain solution data type
`getPNames`	Get parameter names
`getParamName`	Get parameter names for parametric sweep
`getParamVals`	Get parameter values for parametric sweep

SOLUTION DATA

TABLE 6-4: SOLUTION DATA ACCESS METHODS

METHOD	DESCRIPTION
`getU`	Get real part of solution vector
`getUDot`	Get real part of the first time-derivative solution vector
`getUImag`	Get imaginary part of solution vector
`getUDotImag`	Get imaginary part of first time-derivative solution vector
`getPVals`	Get the real part of the parameter values
`getPValsImag`	Get the imaginary part of the parameter values
`getUBlock`	A blocked version of the getU method
`getUDotBlock`	A blocked version of the getUDot method
`getUImagBlock`	A blocked version of the getUImag method
`getUDotImagBlock`	A blocked version of the getUDotImag method

SOLUTION CREATION

TABLE 6-5: SOLUTION CREATION METHODS

METHOD	DESCRIPTION
`setU`	Set real part of solution vector
`setUDot`	Set real part of the first time-derivative solution vector
`setUImag`	Set imaginary part of solution vector
`setUDotImag`	Set imaginary part of first time-derivative solution vector
`setPVals`	Set the real part of the parameter values
`setPValsImag`	Set the imaginary part of the parameter values
`setUBlock`	A blocked version of the setU method
`setUDotBlock`	A blocked version of the setUDot method
`setUImagBlock`	A blocked version of the setUImag method
`setUDotImagBlock`	A blocked version of the setUDotImag method

ERRORS AND WARNINGS

See Errors and Warnings in the *General Commands* chapter for handling of errors and warnings in solver sequences.

GENERAL INFORMATION

TABLE 6-6: GENERAL MATRIX INFORMATION METHODS

METHOD	DESCRIPTION
`isReal`	Check if matrix is real
`getM`	Get number of rows
`getN`	Get number of columns
`getNnz`	Get number of nonzeros in sparse matrix

MATRIX DATA

TABLE 6-7: MATRIX ACCESS METHODS

METHOD	DESCRIPTION
`getSparseMatrixVal`	Get matrix values
`getSparseMatrixValImag`	Get the imaginary matrix values
`getSparseMatrixCol`	Get column indices of matrix values
`getSparseMatrixRow`	Get row indices of matrix values
`getVector`	Get the vector associated with the matrix type
`getVectorImag`	Get the imaginary part of the vector associated with the matrix type
`getSparseMatrixValBlock`	A blocked version of getSparseMatrixVal
`getSparseMatrixValImagBlock`	A blocked version of getSparseMatrixValImag
`getSparseMatrixColBlock`	A blocked version of getSparseMatrixCol
`getSparseMatrixRowBlock`	A blocked version of getSparseMatrixRow
`getVectorBlock`	A blocked version of getVector
`getVectorImagBlock`	A blocked version of getVectorImag

MATRIX CREATION

TABLE 6-8: MATRIX CREATION METHODS

METHOD	DESCRIPTION
`createSparseMatrix`	Create sparse matrix
`addSparseMatrixVal`	Add matrix values to the created matrix
`addSparseMatrixValImag`	Add imaginary matrix values to the created matrix
`createVector`	Create vector
`setVector`	Set the vector associated with the matrix type
`setVectorImag`	Set the imaginary part of the vector associated with the matrix type
`setVectorBlock`	A blocked version of setVector
`setVectorImagBlock`	A blocked version of setVectorImag

Solution Object Data

The solver sequence works as a solution object itself. The solution object data produced by running the sequence (partially or in whole) can be obtained by a number of access methods on the sequence. See Table 6-3 and Table 6-5 for an overview.

In this section:

General Information

This section contains information about general solution object information methods, listed in the following table and further described below.

TABLE 6-9: GENERAL SOLUTION OBJECT INFORMATION METHODS

METHOD	OUTPUT TYPE
`isAttached()`	Boolean
`isRealU()`	Boolean
`isRealU(int)`	Boolean
`isRealU(int,string)`	Boolean
`isRealU(int,string,int)`	Boolean
`isRealUDot()`	Boolean
`isRealUDot(int)`	Boolean
`isRealPVals()`	Boolean
`getType()`	String
`getSize()`	int[2]
`getSize(int)`	int[2]
`getSizeMulti()`	int[2]
`getMesh(string)`	String
`getMesh(string,int)`	String
`getNU(String)`	int
`getPNames()`	String[]
`getPVals()`	double[]
`getParamNames()`	String[]
`getParamVals()`	double[]
`getSolutioninfo()`	SolutionInfo

- `model.sol(<tag>).isAttached()` returns true if the solution solver sequence is attached to a study.
- `model.sol(<tag>).isRealU()` returns true if the solution is real.
- `model.sol(<tag>).isRealU(<solnum>)` returns true if solution `<solnum>` is real.

- `model.sol(<tag>).isRealU(<solnum>,<uType>)` returns true if the solution `<solnum>` of type `<uType>` is real.
- `model.sol(<tag>).isRealU(<solnum>,<uType>,<uNum>)` returns true if the solution `<solnum>` of type `<uType>` and solution index `<uNum>` is real.
- `model.sol(<tag>).isRealUDot()` returns true if the first time derivative is real.
- `model.sol(<tag>).isRealUDot(<solnum>)` returns true if first time derivative `<solnum>` is real.
- `model.sol(<tag>).isRealPVals()` returns true if the parameter values are real.
- `model.sol(<tag>).isRealU()` returns true if the solution vector is real.
- `model.sol(<tag>).getType()` returns a string for the solution type which can be any of the strings; `Stationary`, `Parametric`, `Time`, `Eigenvalue`, and `None`.
- `model.sol(<tag>).getSequenceType()` returns a string for the solver sequence type, which can be any of the strings `SolverSequence`, `CopySolution`, `ParametricStore`, `Stored`, `Parametric`, and `None`.
- `model.sol(<tag>).getSize()` returns an array of sizes for the solution data. The number of degrees of freedoms is stored in the first position and the number of solutions (`solnums`) in the second.
- `model.sol(<tag>).getSize(<iMulti>)` returns an array of sizes for the solution number `<iMulti>` of the multi-solution. The number of degrees of freedoms is stored in the first position and the number of solutions (`solnums`) in the second.
- `model.sol(<tag>).getSizeMulti()` returns an array of sizes for the multi-solution. The number of local solution objects is stored in the first position and the total number of solutions (`solnums`) in the second.
- `model.sol(<tag>).getMesh(<geom>)` returns the mesh name associated with the solution and the geometry `<geom>`.
- `model.sol(<tag>).getMesh(<geom>,<iMulti>)` returns the mesh name associated with the solution number `<iMulti>` of the multi solution and the geometry `<geom>`.
- `model.sol(<tag>).getNU(<uType>)` returns the number of solutions stored of the type `<uType>`. Here `<uType>` is the solution type as a string: `Sol` (main solution), `Reacf` (reaction force), `Adj` (adjoint solution), `Fsens` (functional sensitivity), and `Sens` (forward sensitivity).
- `model.sol(<tag>).getPNames()` returns the parameter names from continuation solver as an array of strings.
- `model.sol(<tag>).getParamNames()` returns the parameter names from a parametric sweep as an array of strings.
- `model.sol(<tag>).getParamVals()` returns the parameter values from a parametric sweep as an array of double.

TABLE 6-10: SOLUTION DATA ACCESS METHODS, REAL PART

METHOD	OUTPUT TYPE
`getU(int,string,int)`	double[]
`getU(int,string)`	double[]
`getU(int)`	double[]
`getU()`	double[]
`getUDot()`	double[]
`getUDot(int)`	double[]
`getPVals()`	double[]
`getPVals(int)`	double[]

- `model.sol(`*`<tag>`*`).getU(`*`<solnum>`*`,`*`<uType>`*`,`*`<uNum>`*`)` returns the real part of the solution vector for solution number *`<solnum>`*, the solution type *`<uType>`*, and the 1-based solution index *`<uNum>`*. Here, `1 <=` *`<uNum>`* `<= N`, where `N = model.sol(`*`<tag>`*`).getNU(`*`<uType>`*`)`.
- `model.sol(`*`<tag>`*`).getU(`*`<solnum>`*`,`*`<uType>`*`)` returns the real part of the solution vector for the solution number *`<solnum>`* and the solution data type *`<uType>`*. The solution index *`<uNum>`*`=1`.
- `model.sol(`*`<tag>`*`).getU(`*`<solnum>`*`)` returns the real part of the solution vector for solution number *`<solnum>`*. The solution data type *`<uType>`* `=Sol` and the solution index *`<uNum>`*`=1`.
- `model.sol(`*`<tag>`*`).getU()` returns the real part of the solution vector. For a Time-dependent and Parametric type, the last solution number is used, and for a Eigenvalue type the first solution number. The solution data type *`<uType>`* `=Sol` and the solution index *`<uNum>`*`=1`.
- `model.sol(`*`<tag>`*`).getUDot()` returns the real part of the first time-derivative solution vector for a Time-dependent type and if the time-derivatives have been stored. The last solution number is used. For other types and if the time derivatives have not been stored, an error message is given.
- `model.sol(`*`<tag>`*`).getUDot(`*`<solnum>`*`)` returns the real part of the first time-derivative solution vector for the solution number *`<solnum>`*.
- `model.sol(`*`<tag>`*`).getPVals()` returns for a solution of a Parametric type the real part of all the parameter values stored. For multiple parameters all the parameter tuples are concatenated. For a solution of a Time-dependent type, this is the times for which solution data is stored. For a solution of an Eigenvalue type, this is the real part of the eigenvalues stored. For a Time-dependent and Parametric type, the last solution number is used, and for a Eigenvalue type the first solution number.
- `model.sol(`*`<tag>`*`).getPVals(`*`<solnum>`*`)` returns for a solution of a Parametric type the real part of the parameter tuples stored for solution number *`<solnum>`*. For a solution of a Time-dependent type, this is the time for solution number *`<solnum>`*. For a solution of an Eigenvalue type, this is the real part of the eigenvalue stored at solution number *`<solnum>`*.

TABLE 6-11: SOLUTION DATA ACCESS METHODS, IMAGINARY PART

METHOD	OUTPUT TYPE
`getUImag()`	double[]
`getUImag(int)`	double[]
`getUImag(int,string)`	double[]
`getUImag(int,string,int)`	double[]
`getUDotImag()`	double[]
`getUDotImag(int)`	double[]

TABLE 6-11: SOLUTION DATA ACCESS METHODS, IMAGINARY PART

METHOD	OUTPUT TYPE
`getPValsImag()`	double[]
`getPValsImag(int)`	double[]

- `model.sol(<tag>).getUImag()` returns the imaginary part of the solution vector. The same *<solnum>*, *<uType>*, and *<uNum>* is used as for the method `getU()`. And similarly for the other `Imag` methods.

TABLE 6-12: SOLUTION DATA ACCESS METHODS, BLOCKED VERSIONS

METHOD	OUTPUT TYPE
`getUBlock(int,int)`	double[]
`getUBlock(int,int,int)`	double[]
`getUBlock(int,string,int,int)`	double[]
`getUBlock(int,string,int,int,int)`	double[]
`getUDotBlock(int,int)`	double[]
`getUDotBlock(int,int,int)`	double[]
`getUImagBlock(int,int)`	double[]
`getUImagBlock(int,int,int)`	double[]
`getUImagBlock(int,string,int,int)`	double[]
`getUImagBlock(int,string,int,int,int)`	double[]
`getUDotImagBlock(int,int)`	double[]
`getUDotImagBlock(int,int,int)`	double[]

- `model.sol(<tag>).getUBlock(<startpos>,<endpos>)` returns a subset of the vector returned by `getU()`, the subarray from position *<startpos>* to the position *<endpos>*. And similarly for the other `Block` methods.

SolutionInfo Object and Its Methods

For each solver sequence, there is an associated `SolutionInfo` object, which can be accessed by the function `getSolutioninfo()`. This object has several methods to access the solution data generated by a parametric sweep. Such parametric sweep generated solution data is normally stored in solver sequences of type Parametric or of type SolverSequence, depending on whether so-called outer parametric sweeps have been used or not. It can also be used to convert between so-called loop-level settings and solution numbers. The following methods in Table 6-13 are supported.

TABLE 6-13: SOLUTIONINFO METHODS

METHOD	OUTPUT TYPE
`getIndices(int, int[])`	int[]
`getISol(int, double)`	int
`getISol(int, int)`	int[]
`getLevelDescription(int)`	String
`getLevelNames()`	String[]
`getLevels()`	int
`getMaxInner(int[])`	int
`getMaxLevels()`	int
`getName(int)`	String
`getOuterSolnum()`	int[]
`getPNamesOuter()`	String[]

TABLE 6-13: SOLUTIONINFO METHODS

METHOD	OUTPUT TYPE
`getPUnitsOuter()`	String[]
`getSol(int)`	String
`getSolDescriptions(int, int[], boolean, boolean)`	String[]
`getSolnum(int, boolean)`	int[]
`getSplitLevelDescriptions()`	String[]
`getSplitLevelNames()`	String[]
`getSplitLevelUnits()`	String[]
`getSplitName(int)`	String[]
`getSplitUnit(int)`	String[]
`getUnit(String)`	String
`getVals(int, int[])`	double[][]
`getValsImag(int, int[])`	double[][]
`isStructured()`	Boolean
`isValid()`	Boolean
`mapToLevel(int[], int[], boolean)`	int[][]
`mapToSolnum(int[][], boolean)`	int[][]

```
info = model.sol(<tag>).getSolutioninfo()
```

- `getIndices(int level, int[] levels)` Returns the one-based indices available for the loop level, `level` (index-zero based). The current level setting can be given in `levels` (index-one based). The returned values are 1,…, N, where N is the number of values or tuples for the given level. When `level=getMaxLevel()-1`, the indices can be the result of an outer product between levels. When the format is unstructured, and when `levels` is set, then the unstructured list of indices is returned. When the format is unstructured, and when `levels=null` or `levels.length=0`, an error is given if `level` is such that there are no structured data to return (currently `level=0` and multiple inner parameter names).

  An example: A parameter `p` taking the values 1 and 2, for which a time-dependent simulation is done. All time steps from the solver are saved. Assume that `p` is affecting the time stepping. Using the Time Parametric solver (or a Parametric Sweep for a time-dependent study) will result in a SolutionInfo object with two levels, one for the time `t` (level 0) and one for `p` (level 1). To access the indices for the solutions on level 0, use the method `getIndices`:

  ```
  SolverSequence sol = model.sol("sol1");
  SolutionInfo info = sol.getSolutioninfo();
  int [] indx_1 = info.getIndices(0, int [] {1,1});
  int [] indx_2 = info.getIndices(0, int [] {1,2});
  ```

- `getISol(int outersolnum, int innersolnum)` returns the index zero based multi-solution object number and the index zero based solution number within it, for the index one based outer and inner solution numbers. The solution object number is returned in the first position and the corresponding solution number in the second. The solution object number is normally the same (0) for all `innersolnum`, but can vary for time-dependent adaptation or for automatic remeshing.
- `getISol(int outersolnum, double t)` returns the index-zero based multi solution object number for the one-based outer solution number `outersolnum` and time value `t`. The returned solution number is normally the same (0) for all `t`, but can vary for time-dependent adaptation or for automatic remeshing.
- `getLevelDescription(int level)` returns a description of the index zero based loop level, `level`.
- `getLevelNames()` returns the names of the different loop levels. Some of these can be a concatenated string such as `"p1,p2"`.

- `getLevels()` returns the number of loop levels, `getLevels()<=getMaxLevels()`.
- `getMaxInner(int[] outersolnum)` returns the maximum number of inner solutions for the given index one based outer solution numbers. If `outersolnum` is null, the maximum is taken over all outer solutions.
- `getMaxLevels()` returns the maximum number of used loop levels, `getLevels()<=getMaxLevels()`.
- `getName(int level)` returns the parameter name for the index zero based looplevel `level`. This name can be a concatenated string such as `"p1, p2"`.
- `getOuterSolnum()` returns the one based indices for the outer solutions. If there are no outer parameters or added corresponding parameter values the array is empty.
- `getPNamesOuter()` returns the subset of parameter names that are looped by a job sequence parametric sweep.
- `getSol(int outersolnum)` returns the solver sequence tag for the index one based outer solution number `outersolnum`. If the solution number is invalid, null is returned.
- `getSolDescriptions(int level, int[] levels, boolean paramInclusion, boolean indexInclusion)` returns the descriptions for the solutions for the index-zero based loop level, `level`. The current level setting can be given in `levels` (index one based). One string for each solution is returned. When `paramInclusion` is true, the description always includes the parameter name, even if this level contains only one. When `paramInclusion` is false, the parameter name is only included when there is more than one parameter name on this level. When the format is unstructured, and when `levels` is set, then the unstructured list of descriptions is returned. When the format is unstructured, and when `levels`==null or `levels.length`==0, an error is given if `level` is such that there are no structured data to return.
- `getSolnum(int outersolnum, boolean strict)` returns the one based inner solution numbers for the index one based outer solution number `outersolnum`. If `strict` is true the inner solution numbers is returned if `outersolnum` is a valid outer solution number and else a zero array is returned. If `strict` is false and if the `outersolnum` does not match, then the solution numbers for the containing solution object is returned.
- `getSplitLevelDescriptions()` returns the description of the different parameters, split into an array for the case when there is more than one parameter for a loop level.
- `getSplitLevelNames()` returns the names of the different parameters, split into an array for the case when there's more than one parameter for a looplevel.
- `getSplitLevelUnits()` returns the units for the parameters. It returns a vector of the same length and order as `getSplitLevelDescriptions`, with `null` as the contents when units are not used or defined.
- `getSplitNames(int level)` returns the parameter names for the index-zero based looplevel `level`.
- `getUnit(String name)` returns the unit of the sweep parameter name.
- `getVals(int level, int[] levels)` returns the parameter values for the index-zero based loop level, `level`. The current level setting can be given in `levels` (index-one based). For `level < getMaxLevels()-1` this is just the values of the parameters for this level. The number of rows is the same as the number of parameters for this level. The columns are the values. For `level = getMaxLevels()-1` the values are expanded into tuples for the case that levels have been merged. When the format is unstructured, and when `levels` is set, then the unstructured lists of values are returned. When the format is unstructured, and when `levels==null` or `levels.length=0`, an error is given if `level` is such that there are no structured data to return.
- `getValsImag(int level, int[] levels)` returns the imaginary parts of the parameter values for the index-zero based loop level, `level`. The current level setting can be given in `levels` (index-one based). For `level < getMaxLevels()-1` this is just the values of the parameters for this level. The number of rows is the same as the number of parameters for this level. The columns are the values. For `level = getMaxLevels()-1` the values are expanded into tuples for the case that levels have been merged. When the format is unstructured, and when `levels` is set, then the unstructured lists of values are returned. When the format is unstructured, and when `levels==null` or `levels.length=0`, an error is given if `level` is such that there are no structured data to return.

- `isStructured()` returns true unless the underlying solution object/objects has a parameter variation that depends on the solution process itself. Examples are time-dependent simulations where the output is determined by the steps taken by the solver or eigenvalue simulations.
- `isValid()` returns true if the underlying solution data is consistent with this info object.
- `mapToLevel(int[] outersolnum, int[] innersolnum, boolean compressedOutput)` returns the index one based level representation of the index-one based outer and inner solution numbers, `outersolnum` and `innersolnum` respectively. The number of rows of the returned data is equal to the number of levels. When `compressedOutput` is `false`, the columns represent the tuples, which is the most general format. When `compressedOutput` is `true`, the level settings are made unique on each level.

When `compressedOutput` is `true` and if the compressed representation does not match the input, an array with the right number of rows, but each with zero length, are returned.

- `mapToSolnum(int[][] levelSetting, boolean expandInput)` returns the one based solution number representation of a loop level setting `levelSetting`. The first row in the output is the inner and the second the outer solution numbers. The `levelSettings` must have the same number of rows as there are levels. On each row, index one based settings for each level should be given. If `expandInput` is `false` the number of columns must be the same and the columns are treated as level-tuples. If `expanInput` is true, the number of columns can be different and the output is expanded to the outer product of each levels setting.

Solution Creation

TABLE 6-14: SOLUTION CREATION METHODS, REAL PART

METHOD	OUTPUT TYPE
`setU(double[])`	
`setU(int,double[])`	
`setPNames(String[])`	
`setPVals(double[])`	
`setPVals(int,double[])`	
`createSolution()`	

- `model.sol(<tag>).setU(<vals>)` sets the real part of the solution vector to *<vals>*.
- `model.sol(<tag>).setU(<solnum>,<vals>)` sets the real part of solution vector *<solnum>*, to *<vals>*.
- `model.sol(<tag>).setPNames(<pnames>)` sets parameter names of the solution vectors to *<pnames>*.
- `model.sol(<tag>).setPVals(<vals>)` sets the parameter values to *<vals>*.
- `model.sol(<tag>).setPVals(<solnum>,<vals>)` sets the parameter values *<solnum>* to *<vals>*.
- `model.sol(<tag>).createSolution()` creates solutions based on the input from the vectors previously set. The solution is created at this stage. Afterward the user input is cleared. If a created solution is used before this function is run the result is unpredictable.

TABLE 6-15: SOLUTION CREATION METHODS, IMAGINARY PART

METHOD	OUTPUT TYPE
`setUImag(double[])`	
`setUImag(int,double[])`	
`setPValsImag(double[])`	
`setPValsImag(int,double[])`	

- `model.sol(<tag>).setUImag(<solnum>,<vals>)` sets the imaginary part of solution vector `<solnum>` to `<vals>` (and similarly for the other `Imag` methods).

TABLE 6-16: SOLUTION CREATION METHODS, REAL PART

METHOD	OUTPUT TYPE
`setUBlock(double[],int)`	
`setUBlock(int,double[],int)`	
`setUBImaglock(double[],int)`	
`setUImagBlock(int,double[],int)`	
`setUDotBlock(double[],int)`	
`setUDotBlock(int,double[],int)`	
`setUImagBlock(double[],int)`	
`setUImagBlock(int,double[],int)`	

- `model.sol(<tag>).setUBlock(<solnum>,<vals>,<start>)` sets the real part of solution vector `<solnum>`, the subarray from position `<start>` to position `<start>+<vals>.length-1` to `<vals>` (and similarly for the other `Imag` methods).

General Matrix Information

TABLE 6-17: GENERAL MATRIX OBJECT INFORMATION METHODS

METHOD	OUTPUT TYPE
`isReal(String)`	Boolean
`getM(String)`	int
`getN(String)`	int
`getNnz(String)`	int

- `model.sol(<tag>).feature(<ftag>).isReal(<mname>)` returns true if the matrix `<mname>` is real.
- `model.sol(<tag>).feature(<ftag>).getM(<mname>)` returns number of rows in the matrix `<mname>`.
- `model.sol(<tag>).feature(<ftag>).getN(<mname>)` returns number of columns in the matrix `<mname>`.
- `model.sol(<tag>).feature(<ftag>).getNnz(<mname>)` returns number of nonzero entries in the matrix `<mname>`.

Matrix Data

TABLE 6-18: MATRIX DATA ACCESS METHODS, REAL PART

METHOD	OUTPUT TYPE
`getSparseMatrixVal(String)`	double[]
`getSparseMatrixCol(String)`	int[]
`getSparseMatrixRow(String)`	int[]
`getVector(String)`	double[]

- `model.sol(<tag>).feature(<ftag>).getSparseMatrixVal(<mname>)` returns the real part of the sparse matrix values of matrix `<mname>` stored in feature `<ftag>`. Here, `<mname>`, is one of "K", "D", "E", "N", "NF", "NP", "Kc", "Dc", "Ec", "Null", "Nullf", "Mc", "MA", "MB", "C".
- `model.sol(<tag>).feature(<ftag>).getSparseMatrixCol(<mname>)` returns the column numbers of the sparse matrix values of matrix `<mname>` stored in feature `<ftag>`. Here, `<mname>`, is one of "K", "D", "E", "N", "NF", "NP", "Kc", "Dc", "Ec", "Null", "Nullf", "Mc", "MA", "MB", "C".

- `model.sol(<tag>).feature(<ftag>).getSparseMatrixRow(<mname>)` returns the row numbers of the sparse matrix values of matrix `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "K", "D", "E", "N", "NF", "NP", "Kc", "Dc", "Ec", "Null", "Nullf", "Mc", "MA", "MB", "C".
- `model.sol(<tag>).feature(<ftag>).getVector(<mname>)` returns the real part of the vector `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "L", "M", "MP", "MLB", "MUB", "ud", "uscale", "xO".

TABLE 6-19: MATRIX DATA ACCESS METHODS, IMAGINARY PART

METHOD	OUTPUT TYPE
`getSparseMatrixValImag(String)`	double[]
`getVectorImag(String)`	double[]

- `model.sol(<tag>).feature(<ftag>).getSparseMatrixValImag(<mname>)` returns the imaginary part of the sparse matrix values of matrix `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "K", "D", "E", "N", "NF", "NP", "Kc", "Dc", "Ec", "Null", "Nullf", "Mc", "MA", "MB", "C".
- `model.sol(<tag>).feature(<ftag>).getVectorImag(<mname>)` returns the imaginary part of the vector `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "L", "M", "MP", "MLB", "MUB", "ud", "uscale", "xO".

TABLE 6-20: MATRIX DATA ACCESS METHODS, BLOCKED VERSIONS

METHOD	OUTPUT TYPE
`getSparseMatrixValBlock(String,int,int)`	double[]
`getSparseMatrixColBlock(String,int,int)`	int[]
`getSparseMatrixRowBlock(String,int,int)`	int[]
`getVectorBlock(String,int,int)`	double[]
`getSparseMatrixValImagBlock(String,int,int)`	double[]
`getVectorImagBlock(String,int,int)`	double[]

- `model.sol(<tag>).feature(<ftag>).getSparseMatrixValBlock(<mname>, <startpos>,<endpos>)` returns a subset of the real part of the sparse matrix values returned by `getSparseMatrixVal(<mname>)`, the subarray from the position *<startpos>* to the position *<endpos>*. And similarly for the other `Block` methods.
- `model.sol(<tag>).feature(<ftag>).getVectorBlock(<mname>,<vals>)` returns a subset of the real part of the vector values returned by `getVector(<mname>)`, the subvector from the position *<startpos>* to the position *<endpos>*. Here, *<mname>*, is one of "L", "M".

Matrix Creation

TABLE 6-21: MATRIX DATA CREATION METHODS, REAL PART

METHOD	OUTPUT TYPE
`createSparseMatrix(String,int,int,int,boolean)`	void
`addSparseMatrixVal(String,int[],int[],double[])`	void
`createVector(String,int,boolean)`	void
`setVector(String,double[])`	void

- `model.sol(<tag>).feature(<ftag>).createSparseMatrixVal(<mname>,<M>,<N>,<Nnz>,<isReal>)` creates a sparse matrix `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "K", "D", "E", "N", "NF" and `<M>` is the number of rows, `<N>` is the number of columns, `<Nnz>` is the number of nonzeros, and `<isReal>` is true if the matrix is zero.
- `model.sol(<tag>).feature(<ftag>).addSparseMatrixVal(<mname>,<row>,<col>,<val>)` adds the values stored in <val> to the sparse matrix `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "K", "D", "E", "N", "NF", and `<row>` is the rows, `<col>` is the columns, and `<val>` is the values of the entries.

- `model.sol(<tag>).feature(<ftag>).createVector(<mname>,<M>,<isReal>)` creates a vector `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "L", "M", and `<M>` is the size of the vector and `<isReal>` is true if the vector is real.
- `model.sol(<tag>).feature(<ftag>).setVector(<mname>,<val>)` sets the real part of the vector `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "L", "M", and `<val>` is the values to store in the vector.

TABLE 6-22: MATRIX DATA CREATION METHODS, IMAGINARY PART

METHOD	OUTPUT TYPE
`addSparseMatrixValImag(,int[],int[],double[])`	void
`setVectorImag(String,double[])`	void

- `model.sol(<tag>).feature(<ftag>).addSparseMatrixValImag(<mname>,<M>,<N>,<Nnz>,<isReal>)` creates the imaginary part of the sparse matrix values of matrix `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "K", "D", "E", "N", "NF", and `<row>` is the rows, `<col>` is the columns, and `<val>` is the imaginary values of the entries.
- `model.sol(<tag>).feature(<ftag>).setVectorImag(<mname>,<val>)` sets the imaginary part of the vector `<mname>` stored in feature *<ftag>*. Here, *<mname>*, is one of "L", "M", and `<val>` is the values to store in the vector.

TABLE 6-23: MATRIX DATA CREATION METHODS, BLOCKED VERSIONS

METHOD	OUTPUT TYPE
`setVectorBlock(String,double[],int)`	void
`setVectorImagBlock(String,double[],int)`	void

- `model.sol(<tag>).feature(<ftag>).setVectorBlock(<mname>,<vals>,<startpos>)` sets a subset of the real part of the vector values set by `setVector(<mname>,<vals>)`, the subvector from the position *<startpos>*. Here, *<mname>* is one of "L", "M".

Adaption

Adaptive mesh refinement.

DESCRIPTION

The `Adaption` feature can be created from study steps of `Eigenvalue` or `Stationary` types See `Stationary` for the properties that control mesh adaptation and error estimates. See also `TimeAdaption` for the feature for time-dependent adaptation.

Advanced

Handle advanced general solver properties.

SYNTAX

```
model.sol(sname).feature(solv).create(fname,"Advanced")
model.sol(sname).feature(solv).feature(fname).set(pname,value)
```

DESCRIPTION

Feature for a number of advanced solver settings and assembly settings.

TABLE 6-24: VALID GENERAL PROPERTY/VALUE PAIRS FOR ADVANCED

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`autorescale`	`on` | `off`	`on`	Automatic rescaling of linear equations (for the Stationary solver).
`blocksize`	positive integer | `auto`	`auto`	Assembly block size.
`cachepattern`	`true` | `false`	`false`	Reuse sparsity pattern during assembly.
`checkmatherr`	`on` | `off`	`off`	Check for undefined numerical values after each operation.
`complexfun`	`on` | `off`	`off`	Use complex-valued functions with real input.
`convinfo`	`on` | `detailed` | `off`	`on`	Print info to log.
`D, E, K, L, M, N`	`on` | `off`		Manual control of reassembly.
`keep`	`on` | `off`		Manual control of reassembly.
`logsampling`	double, zero or positive	`0.005`	Minimum time (in seconds) for log sampling of time-dependent solvers.
`matherr`	`on` | `off`	`on`	Error for undefined operations.
`matrixformat`	`auto` | `sparse` | `filled` | `matrixfree`	`auto`	Matrix format.
`orthonormallimit`	double	`1e7`	Limit, as an estimate of the complexity (number of operations), for using the orthonormal method in the automatic null-space function.
`nullfun`	`flnullorth` | `flspnull` | `auto`|`explicitorth`| `explicitsp`	`auto`	Null-space function.
`rowscale`	`on` | `off`	`on`	Equilibrate rows.
`storeresidual`	`off` | `solving` | `solvingandoutput`	`off`	Store the latest residual while solving or while solving and in the output.
`symmetric`	`auto` | `on` | `off` | `hermitian`	`auto`	Symmetric matrices.

The Advanced section in the *COMSOL Multiphysics Reference Manual*, describes the functionality corresponding to the properties `blocksize`, `complexfun`, `nullfun`, and `rowscale`.

You can use the property `symmetric` to tell the solver that the model is symmetric or Hermitian, or you can use the automatic feature to find out (see Advanced in the *COMSOL Multiphysics Reference Manual*).

You can set `convinfo=detailed` to print more detailed information about the solver process in the log window. For example information about individual linear iterations or the scales per field computed by the automatic scaling algorithm. When `convinfo=off`, only minimal information about the solution process is printed.

By default, COMSOL Multiphysics gives an error message if the solver encounters an undefined mathematical operation when solving the model, for instance `0/0` or `log(0)`. If you instead want the solver to proceed, put the property `matherr=off`. Then `0/0=NaN` (not a number) and `log(0)=-Inf`.

The properties `keep` and `D`, `E`, `K`, `L`, `M`, and `N` allow manual control of reassembly. If `keep=on`, each of the other properties controls reassembly of a specific matrix or vector. Setting the property value to on, means that the quantity is constant, and therefore can be assembled once and then kept. The letters have the following meaning: `E`=constant mass, `D`=constant damping, `K`=constant Jacobian, `L`=constant load, `M`=constant constraint, `N`=constant constraint Jacobian.

The `autorescale` property control if the automatically computed scales should be recomputed. This property only affects stationary nonlinear problems and fields that are using the automatic scaling method and for the constant damping technique. The initially computed scales are based on the initial assembled matrix. When `autorescale=on` the scales are recomputed in each nonlinear iteration based on the current solution.

You can use the property `matrixformat` to tell the solver which matrix format to store the system matrices in:

- `sparse` stores the matrix in a sparsely populated matrix format.
- `filled` stores the matrix in a densely populated format.
- `matrixfree` does not store matrices. The effects of matrix operations are assembled when needed.

When you specify `auto` (the default), the format is automatically determined based on the solver used.

By default, COMSOL does not check for undefined numerical values (for example, from numerical overflow) after each numerical operation. Set the property `checkmatherr` to `on` to make COMSOL check for such undefined numerical values, which will give more accurate error messages if such undefined numerical values occur.

Assemble

Assemble and store the matrices generated during assembly.

SYNTAX

```
model.sol(sname).create(fname,"Assemble")
model.sol(sname).feature(fname).set(pname,value)
model.sol(sname).feature(fname).getSparseMatrixVal(mname)
model.sol(sname).feature(fname).getSparseMatrixValImag(mname)
model.sol(sname).feature(fname).getSparseMatrixRow(mname)
model.sol(sname).feature(fname).getSparseMatrixCol(mname)
model.sol(sname).feature(fname).getVector(vname)
model.sol(sname).feature(fname).getVectorImag(vname)
model.sol(sname).feature(fname).getSparseMatrixValBlock(mname,start,stop)
model.sol(sname).feature(fname).getSparseMatrixValImagBlock(mname,start,stop)
model.sol(sname).feature(fname).getSparseMatrixRowBlock(mname,start,stop)
model.sol(sname).feature(fname).getSparseMatrixColBlock(mname,start,stop)
model.sol(sname).feature(fname).getVectorBlock(vname,start,stop)
model.sol(sname).feature(fname).getVectorImagBlock(vname,start,stop)
model.sol(sname).feature(fname).isReal(mname)
model.sol(sname).feature(fname).getM(mname)
model.sol(sname).feature(fname).getN(mname)
```

DESCRIPTION

Assemble feature.

TABLE 6-25: VALID GENERAL PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
K	on | off	off	Assemble the stiffness matrix
L	on | off	off	Assemble the load vector
M	on | off	off	Assemble the constraint vector
N	on | off	off	Assemble the constraint Jacobian
D	on | off	off	Assemble the damping matrix
E	on | off	off	Assemble the mass matrix
NF	on | off	off	Assemble the constraint force Jacobian
NP	on | off	off	Assemble the optimization constraint Jacobian
MP	on | off	off	Assemble the optimization constraint vector
MLB	on | off	off	Assemble the lower bound constraint vector

TABLE 6-25: VALID GENERAL PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
MUB	on | off	off	Assemble the upper bound constraint vector
Kc	on | off	off	Assemble the eliminated stiffness matrix
Lc	on | off	off	Assemble the eliminated load vector
Dc	on | off	off	Assemble the eliminated damping matrix
Ec	on | off	off	Assemble the eliminated mass matrix
Null	on | off	off	Assemble the constraint null-space basis
Nullf	on | off	off	Assemble the constraint force null-space basis
ud	on | off	off	Assemble the particular solution ud
uscale	on | off	off	Assemble the scale vector
clist	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
cname	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
eiguse	on | off	off	Assemble an eigenvalue problem using the eigname as the eigenvalue
eigname	String	lambda	The name of the eigenvalue
eigref	String	0	Value of eigenvalue linearization point
message	String		The log message from the last assembly process

The assemble feature assembles the matrices specified as output matrices and stores them in the feature. The output is stored in the feature. You can access the result using the matrix and vector access methods. The linearization point is determined by the current solution (that is, the solution computed by the previous feature in the sequence). The linearization point is stored in the sequence after the run. For information about the eliminated system, see Advanced in the *COMSOL Multiphysics Reference Manual*.

AutoRemesh

Iteratively and automatically create deformed geometries and remesh these geometries. In each step, map the solution and restart the simulation.

SYNTAX

```
model.sol(sname).feature(tname).create(fname,"AutoRemesh")
model.sol(sname).feature(tname).feature(fname).set(pname,pvalue)
```

DESCRIPTION

Operation feature. The following property/values are accepted:

TABLE 6-26: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
autoremeshgeom	String		Name of geometry sequence
consistentremesh	on | off	off	Consistent initialization after remesh
initialstepremesh	positive scalar	0.001	Initial time step size after remesh
initialstepremesh active	on | off	off	Use initialstepremesh
solutionremesh	tout | tstep	tstep	Solution to use for remeshing
stopcondtype	quality | distortion | general	quality	Type of condition for remeshing
stopdistexpr	String		Distortion expression

TABLE 6-26: VALID PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
stopdistval	String	2	Maximum distortion allowed
stopexpr	String		Mesh quality expression
stopgenexpr	String		Logical condition for remeshing
stopval	String	0.2	Minimal mesh quality

The automatic remeshing solver works in one geometry at a time. You specify the name of the geometry sequence in the property autoremeshgeom. Automatic remeshing is available for Time-Dependent studies and is intended for use with the Moving Mesh and Deformed Geometry interfaces.

Use the stopcondtype property to select the type of condition for when remeshing should occur:

- quality. This means that the solver remeshes when the value of stopexpr becomes smaller than the value of stopval.
- distortion. This means that the solver remeshes when the value of stopdistexpr becomes larger than the value of stopdistval.
- general. This means that the solver remeshes when the stopgenexpr property becomes true (nonzero).

The solutionremesh property determines which previous solution is used for the remeshing:

- tout means that remeshing is done on the last solution that would have been stored by the solver if remeshing would not have occurred. This setting discards any solver progress done since the last output.
- tstep means that the remeshing is done using the solution from the last solver step before the condition for remeshing became fulfilled. Only the very last solver step, at which the condition was triggered, is discarded. Typically this setting is preferred because then the progress of the automatic remeshing does not depend on the solver's list of output times.

After each remeshing the time integration is restarted and you can control the time stepping by the Time type analogous properties consistentremesh and initialstepremesh.

If the time integrator runs into problems the computation is restarted at the beginning of the previous time interval using stricter time stepping controls.

AWE

Solve a parametric problem using asymptotic waveform evaluation (AWE).

SYNTAX

```
model.sol(sname).create(fname,"AWE")
model.sol(sname).feature(fname).set(pname,pvalue)
```

DESCRIPTION

Operation feature. The following properties are accepted:

TABLE 6-27: VALID AWE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
acceptshort	on | off	on	If on, the solver accepts short intervals unconditionally
atol	scalar	0.001	Absolute tolerance for parameter sweep
aweassemble	all | one	all	Either assemble all the needed matrices at once, or one at a time
awefunc	string | vector of strings		Expression(s) used in the search algorithm

TABLE 6-27: VALID AWE PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
clist	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
cname	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
control	String	user	Name of controlling study step.
expeval	scalar|numeric vector	range(0.1,0.1,0.9)	Where to check the error in each subinterval.
expsize	scalar	3	Number of terms in expansion.
exptype	pade | taylor	pade	Use Padé or Taylor expansions to approximate the unknown.
keeplog	on | off	off	Keep warnings in stored log.
minint	scalar	0	The shortest allowed subinterval length
minintactive	on | off	off	If off, rtol times the parameter span is. used. If on, minint is used.
message	String		The log message from the last solution process.
outsollinearized	du | u	du	Store the total solution (u) or deviation and linerization point (du), when storelinpoint=off.
plist	scalar|numeric vector		Parameter list.
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
pname	vector of strings		Parameter names.
pout	plist | psteps	plist	Output either the parameters in plist or the solution at the expansion points.
probesel	all | none | manual	all	The probes to compute.
probes	vector of strings		Probes to use when probesel=manual.
romdata	String	new	Tag of the target container for the reduced model (new for a new reduced model).
romReconstruct	true | false	true	Enable reconstruction in the produced reduced model.
rtol	scalar	0.01	Relative tolerance for parameter sweep.
soltypeonline	on | off	off	Create a reduced model,
soltypesol	on | off	on	Perform frequency sweep using the AWE approximation.
storelinpoint	on | off	off	Whether to store the linearization point.

The AWE solver computes expansions of an underlying problem around certain parameter values. In the first step the largest and smallest values of plist are used as expansion points. Using these expansions, the values of one or more functions at intermediate parameter values are computed. If the two expansions give similar enough functional values at these internal points, the interval is accepted and no subdivisions of that particular interval are deemed necessary.

The property awefunc is used to specify the functionals of interest and the property expeval determines at which internal points these functionals are to be evaluated. The values for expeval are given relative the interval. That is, a value of 0.5 means that the functionals are evaluated at the midpoint of each interval. When the functional-values from the two expansions are compared, a check is performed to see if they fulfill the specified tolerances atol and rtol. If neither of the tolerances are fulfilled, the interval is bisected and the process is repeated for each

subinterval. Before a bisection is performed a check is made to make sure that the new intervals are not shorter than the shortest allowed. By default the shortest allowed interval is given by the relative tolerance times the length of the interval defined by `plist` (when `minintactive` is set to `off`). If `minintactive` has been set to `on` the value of `minint` is the shortest interval allowed. If `minint` has been specified, the value of `minintactive` is `on` by default. The property `acceptshort` determines how to handle too short intervals. If `acceptshort` is set to `off` and a short interval is detected, the solver is interrupted with an error/warning. If `acceptshort` is set to `on` and a short interval is detected, the solver accepts the interval even if the tolerances have not been fulfilled.

In AWE several matrices are needed to compute each expansion. There are two options when it comes to assembling these matrices: With `aweassemble` set to `all` everything is assembled in a single call to the `Xmesh`. With `aweassenble` set to `one`, the matrices are assembled one at a time. The first option is faster but requires more memory.

CombineSolution

Combine two solutions using concatenation or summing of solutions or by removing solutions.

SYNTAX

```
model.sol(sname).create(fname,"CombineSolution")
model.sol(sname).feature(fname).set(pname,pvalue)
```

DESCRIPTION

This feature combines solutions by concatenation or summation. The concatenation can, for example, take two time-dependent solutions solver over different time spans and combine them into a single time-dependent solution including all times from both solutions. You can also remove solutions. Stationary solutions are not possible to use. The following properties are accepted:

TABLE 6-28: VALID COMBINESOLUTION PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`clearscrsol`	`boolean`	`false`	Clear the source solution when creating a weighted summation or removing solutions.
`cssol`	`current` | any available solution	`current`	The solution to sum, when `soloper` is set to `summation`.
`cssol1`	`current` | any available solution	`current`	The first solution to concatenate, when `soloper` is set to `concatenation`.
`cssol2`	`current` | any available solution	`current`	The second solution to sum, when `soloper` is set to `concatenation`.
`excludeorinclude`	`explicit` | `implicit`	`explicit`	Exclude or include selected solutions when `soloper` is set to `remsol`
`excmethod`	`explicit` | `implicit`	`explicit`	Exclude method: explicit or implicit selection.
`incmethod`	`explicit` | `implicit`	`explicit`	Include method: explicit or implicit selection.
`listsolnum`	vector of integers	`{1}`	Indices to solutions to use as linearization points when `solnum` = `from_list`.
`manualsolnum`	vector of positive integers		Identifies the solutions used when `solnum` = `manual`.
`removesol`	`current` | any available solution	`current`	The solution to remove from, when `soloper` is set to `remsol`.
`remsolfromexprexc`	String		Logical expression for solutions to exclude, when `soloper` is set to `remsol`.

TABLE 6-28: VALID COMBINESOLUTION PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
remsolfromexprinc	String		Logical expression for solutions to include, when soloper is set to remsol.
solnum	all | from_list | manual	all	Selection of solutions to exclude or include, when soloper is set to remsol: All, from listsolnum, or from manualsolnum.
soloper	concatenation | summation | wgtsum | remsol	concatenation	Combine solutions using concatenation, summation, or weighted summation, or remove solutions.
solvertype			
weightsmethod	oneexpr | listexpr	oneexpr	Use one expression or a list of expressions for the weighted summation.
weightoneexpr	String	1	A single expression as weight for the summation (when weightsmethod is set to oneexpr).

When weightsmethod is set to listexpr, use setIndex with the properties wsolnum. weightlistexpr, and weightlistexpractive to specify the index (solution number), lists of weights, and active flags, respectively, for the case with a list of weights for a weighted summation.

CopySolution

Handle a solution copy from another solver.

SYNTAX

```
model.sol(sname).create(fname,"CopySolution")
```

DESCRIPTION

This feature gives access to a copy of a solution from another solver. The following property is accepted:

TABLE 6-29: VALID COPYSOLUTION PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
sol	String	none	Name of solution to copy, or "none" if empty.

Eigenvalue

Solve a PDE eigenvalue problem.

SYNTAX

```
model.sol(sname).create(fname,"Eigenvalue")
model.sol(sname).feature(fname).set(pname,value)

model.sol(sname).feature(fname).create(fname2,LinearType)

model.sol(sname).feature(fname).create(fname2,"Advanced")
```

Here LinearType is any of the allowed linear solver feature types.

DESCRIPTION

Operation feature.

For both linear and nonlinear problems, the eigenvalue problem is that of the linearization about a solution U_0. If the eigenvalue appears nonlinearly, COMSOL Multiphysics reduces the problem to a quadratic approximation around a value λ_0 specified by the property eigref. The discretized form of the problem reads

$$KU - (\lambda - \lambda_0)DU + (\lambda - \lambda_0)^2 EU = -N_F\Lambda$$
$$NU = M$$

where K, D, E, N, and N_F are evaluated for $U = U_0$ and $\lambda = \lambda_0$. Λ is the Lagrange multiplier vector, and λ is the eigenvalue. The eigenvalue name can be given by the property `eigname`. The linearization point U_0 can be given with the property `U`. The shift, described below, is compensated according to the linearization point for the eigenvalue. Therefore, changing the linearization point has no effect at all for linear or quadratic eigenvalue problems. The eigenvalue search method can be manual or a region in the complex plane (controlled by the property `eigmethod`).

The feature `eigenvalue` accepts the following property/value pairs:

TABLE 6-30: VALID EIGENVALUE PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`appnreigs`	positive integer		Approximate number of eigenvalues (for eigmethod = region).
`clist`	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
`cname`	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
`control`	String	`user`	Name of the controlling study step or `"user"` if the feature is controlled manually.
`eigfunscale`			
`eigli`	real scalar	0	Largest imaginary value of search region.
`eiglr`	real scalar	0	Largest real value of search region.
`eigmethod`	`manual` | `region` | `all`	`manual`	Eigenvalue search method; the `all` method finds all eigenvalues for a full matrix and can only be used for small eigenvalue problems.
`eigname`	String	`lambda`	Name of eigenvalue variable.
`eigref`	String	0	Linearization point for the eigenvalue.
`eigsi`	real scalar	0	Smallest imaginary value of search region.
`eigsr`	real scalar	0	Smallest real value of search region.
`eigsymchk`	`true` | `false`	`false`	Real symmetric eigenvalue consistency check. Active if `usesymeig` is `auto`.
`eigwhich`	`lm`|`lr`|`sr`|`li`|`si`	`lm`	Eigenvalue search direction (for eigmethod=manual).
`keeplog`	`on` | `off`	`off`	Keep warnings in stored log.
`krylovdim`	positive integer		Dimension of Krylov space.
`linpmethod`	`init` | `solution`	`init`	Method used for linearization point.
`linpsol`	`zero` | `solution object`	`zero`	Linearization point solution.
`linpsoluse`	`current` | solution store	`current`	Linearization point solution to use.
`maxeigit`	positive integer	300	Maximum number of eigenvalue iterations.
`maxnreigs`	positive integer	200	Maximum number of eigenvalue.
`message`	String		The log message from the last solution process.
`neigs`	positive integer	6	Number of eigenvalues sought.
`neigsactive`	`on` | `off`	`off`	Specify the number of eigenvalues to search for.
`rtol`	scalar	`1e-4`	Relative tolerance.

TABLE 6-30: VALID EIGENVALUE PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
shift	scalar	0	Eigenvalue search location.
shiftactive	on | off	off	Specify eigenvalue search location.
shiftregman	scalar	0	Eigenvalue shift (when shiftregselect = manual).
shiftregselect	auto | manual	auto	Search for eigenvalues around (auto = center of search region).
solnum	auto | all | positive integer	auto	The solution numbers to use.
storelinpoint	on | off	off	Whether to store the linearization point.
transform	String	none	Eigenvalue transformation.
usesymeig	auto | false	auto	Use real symmetric eigenvalue solver.

Specify where to look for the desired eigenvalues with the property `shift`. Enter a real or complex scalar; the default value is 0, meaning that the solver tries to find eigenvalues close to 0.

For more information about the eigenvalue solver, see Eigenvalue Solver in the *COMSOL Multiphysics Reference Manual*.

EigenvalueParam

Handle properties for parameter stepping for a parametric eigenvalue problem.

SYNTAX

```
model.sol(sname).create(fname,"Eigenvalue")
model.sol(sname).feature(fname).create(parname,"EigenvalueParam")
model.sol(sname).feature(fname).feature(parname).set(pname,pvalue)
```

DESCRIPTION

Attribute feature.

TABLE 6-31: EIGENVALUE PARAMETRIC PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
pdistrib	on | off	off	If the solver should distribute the parameter sweep.
plist	real array		List of parameter values. Obsolete, use plistarr instead.
plistarr	real matrix		Lists of parameter values. One row of values for each parameter name.
pname	vector of strings		Parameter names.
pwork	integer	1	Maximum number of distributed groups.
sweeptype	sparse | filled	sparse	Method for doing the parameter variation. For sweeptype=sparse, the parameter tuples defined by the columns in plistarr are solved for. This method requires equal length for the rows. For sweeptype=filled, all parameter combinations given by plistarr are solved for.

FFT

Compute a fast Fourier transform (FFT) or inverse fast/nonuniform Fourier transform (IFFT/INFT) using an FFT study step and solver,

SYNTAX

```
model.sol(sname).create(fname,"FFT")
model.sol(sname).feature(fname).set(pname,pvalue)
```

DESCRIPTION

Operation feature. The following property/values are accepted:

TABLE 6-32: VALID FFT SOLVER PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
addstatsol	on | off	off	Add stationary solution.
control	String	user	Set control for FFT solver by study.
fftderiv	sol | firstderiv | secderiv	sol	Use the solution or its first or second time derivative as the input for a forward FFT.
fftendf	double	1.0	Endpoint of frequency interval, only applicable when fftsteptypef = interval.
fftendtime	double	1.0	End time for the time interval in a forward FFT.
fftextend	on | off	on	For an inverse NFT/FFT, extend the input data samples by adding complex conjugate pairs.
fftfile	on | off	off	Store intermediate FFT data on disk.
fftmaxfreq	double	10	Maximum output frequency in forward FFT.
fftoutorder	nat | sym	nat	Output order (natural or symmetric) of frequencies for forward FFT.
fftouttrange	double array		Output times for inverse NFT/FFT.
fftperiodic	on | off	off	Periodicity of input data; only available if fftextend is set to off for inverse NFT/FFT (always available for forward FFT).
fftphaseinexpr	String		Expression for input phase function, can be expressed in terms of t, freq, and niterFFTin (if applicable).
fftphaseoutexpr	String		Expression for output phase function, can be expressed in terms of t, freq, and niterFFTout (if applicable).
fftphasetypein	none | fromexpr	none	Method for input phase function.
fftphasetypeout	none | fromexpr	none	Method for output phase function.
fftrealstore	on | off	on	Do not store negative frequencies for real input.
fftscaling	cont | discrete	discrete	Use a discrete or continuous scaling for the Fourier transform.
fftstartf	double	0.0	Starting point of frequency interval, only applicable when fftsteptypef = interval.
fftstarttime	double	0.0	Start time for the time interval in a forward FFT.
fftsteptypef	allfreqs | interval	allfreqs	Method for selecting frequencies from range.
fftstoretimes	out | store	out	Store time steps taken by the solver (out) or output times stored in fftstoretrange (store).

TABLE 6-32: VALID FFT SOLVER PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
fftstoretrange	String (vector of output times)		Output times for the inverse FFT if fftstoretimes is set to store.
ffttranstype	transfft | transifft	transfft (depends on type of FFT study step)	Type of FFT transformation: forward or inverse.
fftwinalpha	double	0.5	Window parameter for a Tukey window.
fftwincenterfw	double	0.5	Window center for a Gaussian window function in a forward FFT.
fftwincenterinv	double	50	Window center for a Gaussian window function in an inverse NFT/FFT.
fftwindev	double	1	Standard deviation for a Gaussian window function.
fftwincutoff	double	1.0	Cut-off fraction for window function in [0, 1].
fftwindowfw	on | off	off	Use window function in forward FFT.
fftwindowinv	on | off	off	Use window function in inverse NFT/FFT.
fftwinexpr	String		Expression for window function, can be expressed in terms of t, freq, niterFFTin, and niterFFTout (if applicable).
fftwinmaxfw	double	1	Maximum (end) value for window in forward FFT.
fftwinmaxinv	double	100	Maximum (end) value for window in inverse NFT/FFT.
fftwinminfw	double	0	Minimum (start) value for window in forward FFT.
fftwinmininv	double	0	Minimum (start) value for window in inverse NFT/FFT.
fftwintypefw	fromexpr | cutoff | rectangle | gauss | hamming | hanning | blackman | tukey	fromexpr	Method for window function in a forward FFT.
fftwintypeinv	fromexpr | cutoff | rectangle | gauss | hamming | hanning | blackman | tukey	fromexpr	Method for window function in an inverse NFT/FFT.
keeplog	on | off	off	Keep warnings in stored log.
linpmethod	sol | init	sol	Prescribe the input values using a solution or an initial expression.
linpsol	String	current	Solution that defines the input values for the FFT study step/FFT solver.
linpsoluse	String	current	Subsolution that defines the input value for the FFT study step/FFT solver.
linpstudy	String	current	Study that defines input values for the FFT study step.
punit	String	Hz	Frequency unit.

TABLE 6-32: VALID FFT SOLVER PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
statmethod	init | sol	sol	For an added stationary solution, use a solution or initial expression.
statsol	String		Solution to use as an added stationary solution.
statsolnum	String		The solution number to use for the solution used as an added stationary solution.
statsoluse	A stored solution or current.	current	Use the current solution or a stored solution as the added stationary solution.
statstudy	String		Study from which the added stationary solution is chosen.
statt	double		Time value at which the added stationary solution is chosen.
statmanualsolnum	integer		Solution number of the added stationary solution.
tunit	String	s	Time unit.
winpunit	unit	Hz	Frequency unit for window in an inverse NFT/FFT.

EXAMPLE

Code for Use with Java

```
model.study("std2").create("tdfft", "TimeToFreqFFT");
model.study("std2").feature("tdfft").set("linpstudy", "std1");
model.study("std2").feature("tdfft").set("fftstarttime", "0.5");
model.study("std2").feature("tdfft").set("fftendtime", "2.0");
model.study().create("std3");
model.study("std3").create("fdfft2", "FreqToTimeFFT");
model.study("std3").feature("fdfft2").set("linpstudy", "std2");

...

model.sol("sol7").create("fft1", "FFT");
model.sol("sol7").feature("fft1").set("ffttranstype", "transfft");
model.sol("sol7").feature("fft1").set("fftstarttime", "0.5");
model.sol("sol7").feature("fft1").set("fftendtime", "2.0");
model.sol("sol7").feature("fft1").set("control", "tdfft");

...

model.sol("sol9").feature("fft1").set("ffttranstype", "transifft");
model.sol("sol9").feature("fft1").set("control", "fdfft2");

model.study("std3").feature("fdfft2").set("linpmethod", "sol");
model.study("std3").feature("fdfft2").set("linpstudy", "std2");
model.study("std3").feature("fdfft2").set("linpsol", "current");
model.study("std3").feature("fdfft2").set("linpsoluse", "current")

...

model.sol("sol2").feature("ft1").set("fftstarttime", "0.5");
model.sol("sol2").feature("ft1").set("fftendtime", "2.0");
model.sol("sol2").feature("ft1").set("fftperiodic", "off");
model.sol("sol2").feature("ft1").set("fftoutorder", "nat");

...

model.sol("sol2").feature("ft1").set("fftphase", "on");
model.sol("sol2").feature("ft1").set("fftwintypefw", "fromexpr");
model.sol("sol2").feature("ft1").set("fftwinexpr","(niterFFTin<5)*niterFFTin");
model.sol("sol2").feature("ft1").set("fftphasetypein", "fromexpr");
```

```
model.sol("sol2").feature("ft1").set("fftphaseinexpr", "5+i*2*niterFFTin");
model.sol("sol2").feature("ft1").set("fftphasetypeout", "fromexpr");
model.sol("sol2").feature("ft1").set("fftphaseoutexpr","2+i*4*niterFFTout");
```

COMPATIBILITY

The properties `fftbwalgtype` and `fftmeasure` from earlier versions are no longer available since version 5.2.

In version 5.2, the property `fftwintype` for the window type in earlier versions was replaced by `fftwintypefw` and `fftwintypeinv` for the window type for a forward FFT and for an inverse NFT/FFT, respectively.

In version 5.2, the property `fftwindow` for switching a window on and off in earlier versions was replaced by `fftwindowfw` and `fftwindowinv` for the window type for a forward FFT and for an inverse NFT/FFT, respectively.

In version 5.2, the property `tlist` for the input time range to a forward FFT in earlier versions was replaced by the properties `fftstarttime` and `fftendtime` for the start time and end time, respectively.

For, EndFor

Add for loops to a solver sequence.

SYNTAX

```
model.sol("sol1").create("for1", "For");
model.sol("sol1").create("endfor1", "EndFor");
```

DESCRIPTION

`model.sol("sol1").create("for1", "For")` adds the start of a for loop.

`model.sol("sol1").create("endfor1", "EndFor")` adds the end of a for loop.

Use For and EndFor to enclose a sequence of solver commands that you want to iterate in a for loop. You can add more than one for loop, but they must be balanced so that each For ends with a corresponding EndFor.

You control the number of iterations in the loop using the following property:

TABLE 6-33: PROPERTY/VALUE PAIR FOR THE FOR LOOP

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`control`	String	`user`	Name of the controlling study step or `"user"` if the feature is controlled manually.
`expr`	String	1	Global expression used to compute relative error when `method=convergence`.
`iter`	Positive integer	5	Number of iterations of the solver loop when `method=iterations`.
`maxiter`	Positive integer	25	Maximum number of iterations in the solver loop when `method=convergence`.
`method`	`convergence` | `iterations`	`iterations`	Choose whether termination of the solver loop is based on the convergence of a global variable or a fixed number of iterations.
`miniter`	Positive integer	1	Minimum number of iterations in the solver loop when `method=convergence`.
`rtolterm`	Positive real number	`0.001`	Relative tolerance for termination of the solver loop when `method=convergence`.
`rtolthresh`	Positive real number	1	Threshold used to avoid division by zero while computing the relative error when `method=convergence`.

FullyCoupled

Handle the fully coupled nonlinear solution approach.

SYNTAX

```
model.sol(sname).feature(solv).create(fname,'FullyCoupled')
model.sol(sname).feature(solv).feature(fname).set(pname,value)
model.sol(sname).feature(fname).feature(sname).set(pname,value)
```

DESCRIPTION

This feature can be used as an attribute to the `Time` and `Stationary` features. The nonlinear solver is an affine invariant form of the damped Newton method.

TABLE 6-34: VALID FULLY COUPLED PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`aaccdelay`	positive integer	0	Number of iterations between pseudo time stepping becomes inactive and Anderson acceleration becomes active when `segstabacc` = `segaacc`.
`aaccdim`	positive integer	10	Dimension of Anderson iteration space when `segstabacc` = `segaacc`.
`aaccmix`	scalar 0–1	1	Mixing parameter when `segstabacc` = `segaacc`.
`cflaadelay`	positive integer	0	Number of iterations between pseudo time stepping becomes inactive and Anderson acceleration becomes active when `segstabacc` = `cflcmp`.
`clfaacfl`	positive scalar	100	CFL threshold when `segstabacc` = `cflcmp`.
`clfaadim`	positive integer	10	Dimension of Anderson iteration space when `segstabacc` = `cflcmp`.
`clfaamix`	scalar 0–1	1	Mixing parameter when `segstabacc` = `cflcmp`.
`cfljtech`	`true` | `false`	`false`	Override Jacobian update for step when `stabacc` = `cflcmp`.
`cfljtechval`	`onfirst` | `minimal`	`onfirst`	Jacobian update on first iteration or minimal when `stabacc` = `cflcmp` and `cfljtech` = `true`.
`cfltol`	positive scalar	`0.1`	Target error estimate for pseudo time stepping.
`damp`	positive real	1	Damping factor for the damped Newton method.
`ddoginitdamp`	nonnegative scalar	1	Initial damping factor for `dtech` set to `ddog`.
`ddogrestart`	positive integer	7	Number of iterations before restart for double dogleg solver.
`dtech`	`const` | `auto` | `hnlin` | `ddog`	`auto` | `const` (Time)	Damping technique.
`initcfl`	positive scalar	`5.0`	Initial CFL number for pseudo time stepping.
`initstep`	nonnegative scalar	1	Initial damping factor for `dtech` set to `auto`.

TABLE 6-34: VALID FULLY COUPLED PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initsteph	nonnegative scalar	1e-4	Initial damping factor for dtech set of hnlin.
jtech	minimal | once | onevery	onevery | minimal (Time)	Jacobian update technique for dtech set to const.
jtechcfl	positive scalar	100	CFL threshold for Jacobian update when segstabacc = cflcmp and cfljtech = true.
kdpid	positive scalar	0.05	PID controller - derivative for pseudo time stepping.
kipid	positive scalar	0.05	PID controller - integral for pseudo time stepping.
kppid	positive scalar	0.65	PID controller - proportional for pseudo time stepping.
maxiter	positive integer	25 | 4 (Time)	Maximum number of Newton iterations.
minstep	positive scalar	1	Minimum damping factor for dtech set to auto.
minsteph	positive scalar	1e-4	Minimum damping factor for dtech set to hnlin.
niter	positive integer	1	Fixed number of iterations.
ntermauto	tol | itertol	tol	Termination techniques for dtech set to auto/hnlin.
ntermconst	iter | tol | itertol	tol	Termination techniques for dtech set to const.
ntolfact	positive scalar	1	Tolerance factor.
ratelimit	positive scalar	0.9 (dtech set to const)	Limit on nonlinear convergence rate.
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probesel	all | none | manual	all	The probes to compute.
probes	vector of strings		Probes to use when probesel=manual.
reserrfact	positive scalar	100	Residual factor for termonres=auto.
resscale	scalefieldwise | scaleuniform	scalefieldwise	Residual scaling technique for dtech set to ddog.
rstep	positive scalar	10	Restrictions for step-size update (limits how much the damping factor is allowed to change in a Newton iteration),
rstepabs	positive scalar 0–1	1	Restrictions for step-size increase (maximum for the allowed absolute increase in the damping factor for a Newton iteration).
stabacc	none | cflcmp | aacc	none	Stabilization and acceleration: None, pseudo time stepping (for stationary solvers), or Anderson acceleration.

TABLE 6-34: VALID FULLY COUPLED PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
termonres	off | on | auto | both	auto	Termination criterion: Solution, residual, solution or residual, or solution and residual.
updweightsauto	true | false | wthresh	true	Updates the weights for automatic scales if they change two orders of magnitude and then restart the Newton solver from the current solution if true. If set to wthresh, you can use thresholds for the weights. All updweights properties are available for stationary and parametric studies and for Newton solvers only (that is, dtech is not ddog or const).
updweightsdamp	current | manual	current	Available if updweightsauto is wthresh. Use fraction of the current damping factor at update (current) or a constant update damping factor (manual).
updweightsdampval	positive scalar	1	Fraction of current damping factor. If updweightsauto is wthresh and updweightsdamp is current.
updweightsdampvalconst	positive scalar	0.1	Update damping factor. If updweightsauto is wthresh and updweightsdamp is manual.
updweightsfac	scalar	100	Weights threshold factor for update. If updweightsauto is wthresh.
useratelimit	on | off	off | on (Time)	Use limit on nonlinear convergence rate.

The property dtech controls which damping factor to use in the damped Newton iterations.

For dtech set to auto, the solver determines an appropriate damping factor automatically. For this method the initial and minimally allowed damping factors are controlled by the properties initstep and minstep respectively.The termination technique is controlled by the property ntermauto.

For dtech set to hnlin, the solver determines an appropriate damping factor automatically but treat the problem as being highly nonlinear. This option can be tried if there is no convergence with dtech set to auto. For this method the initial and minimally allowed damping factors are controlled by the properties initsteph and minsteph respectively. Moreover, certain internal control structures are adapted. Especially, the error control is biased from a more absolute norm toward a relative norm. So this parameter is also useful if a solution with components of highly varying orders of magnitudes are present. In the context of parameter stepping, you can also try this option if the step sizes in the parameter seem to be too small.

When dtech=const, the constant damping factor specified in the property damp is used. For this method the termination technique is controlled by the property ntermconst. Furthermore, the property jtech can be used to control how often the Jacobian is updated. With jtech=minimal, the Jacobian is updated as seldom as possible (only once for a stationary problem and at most once per time step for a time-dependent problem). For time-dependent problems, the choice jtech=once makes the solver update the Jacobian once per time step. With jtech=onevery, the Jacobian is updated on every Newton iteration. The default is onevery for stationary problems and minimal for time-dependent problems.

When dtech is set to ddog (stationary problems), the double dogleg solver is used. The initial damping factor is controlled by the property ddoginitdamp and the property resscale controls the residual scaling. The option

`resscale=scalefieldwise` scales the equations based on the field-wise sizes of the initial residual. When the option `resscale=scaleuniform` is selected the algorithm terminates on the relative residual based on the initial residual.

The tolerance `ntol` gives the criterion for convergence for a stationary problem; see Stationary Solver in the *COMSOL Multiphysics Reference Manual*.

The property `ntolfact` controls how accurately the nonlinear system of equations is solved. The value given in `ntolfact` is multiplied with the main solver tolerance and used in the convergence criteria. Also, the solution process is interrupted (and the Jacobian updated or the time step reduced) if the convergence is too slow. This can be disabled by setting `useratelimit=off`. When `useratelimit=on`, what is to be considered as too slow convergence can be controlled through the property `ratelimit`. The solution process is interrupted if the estimated linear convergence rate (of all steps, when the segregated solver is used) becomes larger than the value given in `ratelimit`.

The property `stabacc` enables or disables pseudo time stepping (for stationary problems) or Anderson acceleration. When enabled the pseudo time stepping is controlled by the scalar-valued controller parameters `cfltol`, `initcfl`, `kdpid`, `kipid`, and `kppid`. For the Anderson acceleration, the parameter `aaccdim` specifies the dimension of the Anderson iteration space.

The property `termonres` controls the termination criterion for stationary problems when `dtech=const` (and `ntermconst` is not `iter`), `auto`, or `hnlin`. When `termonres=off` the estimated error is solution-based, with `termonres=on` it is based on a relative residual and for `termonres=auto` the estimated error is the minimum of the solution and residual based errors. For `termonres=auto` the property `reserrfact` is a scalar factor multiplying the relative residual error.

COMPATIBILITY

The property `usecflcmp` from earlier versions of COMSOL Multiphysics is not used in version 5.0. Use the property `stabacc` instead.

InputMatrix

Input matrices and vectors to the linear solvers.

SYNTAX

```
solver=model.sol(sname).feature(solver)
solver.create(fname,'InputMatrix')
solver.feature(fname).set(pname,value)
solver.feature(fname).addSparseMatrixVal(mname,row,col,val)
solver.feature(fname).addSparseMatrixValImag(mname,row,col,val)
solver.feature(fname).createSparseMatrix(mname,M,N,Nnz,isReal)
solver.feature(fname).createVector(mname,M,isReal)
solver.feature(fname).getSparseMatrixVal(mname)
solver.feature(fname).getSparseMatrixValImag(mname)
solver.feature(fname).getSparseMatrixRow(mname)
solver.feature(fname).getSparseMatrixCol(mname)
solver.feature(fname).getVector(vname)
solver.feature(fname).getVectorImag(vname)
solver.feature(fname).getSparseMatrixValBlock(mname,start,stop)
solver.feature(fname).getSparseMatrixValImagBlock(mname,start,stop)
solver.feature(fname).getSparseMatrixRowBlock(mname,start,stop)
solver.feature(fname).getSparseMatrixColBlock(mname,start,stop)
solver.feature(fname).getVectorBlock(vname,start,stop)
solver.feature(fname).getVectorImagBlock(vname,start,stop)
solver.feature(fname).setVector(vname,val)
solver.feature(fname).setVectorImag(vname,val)
solver.feature(fname).setVectorBlock(vname,val,start)
solver.feature(fname).setVectorImagBlock(vname,val,start)
solver.feature(fname).isReal(mname)
solver.feature(fname).getM(mname)
solver.feature(fname).getN(mname)
```

DESCRIPTION

The `InputMatrix` feature can be used to create the raw data of an assembled matrix or vector from Java®. The `InputMatrix` feature can exist as a subfeature of the `Eigenvalue`, `Stationary`, and `Time` solver features. These solver feature automatically pick up matrices from the `InputMatrix` subfeature instead of automatically assembling the matrices. The matrices are not stored in the model when the model is saved. They must be created before computing the solver features.

TABLE 6-35: VALID GENERAL PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
K	on | off	off	Input the stiffness matrix
L	on | off	off	Input the load vector
M	on | off	off	Input the constraint vector
N	on | off	off	Input the constraint Jacobian
D	on | off	off	Input the damping matrix
E	on | off	off	Input the mass matrix
NF	on | off	off	Input the constraint force Jacobian

Linear

Handle linear system solvers with three different attribute features: `Direct`, `Iterative`, and `Multigrid`.

SYNTAX

```
sol.feature(fname).create(lname,"Direct")
sol.feature(fname).feature(lname).set(pname,value)

sol.feature(fname).create(lname,"Iterative")
sol.feature(fname).feature(lname).set(pname,value)
sol.feature(fname).feature(lname).create(pcname,PType);
sol.feature(fname).feature(lname).feature(pcname).set(pname,value)

sol.feature(fname).feature(lname).create(pname,"Multigrid")
sol.feature(fname).feature(lname).feature(pname).feature("pr").create(prename,SType)
sol.feature(fname).feature(lname).feature(pname).feature("po").create(postname,SType)
sol.feature(fname).feature(lname).feature(pname).feature("cs").create(cname,CType)
sol.feature(fname).feature(lname).feature(pname).feature("pr").feature(prename).
  set(pname,value)
sol.feature(fname).feature(lname).feature(pname).feature("po").feature(postname).
  set(pname,value)
sol.feature(fname).feature(lname).feature(pname).feature("cs").feature(cname).
  set(pname,value)
```

PType is any of the allowed preconditioner feature types. These types are Direct preconditioner, Multigrid, Domain decomposition, SCGS, SOR, SOR Gauge, SOR Vector, Vanka, SOR Line, AMS, Incomplete LU, and Krylov preconditioners. *SType* is any of the allowed smoother types. These are the same as the *PType* except Domain decomposition, Multigrid, and AMS. *CType* is any of the allowed coarse grid solver types: Direct and all types listed for *PType*.

Presmoother, Postsmoother, and Coarse Solver

Specify the Presmoother, Postsmoother, and Coarse Solver via `feature("ps")`, `feature("po")`, and `feature("cs")`, respectively. These features are for administrative purposes only and do not contain any settings themselves.

DESCRIPTION

Three attribute features for linear system solvers.

EXAMPLES:

GMRES with ILU as preconditioner:

Code for Use with Java

```
SolverFeature solver = sol.feature(fname).create("iter1","Iterative");
solver.set("solver","gmres");
solver.create("ilu","IncompleteLU");
```

Code for Use with MATLAB

```
solver = sol.feature(fname).create('iter1','Iterative');
solver.set('solver','gmres');
solver.create('ilu','IncompleteLU');
```

Change the preconditioner to GMG/SORVector/SPOOLES:

Code for Use with Java

```
solver.create("gmg","Multigrid");
solver("gmg").set("solver","gmg");
solver("gmg").feature("pr").create("p1","SORVector");
solver("gmg").feature("po").create("p1","SORVector");
SolverFeature csolver = solver("gmg").feature("csolver").create("c1","Direct");
csolver.set("solver","spooles");
csolver.set("errorchkd","on");
```

Code for Use with MATLAB

```
solver.create('gmg','Multigrid');
```

```
solver('gmg').set('solver','gmg');
solver('gmg').feature('pr').create('p1','SORVector');
solver('gmg').feature('po').create('p1','SORVector');
csolver = solver('gmg').feature('csolver').create('c1','Direct');
csolver.set('solver','spooles');
csolver.set('errorchkd','on');
```

Use Conjugate Gradients instead of GMRES:

Code for Use with Java

```
solver.set("solver","cg");
```

Code for Use with MATLAB

```
solver.set('solver','cg');
```

Use the sparse approximate inverse (SAI) preconditioner using a sparsity pattern of SAI defined by a power of 3 of the system matrix:

Code for Use with Java

```
model.sol("sol1").feature("t1").create("i1", "Iterative");
model.sol("sol1").feature("t1").feature("i1").set("linsolver", "cg");
model.sol("sol1").feature("t1").feature("i1").create("sai1", "SAI");
model.sol("sol1").feature("t1").feature("i1").feature("sai1").set("saisymm", "on");
model.sol("sol1").feature("t1").feature("i1").feature("sai1").
   set("saipattern","saipowa");
model.sol("sol1").feature("t1").feature("i1").feature("sai1").set("saipowera", "3");
```

Code for Use with MATLAB

```
iter = model.sol('sol1').feature('t1').create('i1', 'Iterative');
iter.set('linsolver', 'cg');
iter.create('sai1', 'SAI');
iter.feature('sai1').set('saisymm', 'on');
iter.feature('sai1').set('saipattern','saipowa');
iter.feature('sai1').set('saipowera', '3');
```

THE PREFUN PROPERTY

The `prefun` property for the solver (preconditioner) accepts a different set of values depending on the context. In the section below, its possible values and default value is listed for each preconditioner that supports it.

DIRECT PROPERTIES

TABLE 6-36: VALID DIRECT PROPERTIES (FOR ALL SOLVERS)

PROPERTY	VALUES	DEFAULT	DESCRIPTION
errorchk	off | on | auto	auto	Check error estimate.
iterrefine	on | off	on off (eigenvalue solver)	Iterative refinement.
linsolver	mumps | pardiso | spooles | dense	mumps	Method to use.
maxrefinesteps	nonnegative integer	15	Maximum number of iterative refinement steps.
nliniterrefine	on | off	off	Use iterative refinement in nonlinear solver.
prefun	mumps | pardiso | spooles | dense	mumps	Solver for preconditioner (MUMPS, PARDISO, SPOOLES, or Dense Matrix).
rhob	scalar > 1	1	Factor in linear error estimate.

TABLE 6-37: OPTIONAL DIRECT PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
clusterpardiso	on | off	off	Use Parallel Direct Sparse Solver for Clusters (PARDISO).
incore	auto | manual	auto	In-core memory method (PARDISO, MUMPS).
internalmemusage	positive real	3	Internal memory usage factor (PARDISO, MUMPS).
memfracooc	scalar between 0 and 1	0.99	Fraction of memory to store out of core.
minicmemory	positive real	512.0	Minimum in-core memory in MB (PARDISO, MUMPS).
mumpsalloc	scalar at least 1	1.2	MUMPS memory allocation factor (MUMPS).
mumpsblr	on | off	off	Block low rank factorization (MUMPS).
mumpsblrtol	scalar between 0 and 1	1e-8	Block low rank factorization tolerance (MUMPS).
mumpsreorder	auto | amd | amf | qamd | nd	auto	Preordering algorithm (MUMPS).
mumpsrreorder	on | off	on	Row preordering (MUMPS).
ooc	automatic | on | off	automatic	Use out-of-core (PARDISO, MUMPS). The automatic option switches to out-of-core storage if needed.
oocmemory	positive real	512.0	In-core memory in MB (PARDISO, MUMPS).
pardmtsolve	on | off	off	Multithreaded forward and backward solve (PARDISO).
pardreorder	mmd | nd | ndmt	nd	Preordering algorithm (PARDISO).
pardrreorder	on | off	on	Row preordering algorithm (PARDISO).
pardschedule	auto | one | two	auto	Scheduling method (PARDISO).
pivotenable	on | off	on	Use pivoting (MUMPS).
pivotperturb	scalar between 0 and 1	1e-8	Pivot perturbation threshold (PARDISO, MUMPS).
pivotrefines	nonnegative integer	0	Number of forced iterative refinements (PARDISO, MUMPS).
pivotstrategy	on | off	off	Use 2-by-2 Bunch-Kaufman pivoting (on) or 1-by-1 diagonal pivoting (off) (PARDISO).

TABLE 6-37: OPTIONAL DIRECT PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`preorder`	`mmd` | `nd` | `ms` | `bestof`	`nd`	Preordering algorithm (SPOOLES).
`reusereorder`	`true` | `false`	`true`	Reuse preordering (PARDISO, MUMPS).
`thresh`	scalar between 0 and 1	`0.1`	Pivot threshold (MUMPS, SPOOLES).
`usetotmemory`	scalar between 0 and 1	`0.8`	Used fraction of total memory (PARDISO, MUMPS).

ITERATIVE PROPERTIES

TABLE 6-38: VALID ITERATIVE PROPERTIES (FOR ALL SOLVERS)

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`errorchk`	`off` | `on` | `auto`	`auto`	Validate error estimate.
`linsolver`	`gmres` | `fgmres` | `bicgstab` | `tfqmr` | `cg` | `precond`	`gmres`, `ilu` (`precond`)	Method to use.
`maxilinit`	positive integer	100	Maximum number of intermediate iteration for the iterative solver in error checking. Available when `errorchk` is `auto`.
`maxlinit`	positive integer	10000 500 (coarse solver)	Maximum number of linear iterations (when used with a tolerance).
`rhob`	scalar > 1	1	Factor in linear error estimate.

TABLE 6-39: OPTIONAL ITERATIVE PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`droptol`	scalar between 0 and 1	`0.01` when used as preconditioner; 1 when used as presmoother, postsmoother, or coarse solver; 0.001 for Hierarchical LU	Drop tolerance (SPOOLES, Hierarchical LU, Incomplete LU with tolerance element dropping strategy).
`droptype`	`tol` | `fill`	`tol`	Element dropping strategy for Incomplete LU (Tolerance, Fill ratio).
`elimtol`	scalar between 0 and 1	1	Elimination tolerance (Hierarchical LU).
`fillratio`	nonnegative integer	1	Fill ratio (Incomplete LU with Fill ratio element dropping strategy and SAI).
`hybridcomp`	vector of strings		Field/State components in step if hybridvarspec=manual.
`hybridization`	`single` | `multi`	`single`	Use a single preconditioner or multiple preconditioner as a hybrid preconditioner.
`hybridvar`	vector of strings		Fields/States in step.
`hybridvarspec`	`all` | `manual`	`all`	Include all components or specify which manually.
`irestol`	scalar between 0 and 1	`0.01`	Residual tolerance when `prefuntype` is `left` (`gmres`, `cg`, `bicgstab`, `tfqmr`).

TABLE 6-39: OPTIONAL ITERATIVE PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
ilutdroptol	scalar between 0 and 1	0.01	Drop tolerance (ILUT).
ilutfillratio	nonnegative integer	1	Fill ratio (ILUT).
iter	nonnegative integer	2 (1 for ILU and ILUT)	Fixed number of iterations (when used as preconditioner, smoother, or coarse solver), for all iterative solvers except direct preconditioner.
iterm	tol | iter	iter	Termination technique (when Incomplete LU, ILUT, or ILU0 are used as coarse solver).
itrestart	positive integer	50	Number of iterations before restart (gmres, fgmres).
prefun	ilu | ilut | ilu0 | spooles	ilu	Solver (preconditioner) for Incomplete LU, ILUT (Intel MKL), ILU0 (Intel MKL), or SPOOLES).
prefuntype	auto (SAI only) | left | right	left (auto for SAI)	Left or right preconditioning (gmres, cg, bicgstab, tfqmr, SAI). For SAI, the default preconditioning type is auto.
relax	scalar between 0 and 2	1	Relaxation factor (Jacobi, SOR-based algorithms, ILU, ILUT, SAI, Vanka, and Hierarchical LU).
respectpattern	on | off	on	Respect the matrix pattern (ILU).
reuselines	on | off	on	Reuse lines of nodes (SOR line).
reuseprolongations	on | off	on	Reuse blocks of data (SCGS, SOR line, Vanka).
saicolmaxfactor	positive integer	5	Limit the maximum number of nonzero elements of each column in the SAI preconditioner matrix.
saisymm	auto | off | on | hermitian	auto	Symmetry characteristics of SAI method corresponding to Automatic, Nonsymmetric, Symmetric, and Hermitian, respectively.
saipattern	sysmat | saipowa	sysmat	Sparsity pattern of SAI defined by system matrix or power of system matrix.
saipowera	positive integer	2	Power of system matrix for SAI sparsity pattern.
seconditer	nonnegative integer	1	Number of secondary iterations (SOR vector and SOR gauge algorithms), number of SSOR updates (vanka).
sorblocked	on | off	on	Blocked SOR method.
sorvecdof	vector of strings		Vector element variables (SOR vector and SOR gauge algorithms).
symmetric	on | off	off	Use symmetric form; ssor instead of sor, and so forth. (SOR, SORVector, SORGauge, SORLine).
thresh	scalar between 0 and 1	1	Pivot threshold (ILU).
transpose	on | off	off	Use transposed form; soru instead of sor and so forth. (SOR, SORVector, SORGauge, SORLine).

TABLE 6-39: OPTIONAL ITERATIVE PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
usenlweights	true | false	true	Terminate using nonlinear scales (GMRES with left preconditioning).
vankablocked	on | off	on	Blocked Vanka method.
vankarelax	scalar between 0 and 2	0.8	Relaxation factor for Vanka update.
vankarestart	positive integer	100	GMRES restart value (vanka).
vankasolv	gmres | direct	gmres	Local block solver (vanka).
vankatol	positive scalar	0.02	GMRES tolerance (vanka).
vankavars	vector of strings	{}	Lagrange multiplier variables (vanka).

The property divcleantol is used in the inequality $|T^T b| < \text{divcleantol} \cdot |b|$ to ensure that the numerical divergence after divergence cleaning is small enough; see SOR Gauge in the *COMSOL Multiphysics Reference Manual*.

MULTIGRID PROPERTIES

TABLE 6-40: VALID MULTIGRID PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
gmglevels	positive integer	1	Maximum number of geometric multigrid levels.
iter	integer	2	Fixed number of iterations (when used as preconditioner, smoother, or coarse solver).
linsolver	gmg | amg	gmg	Method to use.
maxlinit	positive integer	500	Maximum number of linear iterations (when used with a tolerance).
mgcycle	v | w | f	v	Cycle type.
mglevels	positive integer	5	Maximum number of algebraic multigrid levels.
prefun	gmg | amg | saamg	amg if used as Krylov preconditioner. gmg, otherwise.	Solver for preconditioner (Geometric multigrid, Algebraic multigrid, or Smoothed aggregation AMG).
rhob	scalar > 1	1	Factor in linear error estimate.

TABLE 6-41: OPTIONAL MULTIGRID PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
agglevel	positive integer	2	Multigrid level to start smoothing at, if aggmethod =manual (saamg).
aggmethod	auto | manual	auto	Smoothing of prolongations if usesmooth=on (saamg).
amgauto	integer from 1 to 10	3	Quality of multigrid hierarchy (amg).
compactaggregation	on | off	on	Use an aggregation algorithm that leads to a less rapid coarsening (saamg).
geomuse	vector of strings		Geometries for geometric multigrid hierarchy.
hybridization	single | multi	single	Use a single preconditioner or multiple preconditioner as a hybrid preconditioner.
hybridvar	vector of strings		Fields/States in step.
hybridvarspec	all | manual	all	Include all components or specify which manually.
hybridcomp	vector of strings		Field/State components in step if hybridvarspec=manual.

TABLE 6-41: OPTIONAL MULTIGRID PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
jacdamp	positive scalar	2/3	Jacobi damping facto if usesmooth=on (saamg).
massem	on | off	on	Assemble on multigrid levels (gmg).
maxcoarsedof	positive integer	5000	Maximum number of DOFs at coarsest level (amg, saamg).
mcaseassem	vector of strings		Multigrid levels where assemble should be performed (gmg, mcasegen=manual).
mcasegen	manual | all | any | coarse | coarseorder | refine | refineany | refineall	any	Hierarchy generation method (gmg).
mcaseuse	vector of strings		Multigrid levels which should be used (gmg, mcasegen=manual).
mkeep	on | off	off	Keep generated mesh cases (gmg).
nullspace	constant | rbm		Null-space vectors: constant or rigid body modes (saamg).
reuseprolongators	on | off	on	Reuse prolongators when possible (saamg).
rmethod	regular | longest	regular	Mesh refinement method (gmg).
saamgcompwise	on | off	off	Construct the SAAMG prolongators componentwise (saamg).
scale	vector of positive numbers	2	Mesh scale factor (gmg).
strconn	positive scalar	0.01	Strength of connection (saamg).
usefilter	on | off	on	Use filtering if usesmooth=on (saamg).
usesmooth	on | off	on	Use prolongation smoothing (saamg).

Th useaggressive property is no longer used from version 5.3. For the geometric multigrid solver/preconditioners, the multigrid hierarchy is controlled in the following way (see also Multigrid in the *COMSOL Multiphysics Reference Manual*):

- If mcasegen=all, any, or coarse, coarseorder, then the multigrid hierarchy is automatically constructed starting from the mesh and discretization set by the study. The number of multigrid levels generated is given in the property gmglevels. The method all and any first tries to lower the discretization order for the shape functions used, and secondly coarsens the mesh. The method all lowers the order (by one) if all used shape functions can be lowered. The method any lowers the order (by one) if at least one shape function can be lowered. The method coarse does not lower the order, it only coarsens the mesh. The method coarseorder both lowers the order (for any shape functions that can be lowered by one) and coarsen the mesh, at the same time.
- If mcasegen=refine, refineany, or refineall then the multigrid hierarchy is automatically constructed by a combination of refining the mesh given by the study and changing the discretization. The number of multigrid levels generated is given in the property gmglevels. The refinement method can be specified using the property rmethod. The originally selected mesh for the study is used, in the case of refining the mesh, in a multigridlevel and the finest multigrid level generated is used for the study (solved for). The generated multigrid levels are kept in the model and the mcasegen property is changed into manual. The method refine only refines the mesh and does not change the shape function order. The method refineany and refineall first tries to lower the order, and secondly refines the mesh. The method refineany constructs a multigrid level by lowering the order

(by one) if at least on shape function can be lowered. The method `refineall` generates multigrid levels by lowering the order (by one) if all used shape function can be lowered.

- If `mcasegen=manual`, then the existing multigrid levels (children to the current study) can be used. The subset to use is selected by giving their tags to the `mcaseuse` property.

The construction of coarse level matrices is controlled by the property `massem` and `mcaseassem`. The first property controls if the matrices should be assembled for the automatically generated levels. If set to `off`, prolongation and restriction matrices are used to project the matrices from the top level in the hierarchy. The second property controls which multigrid levels that should use the assemble technique in the `mcasegen=manual` case.

When an iterative solver is used as preconditioner, smoother, or coarse solver, you can choose whether to solve using a tolerance or to perform a fixed number of iterations. When used as a coarse solver, the default is to solve using a tolerance. When used as a preconditioner or smoother, the default is to perform a fixed number of iterations. If both properties `itol` and `iter` are given, the program solves using a tolerance.

DOMAIN DECOMPOSITION PROPERTIES

TABLE 6-42: VALID DOMAIN DECOMPOSITION PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
prefun	ddadd | ddmul | ddhyb | ddsym	ddmul	Domain decomposition solver (Additive Schwarz/Multiplicative Schwarz/Hybrid Schwarz/ Symmetric Schwarz).
iter	integer	1	Number of iterations.
ndom	integer	2	Number of subdomains.
ddreordermethod	none | space	space	Element reordering method: none or using a space-filling curve.
domdofmax	integer	1	Maximum number of nodes per subdomain.
domnodesmax	integer	100000	Maximum number of DOFs per subdomain.
overlap	integer	1	Additional overlap.
overlapmethod	auto | matrix | mesh	auto	Overlap method.
prefermatfree	on | off	off	Automatically choose matrix free format.
usecoloring	on | off	on	Use coloring (for prefun = ddmul | ddsym).
userac	on | off	off	Recompute and clear subdomain data.
domgeom	vector of strings		Partition geometries.
usecoarse	on | algebraic | aggregation | off	on	Use coarse level: geometric (on), algebraic multigrid (algebraic), aggregations AMG (aggregation), or off.
mcasegen	coarseorder | all | any | coarse | refineall | refineany | refine | manual	any	Coarse level generation method.
scale	scalar > 0	2.0	Mesh coarsening factor (for mcasegen = coarseorder | any | all | coarse).
rmethod	longest | regular	longest	Mesh refinement method (for mcasegen = refineall | refineany | refine).
geomuse	vector of strings		Use coarse level in geometries (for mcasegen = coarseorder | all | any | coarse | refineall | refineany | refine).
massem	on | off	on	Assemble on coarse level (for mcasegen = coarseorder | all | any | coarse | refineall | refineany | refine | manual).
mkeep	on | off	on	Keep generated coarse level (for mcasegen = all | any | coarse).
mcaseuse	vector of strings		Coarse level that should be used (for mcasegen = manual).
mglevels	positive integer	5	Maximum number of algebraic multigrid levels (algebraic, aggregation).

TABLE 6-42: VALID DOMAIN DECOMPOSITION PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
maxcoarsedofs active	on | off	off	Enable setting the maximum number of DOFs at coarsest level
maxcoarsedof	positive integer	5000	Maximum number of DOFs at coarsest level (algebraic, aggregation) if maxcoarsedofsactive is on.
amgauto	integer from 1 to 10	3	Quality of multigrid hierarchy (algebraic).
agglevel	positive integer	2	Multigrid level to start smoothing at, if aggmethod =manual (aggregation).
aggmethod	auto | manual	auto	Postpone prolongation smoothing (aggregation).
amgauto	integer from 1 to 10	3	Quality of multigrid hierarchy (algebraic).
compactaggregation	on | off	on	Use an aggregation algorithm that leads to a less rapid coarsening (aggregation).
jacdamp	positive scalar	2/3	Jacobi damping factor (aggregation).
reuseprolongators	on | off	on	Reuse prolongators when possible (aggregation).
strconn	positive scalar	0.01	Strength of connection (aggregation).
useaggressive	on | off	on	Use aggressive coarsening (aggregation).
usefilter	on | off	on	Use filtering (aggregation).
hybridization	single | multi	single	Use a single preconditioner or multiple preconditioner as a hybrid preconditioner.
hybridvar	vector of strings		Fields/states in step / Preconditioner variables (for hybridization = multi).
hybridvarspec	all | manual	all	Include all components or specify which manually (for hybridization = multi).
hybridcomp	vector of strings		Field/state components in step / Preconditioner selection (for hybridvarspec= manual).

Example Code for Use With Java

```
model.sol("sol1").feature("s1").create("i1", "Iterative");
model.sol("sol1").feature("s1").feature("i1").create("dd1","DomainDecomposition");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").feature("ds").
      create("mg1","Multigrid");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").set("prefun","ddadd");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").set("mcasegen","refine");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").set("domnodesmax","2");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").
      set("overlapmethod","mesh");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").set("ndom", "16");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").
      set("domgeom", new String[]{"geom1"});
model.sol("sol1").feature("s1").feature("i1").feature("dd1").feature("cs").
      feature("dDef").set("linsolver","pardiso");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").feature("ds").
```

```
      feature("mg1").set("gmglevels","5");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").
      set("hybridization","multi");
model.sol("sol1").feature("s1").feature("i1").feature("dd1").
      set("hybridcomp", new String[]{"comp1.u"});
```

SOR PREFUN PROPERTY

TABLE 6-43: SOR PREFUN PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
prefun	ssor | sor | soru	ssor	Solver (SSOR, SOR, or SORU).

SSOR GAUGE PREFUN PROPERTY

TABLE 6-44: SSOR GAUGE PREFUN PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
prefun	ssorgauge | sorgauge | sorugauge	sorgauge when used as presmoother; sorugauge when used as postsmoother; ssorgauge otherwise.	Solver (SSOR gauge, SOR gauge, or SORU gauge).

SOR VECTOR PREFUN PROPERTY

TABLE 6-45: SOR VECTOR PREFUN PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
prefun	ssorvec | sorvec | soruvec	sorvec when used as presmoother; soruvec when used as postsmoother; ssorvec otherwise.	Solver (SSOR vector, SOR vector, or SORU vector).

Lower Limit

Handle lower limits for segregated steps. This feature can be added as a subfeature to a Segregated feature.

SYNTAX

```
model.sol(sname).feature(solv).feature(segregated).create(fname,"LowerLimit")
model.sol(sname).feature(solv).feature(segregated).feature(fname).set(pname,value)
```

DESCRIPTION

This feature controls the lower limits for variables used in segregated steps.

TABLE 6-46: VALID LOWER LIMIT PROPERTY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
lowerlimit	String		String of variable and lower limit pairs.

A valid `lowerlimit` string contains pairs of variables names and the associated lower limit. For example, to impose a lower limit of 0.25 for the value of the field u in Component 1, and a lower limit of 0.0 for the value of the field v in Component 1, use the string `"comp1.u 0.25 comp1.v 0.0"`.

Lumped Step

Handle a lumped solution step, which can be added as a subfeature to a Segregated feature.

SYNTAX

```
model.sol(sname).feature(solv).feature(segregated).create(fname,"LumpedStep")
model.sol(sname).feature(solv).feature(segregated).feature(fname).set(pname,value)
```

DESCRIPTION

This feature controls one lumped solution step.

TABLE 6-47: VALID LUMPED STEP PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
segcomp	vector of strings		Field/State components in step if segvarspec=manual
segvar	vector of strings		Fields/States in step
segvarspec	all | manual	all	Include all components or specify which manually

See SegregatedStep for more information about these properties.

Modal

Solve parametric or time-dependent problem using the eigenmodal method.

SYNTAX

```
model.sol(sname).create(fname,"Modal")
model.sol(sname).feature(fname).set(pname,pvalue)
```

DESCRIPTION

Operation feature. The following properties and values are accepted:

TABLE 6-48: VALID MODAL PROPERTY/VALUE PAIRS FOR THE MODAL SOLVER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
analysistype	frequency | transient	frequency	Solve for frequency response or transient response.
clist	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
cname	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
dampratio	scalar | numeric vector	0	Damping ratios for participating modes.
eigsol	solution object		Pre-computed eigenpairs (or other vectors) to be used in the modal analysis.
keeplog	on | off	off	Keep warnings in stored log.
loadfact	string | vector of strings	empty	Scalar function(s) for time and/or parameter dependent boundary conditions.
maxstepbdf	positive scalar	1e-1	Maximum time step when maxstepconstraintbdf is const.
maxstepconstraintbdf	auto | const | expr	auto	Maximum time step for time-dependent modal analysis: automatic (auto), constant (const), or an expression (expr).
maxstepexpressionbdf	String		Expression for the maximum time step when maxstepconstraintbdf is expr.
message	String		The log message from the last solution process.
modes	integer vector	all	Participating modes.

TABLE 6-48: VALID MODAL PROPERTY/VALUE PAIRS FOR THE MODAL SOLVER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
outsollinearized	du | u	du	Store the total solution (u) or deviation and linerization point (du), when analysistype=frequency and storelinpoint=off.
plist	scalar | numeric vector		Frequency list. Only applicable when analysistype has been set to frequency.
pname	vector of strings		Parameter names.
pout	plist | fraction | spread	plist	Use plist as it stands or modify in relation to the participating modes.
romdata	String	new	Tag of the target container for the reduced model (new for a new reduced model).
romReconstruct	true | false	true	Enable reconstruction in the produced reduced model.
rtol	scalar	0.01	Relative tolerance. Only applicable when analysistype has been set to transient.
soltypemat	on | off	off	Store reduced model matrices.
soltypeonline	on | off	off	Create a reduced model.
soltypesol	on | off	on	Perform frequency sweep or transient simulation using the modal solver.
storelinpoint	on | off	off	Whether to store the linearization point.
tlist	scalar | numeric vector		Time list. Only applicable when analysistype has been set to transient.

In addition, the following properties are available for exporting matrices and vectors:

TABLE 6-49: VALID MODAL PROPERTY/VALUE PAIRS FOR MATRIX AND VECTOR EXPORT FROM THE MODAL SOLVER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
AllL	on | off	off	All load vectors, frequency.
BOr	on | off	off	Initial value input matrix, transient.
BOrdot	on | off	off	Initial time derivative input matrix, transient.
Br	on | off	off	Input matrix, transient and frequency.
Brdot	on | off	off	Time derivative input matrix, transient.
Brdotdot	on | off	off	Second time derivative input matrix, transient.
Cr	on | off	off	Output matrix, transient and frequency.
Cstate	on | off	off	State-space matrix C, transient.
Dc	on | off	off	State-space matrix D, transient.
DPartSol	on | off	off	Damping matrix times particular solution, frequency.
Dr	on | off	off	Damping matrix, transient and frequency.
Dra	on | off	off	Damping ratio matrix, transient and frequency.
Dstate	on | off	off	State-space matrix D, transient.
EPartSol	on | off	off	Mass matrix times particular solution, frequency.
Er	on | off	off	Mass matrix, transient and frequency.
F	on | off	off	Input feedback, transient and frequency.
Kr	on | off	off	Stiffness matrix, transient and frequency.
Kud	on | off	off	Stiffness matrix times u_d, transient.
L	on | off	off	Load vector, transient and frequency.
Pm	on | off	off	Projection matrix, transient and frequency.

TABLE 6-49: VALID MODAL PROPERTY/VALUE PAIRS FOR MATRIX AND VECTOR EXPORT FROM THE MODAL SOLVER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
U0	on | off	off	Initial value vector, transient.
Udot0	on | off	off	Initial derivative vector, transient.
Y0	on | off	off	Output bias, transient and frequency.

For frequency response analysis, nonconstant Neumann boundary conditions and constant Dirichlet boundary conditions are supported. The only allowed type of parameter-dependent Dirichlet boundary condition are those that can be written as a constant vector times a scalar function. The scalar function is specified via the property `loadfact`. For transient response analysis only constant Dirichlet boundary conditions are supported. Neumann conditions that can be written as a constant vector times a scalar function (which is specified via the property `loadfact`) are supported for transient response.

The property `modes` is index 0 based.

If `pout` is set to `fraction` the output frequencies are the ones in `plist` multiplied by the absolute value of the largest eigenvalue in `eigsol` (or some other fraction of the largest participating eigenvalue of `eigsol`). The purpose of this property is to be able to automatically compute the frequency response for reasonable frequencies. If `pout` is set to `spread` then `plist` is interpreted as an interval around each participating eigenvalue. For example, if `plist` is set to `range(0.9,0.04,1.1)` then each participating eigenvalue is multiplied by this list, and the resulting lists are concatenated into the `plist` that is used.

REMOVED PROPERTIES

TABLE 6-50: REMOVED PROPERTIES FOR THE MODAL SOLVER SEQUENCE FEATURE

PROPERTY	REASON
Callblevel	Given by the solver sequence attribute feature.
soltype	Deprecated in version 5.3 and replaced with `soltypesol`, `soltypemat`, and `soltypeonline`.

Optimization

Handle optimization solver properties.

SYNTAX

```
model.sol(sname).create(fname,"Optimization")
model.sol(sname).feature(fname).set(pname,value)
model.sol(sname).feature(fname).create(aname,SolverAttribute)
```

DESCRIPTION

Operation feature. Use this feature to solve PDE-constrained optimization problems. The computed solution object contains the PDE solution evaluated for the optimal set of design variables. When the gradient-evaluation method is analytic, it also returns the adjoint solution.

The Optimization Module includes SNOPT and several other optimization solvers. See the *Optimization Module Manual* for details.

To add a stationary solver, substitute `SolverAttribute` above with `StationaryAttrib`. For a time-dependent solver, replace `SolverAttribute` with `TimeAttrib`.

Choosing solver is done with the following property

TABLE 6-51: PROPERTY/VALUE PAIR TO SELECT OPTIMIZATION SOLVER

PROPERTY	VALUE	DEFAULT	DESCRIPTION
optsolver	bobyqa | cobyla | coordsearch | lm | mma | montecarlo | neldermead | snopt	snopt	Optimization solver

The following table includes general optimization solver properties, which a common to all optimization solvers:

TABLE 6-52: GENERAL OPTIMIZATION PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
keeplog	on | off	off	Keep warnings in stored log.
nsolvemax	positive integer	1000	Maximum number of objective evaluations.
opttol	real scalar	0.001	Tolerance.
plot	on | off	off	Whether to plot while solving.
plotgroup	String	default	Name of plot group for plot while solving.
probes	vector of strings		Probes to use if probesel=manual.
probesel	all | none | manual	all	The probes to compute.

When the optimization solver is set to SNOPT (snopt), the following properties are accepted:

TABLE 6-53: VALID PROPERTIES FOR OPTSOLVER SNOPT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
clist	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
cname	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
feastol	real scalar	1e-6	Linear constraint tolerance.
funcprec	real scalar	3.8e-11	Function precision.
gradientmma	analytic | forward | adjoint | forward_numeric	analytic	Gradient/Jacobian evaluation method for MMA.
gradientsnopt	analytic | numeric	analytic	Gradient/Jacobian evaluation method for SNOPT.
hessupd	integer	10	Hessian updates.
linesearch	derivative | nonderivative	derivative	Use a derivative (gradient) or nonderivative (gradient free) linesearch strategy.
linestol	real scalar	0.9	Linesearch tolerance (a value between 0 and 1). A lower value gives a more accurate search.
majfeastol	real scalar	1e-6	Nonlinear constraint tolerance.
manualhessupd	on | off	off	Whether to use property hessupd.
manualstepcond	on | off	off	Whether to use manual step condition.
message	String		The log message from the last solution process.
objcontrib	all | manual	all	Whether to use all objective contributions present or specify manually.

TABLE 6-53: VALID PROPERTIES FOR OPTSOLVER SNOPT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
optobj	String		Objective function that is minimized when objcontrib=manual.
pdistrib	on | off	off	Distribute parametric sweep.
qpsolver	cholesky | cg | qn	cholesky	QP subproblem algorithm.
stepcond	String	empty	Manual step condition.

The property gradientsnopt is used to control if the gradient should be computed analytically (by solving the adjoint problem) or numerically. If the number of design variables is large, numerical computation of the gradient can be very time consuming. Analytic gradient is only supported when the underlying PDE-problem is stationary.

If manualstepcond is set to on, the expression in the property stepcond is evaluated when new values for the design variables have been computed. If the expression becomes negative, the new values are discarded and the optimization solver reduces the step length in the current line search.

When the optimization solver is set to Levenberg-Marquardt (lm), the following properties are accepted:

TABLE 6-54: VALID PROPERTIES FOR OPTSOLVER LM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
gradientlm	numeric	numeric	Gradient/Jacobian evaluation method.
gradorder	first | second	first	Approximation order of the gradient.
lmfact	real scalar	1e-3	Initial Levenberg-Marquardt factor.

When the optimization solver is set to MMA, the following properties are accepted:

TABLE 6-55: VALID PROPERTIES FOR OPTSOLVER MMA

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mmamaxiter	positive integer	1	Maximum outer iterations.
mmamaxiteractive	on | off	off	Enable maximum outer iterations.
mmainnmax	positive integer	10	Maximum inner iterations per outer iteration.
mmagepsfactor	real scalar	0.1	Internal tolerance factor.
mmacfactor	real scalar	1000	Constraint penalty factor.
mmaghinit	real scalar	0.5	Initial asymptote factor (ghinit).
mmaghdecr	real scalar	0.7	Decreasing asymptote factor (ghdecr).
mmaghincr	real scalar	1.2	Increasing asymptote factor (ghincr).
mmaasymin	real scalar	0.01	Minimum asymptote level (asymin).
mmaasymax	real scalar	10	Maximum asymptote level (asymax).
mmaalbeta	real scalar	0.1	Bounds asymptote factor (albefa).
mmaxxmove	real scalar	0.5	Bounds control factor (xxmove).
mmaraai	real scalar	0.00001	Approximation increment (raai).
mmaraamin	real scalar	0.000001	Lower approximation bound (raamin).
mmalsq	on | off	on	Automatically transform least-squares objectives to constraints for efficiency.
mmaminmax	on | off	on	Automatically transform minimax and maximin problems to constraints for efficiency.
gcmma	on | off	on	Use the globally convergent MMA algorithm.

For a description of the optimization properties, see Advanced Solver Properties in the *Optimization Module User's Guide*.

TABLE 6-56: REMOVED FEMOPTIM PROPERTIES

PROPERTY	REASON
Callblevel	Handled by attribute features
Solprop	Handled by stationary or time
Solcomp	Handled by variables
Report	Handled by variables
Out	Solution should be exported

Parametric

Handle parameters for parameter stepping for stationary problems.

SYNTAX

```
model.sol(sname).create(fname,"Stationary")
model.sol(sname).feature(fname).create(parname,"Parametric")
model.sol(sname).feature(fname).feature(parname).set(pname,pvalue)
```

DESCRIPTION

Attribute feature.

TABLE 6-57: PARAMETRIC PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
defsolvergen	global | first | last | all	global	Control when a solver sequence should be generated during a parametric sweep using global parameters or the first, last, or each parameter tuple,
initdampall	off | on | auto	auto	Setting this property to on the initial damping factor is used for all parameter steps.
paramtuning	on | off	off	Setting this property to on enables the use of the properties pinitstep, pmaxstep, and pminstep.
pdistrib	on | off	off	If the solver should distribute the parameter sweep.
pinitstep	positive real		Initial step size for parameter. See paramtuning.
plist	real array		List of parameter values. Obsolete, use plistarr instead.
plistarr	real matrix		Lists of parameter values. One row of values for each parameter name.
pcontinuationmode	no | last | manual	last	Determines if a continuation sweep should be performed for one of the parameters in pname.
pcontinuation	String		For pcontinuationmode=manual this is one of the parameter names from pname.
pdistrib	on | off	off	Distribute parametric sweep.
plooporder	auto | manual	auto	Parametric values loop order. If set to auto, a more efficient loop order is used if possible.
preusesol	no | yes | auto	no	Determines how the converged solutions are reused in the parameter sweep.

TABLE 6-57: PARAMETRIC PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ponerror	stop | empty	stop	Determines what the solver does when there is a solver error or when the continuation backtracking fails: Stop, or store an empty solution.
pmaxstep	positive real		Maximum step size for parameter. See paramtuning.
pminstep	positive real		Minimum step size for parameter. See paramtuning.
pname	vector of strings		Parameter names.
porder	constant | linear	linear	Predictor order for parameter stepping.
pout	plist | psteps	plist	Output either the parameters in plist or the solution at the expansion points.
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probesel	all | none | manual	all	The probes to compute.
probes	array of strings		Probes to use when probesel=manual.
pwork	integer	1	Maximum number of distributed groups.
rstep	real scalar > 1	10	Restriction for step size update.
sweeptype	sparse | filled	sparse	Method for doing the parameter variation. For sweeptype=sparse, the parameter tuples defined by the columns in plistarr are solved for. This method requires equal length for the rows. For sweeptype=filled, all parameter combinations given by plistarr are solved for.

PlugFlow

Solve a stationary plug flow problem.

SYNTAX

```
model.sol(sname).create(fname,"PlugFlow")
```

DESCRIPTION

This solver is a version of the Time-Dependent Solver (see Time). The difference being that it steps in volume instead of time. The available properties are those given in Table 6-67, where the word *time* in the Description column should be understood as *volume*.

Previous Solution

Compute solutions for previous parametric solution parameters and previous time-dependent solution parameters.

SYNTAX

```
model.sol(sname).create(fname,"Stationary")
model.sol(sname).feature(fname).create(parname,"Parametric")
model.sol(sname).feature(fname).feature(parname).create(psname,"PreviousSolution")
model.sol(sname).feature(fname).feature(parname).feature(psname).set(pname,pvalue)

model.sol(sname).create(fname, "Time");
model.sol(sname).feature(fname).create(psname, "PreviousSolution");
model.sol(sname).feature(fname).feature(psname).set(pname, pvalue);
```

DESCRIPTION

Attribute feature. After the solver has converged for a parameter step or a time step, the previous components are solved for in a separate solver step. These components are held fixed (not solved for) during the normal solver procedure.

Segregated

Handle the segregated solution approach.

SYNTAX

```
model.sol(sname).feature(solv).create(fname,"Segregated")
model.sol(sname).feature(solv).feature(fname).set(pname,value)
model.sol(sname).feature(solv).feature(fname).feature(fname2).set(pname,value)
```

DESCRIPTION

This feature can be used as an attribute for the `Time` and `Stationary` features. The approach taken is nonlinear Uzawa iterations in which user-defined groups of variables are solved for separately (a segregated step) while other variables are held fixed. The segregated steps for the segregated solver is handled by subattributes of the sort of `SegregatedStep`, `LumpedStep`, and `LowerLimit`.

The `Segregated` attribute supports the following properties;

TABLE 6-58: VALID SEGREGATED PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`maxsegiter`	positive integer	100, 25 (Time)	Maximum number of segregated iterations.
`ntolfact`	positive scalar	1	Tolerance factor.
`plot`	`on` | `off`	`off`	Plot while solving.
`plotgroup`	String	`default`	Plot group to use for plot while solving.
`probesel`	`all` | `none` | `manual`	`all`	The probes to compute.
`probes`	array of strings		Probes to use when probesel=manual.
`ratelimit`	positive scalar	1	Limit on nonlinear convergence rate.
`segaaccdim`	positive integer	10	Dimension of Anderson iteration space when `segstabacc` = `segaacc`.
`segiter`	positive integer	1	Fixed number of segregated iterations.
`segreserrfact`	positive scalar	100	Residual factor for `segtermonres=auto`.
`segstabacc`	`none` | `segclfcmp` | `segaacc`	`none`	Stabilization and acceleration: None, pseudo time stepping (for stationary solvers), or Anderson acceleration.
`segterm`	`iter` | `tol` | `itertol`	`tol`	Segregated solver termination technique.
`segtermonres`	`off` | `on` | `auto`	`auto`	Termination criterion: Solution, residual, solution or residual.
`segaaccdelay`	positive integer	0	Number of iterations between pseudo time stepping becomes inactive and Anderson acceleration becomes active when `segstabacc` = `segaacc`.
`segaaccdim`	positive integer	10	Dimension of Anderson iteration space when `segstabacc` = `segaacc`.
`segaaccmix`	scalar 0–1	1	Mixing parameter when `segstabacc` = `segaacc`.

TABLE 6-58: VALID SEGREGATED PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
segcflaadelay	positive integer	0	Number of iterations between pseudo time stepping becomes inactive and Anderson acceleration becomes active when segstabacc = segcflcmp.
segclfaacfl	positive scalar	100	CFL threshold when segstabacc = segcflcmp.
segclfaadim	positive integer	10	Dimension of Anderson iteration space when segstabacc = segcflcmp.
segclfaamix	scalar 0–1	1	Mixing parameter when segstabacc = segcflcmp.
segcfljtech	true | false	false	Override Jacobian update for step when segstabacc = segcflcmp.
segcfljtechval	onfirst | minimal	onfirst	Jacobian update on first iteration or minimal when segstabacc = segcflcmp and segcfljtech = true.
segjtechcfl	positive scalar	100	CFL threshold for Jacobian update when segstabacc = segcflcmp and segcfljtech = true.
subcfltol	positive scalar	0.1	Target error estimate for pseudo time stepping.
subinitcfl	positive scalar	5.0	Initial CFL number for pseudo time stepping.
subkdpid	positive scalar	0.05	PID controller - derivative for pseudo time stepping.
subkipid	positive scalar	0.05	PID controller - integral for pseudo time stepping.
subkppid	positive scalar	0.65	PID controller - proportional for pseudo time stepping.
useratelimit	on | off	off, on (time)	Use limit on nonlinear convergence rate.

Termination of the segregated solver is controlled by the property segterm. The default setting is tol, in which case the segregated iterations are terminated when, for each group, the estimated error is below the corresponding tolerance set by the main tolerance for the parent solver multiplied with the nonlinear tolerance factor ntolfact. However, a maximum number of allowed segregated iterations is chosen through the property maxsegiter; if the maximum is reached, the iterations are terminated and an error message is displayed. Termination after a fixed number of segregated iterations is achieved by instead choosing iter. The number of segregated iterations is controlled by the property segiter. The third available option for segterm is itertol, which is a combination of the other two options; the segregated iterations are terminated when one of the two convergence criteria of tol and iter is met. The property maxsegiter is only supported when tol is used for termination. For both the settings iter and itertol, the number of iterations is controlled by the property segiter.

The nonlinear solver uses an adaptive tolerance for termination of iterative linear system solvers. This adaptive tolerance is based on the maximum of ntol and itol. During the nonlinear iterations, it can, however, be larger or smaller than this number. The segregated solver uses the same tolerance as the linear solver when constant damping is used. However, when automatically adjusted damping is used, the adaptive tolerance of the nonlinear solver is used. The parametric solver uses the same tolerance as the corresponding stationary solver.

The property segstabacc enables or disables pseudo time stepping (for stationary problems) or Anderson acceleration. When enabled the pseudo time stepping is controlled by the scalar-valued controller parameters subcfltol, subinitcfl, subkdpid, subkipid, and subkppid. For the Anderson acceleration, the parameter segaaccdim specifies the dimension of the Anderson iteration space.

The property segtermonres controls the termination criterion for stationary problems when segterm is not iter. When segtermonres=off the estimated error is solution-based, with segtermonres=on it is based on a relative residual and for segtermonres=auto the estimated error is the minimum of the solution and residual based errors. For segtermonres=auto the property segreserrfact is a scalar factor multiplying the relative residual error.

COMPATIBILITY

The property `subusecflcmp` from earlier versions of COMSOL Multiphysics is not used in version 5.0 and later versions. Use the property `segstabacc` instead.

SegregatedStep

Handle a segregated solution step, which can be added as a subfeature to a Segregated feature.

SYNTAX

```
model.sol(sname).feature(solv).feature(segregated).create(fname,"SegregatedStep")
model.sol(sname).feature(solv).feature(segregated).feature(fname).set(pname,value)
model.sol(sname).feature(solv).feature(segregated).feature(fname).feature(sname).
  set(pname,value)
```

DESCRIPTION

This feature controls one segregated solution step.

TABLE 6-59: VALID SEGREGATED STEP PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`maxsubiter`	integer	20	Maximum number of substep iterations
`segcomp`	vector of strings		Field/State components in step if segvarspec=manual
`segvar`	vector of strings		Fields/States in step
`segvarspec`	`all` | `manual`	`all`	Include all components or specify which manually
`subdamp`	real	`1.0`	Substep damping factor
`subdtech`	`const` | `auto` | `hnlin` | `ddog`	`const`	Substep damping technique
`subddoginitdamp`	non-negative scalar	1	Initial damping factor for `subdtech` set to `ddog`
`subddogrestart`	positive integer	7	Number of iterations before restart for `subdtech` set to `ddog`.
`subinitstep`	real	1	Substep initial damping factor for subdtech=auto
`subinitsteph`	real	`1e-4`	Substep initial damping factor for subdtech=hnlin
`subiter`	integer	1	Substep iterations
`subjtech`	`minimal` | `once` | `onfirst` | `onevery`	see below	Substep Jacobian update technique for subdtech=const
`subminstep`	real	`1e-4`	Substep minimum damping factor for subdtech=auto
`subminsteph`	real	`1e-8`	Substep minimum damping factor for subdtech=hnlin
`subntolfact`	real	10	Substep tolerance factor
`subreserrfact`	positive scalar	100	Residual factor for `subtermonres=auto`
`subresscale`	`scalefieldwise` | `scaleuniform`	scalefieldwise	Residual scaling technique for subdtech set to ddog
`subrstep`	real	10	Substep restrictions for step-size update
`subtermconst`	`iter` | `tol` | `itertol`	`iter`	Substep termination technique for subdtech=const
`subtermauto`	`tol` | `itertol`	`itertol`	Substep termination technique for subdtech=auto/ hnlin
`subtermonres`	`off` | `on` | `auto`	`auto`	Termination criterion: Solution, residual, solution or residual.

The fields/states to include in the step is defined through the property `segvar`. The property `segvarspec` controls which components of the fields/states in `segvar` to include in the step. By default `segvarspec` is `all`, in which case all components in the fields/states of `segvar` are included. By setting `segvarspec` to `manual`, a subset of the fields/states of `segvar` can be included in the step. The components to include in the step are then defined through the property `segcomp`.

Analogously, the property `subterm` controls how each substep is terminated through the properties `maxsubiter`, `subiter`, and `subntol/subntolfact` for a stationary or time-dependent problem.

The damping technique used in each substep is controlled by the property `subdtech`. The default setting is `const`, which means that damped Newton iterations with a fixed damping factor is used. The damping factor is set in the property `subdamp`. The other available damping technique is `autodamp` in which case the damping factor is automatically adjusted. For substeps which uses `autodamp`, four other properties are supported: `subhnlin`, `subinitstep`, `subminstep`, and `subrstep`. For each substep, these properties set the properties `hnlin`, `initstep`, `minstep`, and `rstep` supported by the nonlinear solver, see `FullyCoupled`.

In substeps with `subdtech=const`, the property `subjtech` controls how often the Jacobian is updated. The values `minimal`, `once`, and `onevery` give the same Jacobian update techniques as they do when applied to the coupled solver through the property `jtech`; see `FullyCoupled`. The value `onfirst` makes the solver update the Jacobian of the substep on the first subiteration each time the substep is solved for. Default value is `onevery` for stationary problems and `minimal` for time-dependent problems.

When `subdtech` is set to `ddog` (stationary problems), the double dogleg solver is used. The initial damping factor is controlled by the property `subddoginitdamp` and the property `subresscale` controls the residual scaling. The option `resscale=scalefieldwise` scales the equations based on the field-wise sizes of the initial residual. When the option `subresscale=scaleuniform` is selected the algorithm terminates on the relative residual based on the initial residual.

The property `subtermonres` controls the termination criterion for stationary problems when `segterm` is not `iter`. When `subtermonres=off` the estimated error is solution-based, with `subtermonres=on` it is based on a relative residual, and for `subtermonres=auto` the estimated error is the minimum of the solution and residual based errors. For `subtermonres=auto` the property `subreserrfact` is a scalar factor multiplying the relative residual error.

Sensitivity

Handle sensitivity solver parameters.

SYNTAX

```
model.sol(sname).feature(solv).create(fname,"Sensitivity")
model.sol(sname).feature(solv).feature(fname).set(pname,value)
```

DESCRIPTION

Attribute feature. This feature can be used to make analytic forward or backward (adjoint) sensitivity analysis. This analysis is done after the main problem has converged. The solution approach (coupled or segregated, Jacobians, and so on) for the main problem is reused.

TABLE 6-60: VALID SENSITIVITY PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`sensfunc`	String		Sensitivity functional variable name
`sensmethod`	`none` | `adjoint` | `forward` | `numeric`	`none`	Sensitivity analysis method

The forward numeric method (`numeric`) is a variant of the forward sensitivity method where the right-hand side of the sensitivity problem is computed by numerical differentiation.

StatAcceleration

Handle stationary acceleration for nonlinear problems with time-periodic stationary solution.

SYNTAX

```
model.sol(sname).feature(solv).create(fname,"StatAcceleration")
```

DESCRIPTION

This feature can added as a subfeature to the Time-Dependent Solver and the Time Discrete Solver. Instead of time marching the problem from start to finish, the Stationary Acceleration node solves for a number of periods and then extrapolates the solution forward in time based on the average solution and the average time derivative. This solution process is repeated until the average time derivative has reached steady state.

TABLE 6-61: VALID PROPERTIES FOR STATACCELERATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
acccomp	vector of strings		Variable components to use stationary acceleration on if accvarspec=manual.
accvar	vector of strings		Variables to use stationary acceleration on.
accvarspec	all | manual	all	Include all components or specify which manually.
stataccfreq	String	13.56[MHz]	Frequency of periodic solution.
statacctol	double	0.01	Stationary tolerance.
stataccnperext	integer	50	Number of extrapolation cycles.
stataccnperavg	integer	5	Number of period averaging cycles.
stataccsmooth	integer	10	Number of smoothing cycles.

StateSpace

Assemble and store matrices that describe a model as a dynamic system.

SYNTAX

```
model.sol(sname).create(fname,"StateSpace")
model.sol(sname).feature(fname).set(pname,value)
model.sol(sname).feature(fname).getSparseMatrixVal(mname)
model.sol(sname).feature(fname).getSparseMatrixValImag(mname)
model.sol(sname).feature(fname).getSparseMatrixRow(mname)
model.sol(sname).feature(fname).getSparseMatrixCol(mname)
model.sol(sname).feature(fname).getVector(vname)
model.sol(sname).feature(fname).getVectorImag(vname)
model.sol(sname).feature(fname).getSparseMatrixValBlock(mname,start,stop)
model.sol(sname).feature(fname).getSparseMatrixValImagBlock(mname,start,stop)
model.sol(sname).feature(fname).getSparseMatrixRowBlock(mname,start,stop)
model.sol(sname).feature(fname).getSparseMatrixColBlock(mname,start,stop)
model.sol(sname).feature(fname).getVectorBlock(vname,start,stop)
model.sol(sname).feature(fname).getVectorImagBlock(vname,start,stop)
model.sol(sname).feature(fname).isReal(mname)
model.sol(sname).feature(fname).getM(mname)
model.sol(sname).feature(fname).getN(mname)
```

DESCRIPTION

State-space feature.

TABLE 6-62: VALID GENERAL PROPERTY/VALUE PAIRS

PROPERTY	VALUES	DEFAULT	DESCRIPTION
input	String array		The input parameters that affect the model
output	String array		The output expressions
static	on | off	on	Static linearized model
Mc	on | off	off	Assemble the Mc matrix
MA	on | off	off	Assemble the McA matrix
MB	on | off	off	Assemble the McB matrix
C	on | off	off	Assemble the C matrix
D	on | off	off	Assemble the D matrix
Null	on | off	off	Assemble the Null matrix
ud	on | off	off	Assemble the ud vector
x0	on | off	off	Assemble the initial data

The state-space feature assembles matrices that describe a model as a dynamic system when `Static` is `off`.

$$Mc\dot{x} = McAx + McBu$$
$$y = Cx + Du$$

In the case when `Static` is `on` a static linearized model of the system is described by

$$y = (D - C(McA)^{-1}McB)u$$

Let *Null* be the PDE constraint null-space matrix and *ud* a particular solution fulfilling the constraints. The solution vector *U* for the problem can then be written

$$U = \mathrm{Null}x + ud + u0$$

where *u*0 is the linearization point, which is determined by the current solution (that is, the solution computed by the previous feature in the sequence). The previous feature can, for example, be a solver or a Dependent Variable node. The Dependent Variable node gives control over which variables to solve for (compute the matrices for). The input linearization point is stored in the sequence after the state-space feature is run.

The input parameters `input` should contain all parameters that are of interest as input to the model. The output expressions `output` should contain a list of all expressions that are to be evaluated as output from the model.

Stationary

Solve a stationary problem with or without parameters, mesh adaptation, sensitivity, or optimization.

SYNTAX

```
model.sol(sname).create(fname,"Stationary")
model.sol(sname).feature(fname).set(pname,value)
```

DESCRIPTION

Operation feature.

The following (intrinsic) properties are available.

TABLE 6-63: STATIONARY PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
clist	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
cname	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
keeplog	on | off	off	Keep warnings in stored log.
keepnotsolstatic	on | off	off	Used in Fatigue analysis to store all solnums from the source solution in the Fatigue solution object (default value is on for Fatigue analysis).
linpmethod	init | sol	init	Method used for linearization point, which for sol is determined by the current solution (that is, the solution computed by the previous feature in the sequence).
linpsol	zero | solution object	zero	Linearization point solution.
linpsoluse	current | solution store	current	Linearization point solution to use.
listsolnum	vector of integers	{1}	Indices to solutions to use as linearization points when solnum = from_list.
lumpedflux	on | off	off	Use lumping when computing fluxes.
manualsolnum	vector of positive integers		Identifies the solutions used when solnum = manual.
nonlin	auto | on | off | linper	auto	Use the nonlinear solver.
message	String		The log message from the last solution process.
outsollinear	du | u	u	Store the total solution (u) or deviation and linearization point (du), when nonlin=off and storelinpoint=off.
outsollinearized	du | u	du	Store the total solution (u) or deviation and linerization point (du), when nonlin=linper and storelinpoint=off.
pdistrib	on | off	off	Distribute parametric sweep.
plot	on | off	off	Whether to plot while solving.
plotgroup	String	default	Name of plot group for plot while solving.
probes	vector of strings		Probes to use if probesel=manual.
probesel	all | none | manual	all	The probes to compute.
reacf	on | off	on	Compute reaction forces.
solnum	auto | all | interp | first | last | from_list | manual | positive integer	auto	Which solnums from another solution to use as linearization point.
stol	positive real	1e-3	Relative tolerance.

TABLE 6-63: STATIONARY PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
storelinpoint	on | off	off	Whether to store the linearization point.
t	real	0	Interpolation time for linearization point from another solution, when solnum=interp.

This solver uses a nonlinear solver if nonlin is on, and it uses the linear solver if nonlin is on or linper. If nonlin is set to auto an analysis is performed to automatically detect if the problem can be solved with a linear solver approach. For a description of the nonlinear solver see the entry under coupling.

The automatic nonlinear/linear detection works in the following way. The linear solver is called if the residual Jacobian matrix (the stiffness matrix, K) and the constraint Jacobian matrix (the constraint matrix, N) are both found not solution dependent and if these matrices are detected as complete. In all other situations the nonlinear solver is used. The analysis is performed by a symbolic analysis of the expressions contributing to these matrices. Complete here means that in the residual and constraint vectors, only expressions were found for which COMSOL Multiphysics computes the correct Jacobian contribution.

Therefore, if you want to solve a linearized (nonlinear) problem, you must set nonlin to off or linper. The off option uses the linearization point for both the residual computation and for the Jacobian and the solution to the liner problem is added to the linearization point. This corresponds to one step in the Newton method. For linper, the linearization point is used for the Jacobian, the zero solution is used for the assembly of the residual and the solution to the linear problem is returned as the solution. Furthermore, the residual assembled for linper is computed using loads marked with the linper operator.

There are variables for which COMSOL Multiphysics is conservative and therefore flags these, and their Jacobian contribution, as solution dependent even though they not always are. For these situations, the nonlinear solver is used even though the linear solver could be used. This should only result in some extra computational effort, and should not influence the result. The opposite situation however, where the linear solver is used for a nonlinear problem is more dangerous. So, select nonlin to off with great care.

The property reacf controls the computation and storage of constraint reaction forces. The value reacf=on (default) means that the solver stores the FEM residual vector L in the solution object model.sol. Because $L = N_F\Lambda$ for a converged solution, the residual is the same as the constraint force. Only the components of L that correspond to nonzero rows of N_F are stored. The value reacf=off gives no computation or storage of the reaction force and saves some memory.

The linear solver uses the property itol for termination of iterative linear system solvers and for error checking for direct solvers (if enabled).

StopCondition

Handle stop conditions for time-dependent, time explicit, and parametric solver processes.

SYNTAX

```
model.sol(sname).create(fname,"Stationary")
model.sol(sname).feature(fname).create(pname,Parametric)
model.sol(sname).feature(fname).feature(pname).create(ocname,StopCondition)
model.sol(sname).feature(fname).feature(pname).feature(ocname).setIndex(pname,pvalue,ix)
```

DESCRIPTION

Attribute feature. Use the StopCondition feature to make sure the solver stops when a specified condition is fulfilled. When you provide a scalar expression, then the expression is evaluated after each time or parameter step. The stepping is stopped if the real part of the expression is evaluated to something negative. The corresponding solution, for which the expression is negative, is not returned. When you provide an integer, the solver stops when

the corresponding implicit event is triggered. Use `setIndex` to set the stop condition properties for multiple stop conditions. For example,

```
model.sol("sol1").feature("t1").feature("st1").setIndex("stopcondarr", "(1/timestep)<200", 1);
```

specifies the second stop condition to be `(1/timestep)<200`.

TABLE 6-64: VALID STOPCONDITION PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`stopcondActive`	Vector with entries "on" and "off"		Vector describing which stop condition expression that are active.
`stopcondarr`	Vector of strings		Stop condition expressions.
`stopconddesc`	Vector of strings		Descriptions for stop condition expressions.
`stopcondition`	String		Stop condition expression (deprecated).
`stopcondterminateon`	Vector with entries "true" and "negative".		For "true" ("negative"), entries, the solver stops if the associated `stopcondarr` entry satisfies ≥1 (<0).

StoreSolution

A placeholder for a solver sequence that is used to store a computed solution.

SYNTAX

```
model.sol(sname).create(fname,"StoreSolution")
model.sol(sname).feature(fname).getString("sol")
```

DESCRIPTION

The store solution feature stores a reference to a computed solution. Use the `sol` property to find out the name of the referenced solution.

TABLE 6-65: VALID STORESOLUTION PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`sol`	String	A solver sequence	Name of solver sequence that stores the solution.

In the case of a parametric sweep you can use the StoreSolution features to find the solutions created during the sweep. You first find out the solver sequence that holds the stored solutions

```
model.batch(pname).feature(fname).getString('psol')
```

where `pname` is the name of the parametric sweep feature that ran and `fname` is the name of the solution feature that stored the solutions. Use

```
model.sol(sname).feature().tags()
```

to find out the tags of the stored solutions. Use

```
model.sol(sname).feature(fname).getString('sol')
```

to find the solver sequence for a parameter. Use

```
model.sol(sname).getParamNames()
```

and

```
model.sol(sname).getParamVals()
```

to find the parameter values that created the solution object.

StudyStep

Specify which problem to use for subsequent solver operations.

SYNTAX

```
model.sol(sname).create(fname,"StudyStep")
model.sol(sname).feature(fname).set(pname,pvalue)
```

DESCRIPTION

Utility feature. This feature determines which problem to use for subsequent solver operations. It contains a reference to a study and a reference to a study step within that study. When run, the corresponding low-level equation representation is compiled.

TABLE 6-66: VALID CONFIGURATION PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`study`	String		Name of study to use
`studystep`	String		Name of study step to use
`splitcomplex`	`on` | `off`	`off`	Represent complex variables by separate degrees of freedom for real and imaginary parts

Time

Solve a time-dependent problem.

SYNTAX

```
model.sol(sname).create(fname,"Time")
model.sol(sname).feature(fname).set(pname,value)
```

DESCRIPTION

Operation feature.

The time interval and possible intermediate time values are given in the property `Tlist`. The output times are controlled by the property `Tout`.

The feature `Time` accepts the following property/values:

TABLE 6-67: VALID PROPERTIES FOR TIME

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`atol`	String	`empty`	Absolute tolerance per field. See below.
`atolmethod`	String	`empty`	How to interpret the atolfields value. See below.
`atolglobal`	positive scalar	`1e-3`	Global absolute tolerance, if `atolglobalvaluemethod` is `manual`.
`atolglobalfactor`	positive scalar	`0.1`	Global absolute tolerance as a factor of the relative tolerance, if `atolglobalvaluemethod` is `factor`.
`atolglobalmethod`	`scaled` | `unscaled`	`scaled`	How to interpret the atolglobal value.
`atolglobalvaluemethod`	`factor` | `manual`	`factor`	Use a factor of the relative tolerance or a user-defined value for the absolute tolerance.
`atoludot`	String	`empty`	Absolute tolerance for time derivatives per field. Only applicable if `atoludotactive` is `on`. See below.
`atoludotactive`	String	`empty`	Used to activate manual specification of absolute tolerance for time derivatives. See below.
`bdforder`	1–5	2	BDF order for manual BDF settings.

TABLE 6-67: VALID PROPERTIES FOR TIME

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`complex`	`on` | `off`	`off`	Allow complex numbers.
`consistent`	`off` | `on` | `bweuler`	`bweuler`	Consistent initialization of DAE systems.
`clist`	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
`cname`	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
`control`	String	`user`	Name of the controlling study step or `"user"` if the feature is controlled manually.
`doprigrowmax`	positive scalar	`10`	Maximum step size growth ratio for Dormand-Prince 5.
`doprigrowmin`	positive scalar	`0.2`	Minimum step size growth ratio for Dormand-Prince 5.
`dopripicontrol`	`smooth` | `quick` | `disabled`	`smooth`	Control behavior of the proportional-integral controller that adds damping on step size changes for Dormand-Prince 5.
`doprisafe`	positive scalar	`0.9`	Step size safety factor for Dormand-Prince 5.
`estrat`	`include` | `exclude`	`include`	Error estimation strategy.
`eventtol`	positive scalar	`0.01`	Event tolerance used for root finding of event conditions when using implicit events for BDF.
`ewtrescale`	`on` | `off`	`on`	Update scaled absolute tolerance for BDF.
`incrdelay`	positive integer	`15`	Number of time steps to delay a time step increase.
`incrdelayactive`	`on` | `off`	`off`	Use delay in time step increase.
`initialstepbdf`	positive scalar	`1e-3`	Initial time step for BDF.
`initialstepbdfactive`	`on` | `off`	`off`	Use an initial time step for BDF.
`initialstepck5`	positive scalar	`1e-3`	Initial time step for Cash-Karp 5.
`initialstepdopri5`	positive scalar	`1e-3`	Initial time step for Dormand-Prince 5.
`initialsteprk34`	positive scalar	`1e-3`	Initial time step for RK34.
`initialstepck5active`	`on` | `off`	`off`	Use an initial time step for Cash-Karp 5.
`initialstepdopri5active`	`on` | `off`	`off`	Use an initial time step for Dormand-Prince 5.
`initialsteprk34active`	`on` | `off`	`off`	Use an initial time step for RK34.
`initialstepgenalpha`	positive scalar	`1e-3`	Initial time step for generalized alpha.
`initialstepgenalphaactive`	`on` | `off`	`off`	Use an initial time step for generalized alpha.
`initialstepfractionbdf-`*`i`*	positive scalar		The fraction of the time step for the initial step of a manual time stepping for BDF. The name and the default depend on the BDF order; for example, `initialstepfractionbdf-2` for BDF order 2.

TABLE 6-67: VALID PROPERTIES FOR TIME

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`initialstepgrowthratebdf-i`	positive scalar		The growth rate for the initial steps of a manual time stepping for BDF. The name and the default depend on the BDF order; for example, `initialstepgrowthratebdf-2` for BDF order 2.
`keeplog`	`on` | `off`	`off`	Keep warnings in stored log.
`lumpedflux`	`on` | `off`	`off`	Use lumping when computing fluxes.
`masssingular`	`yes` | `maybe`	`maybe`	Singular mass matrix.
`maxorder`	integer between 1 and 5	5	Maximum BDF order.
`maxstepbdf`	positive scalar	`1e-1`	Maximum time step for BDF, when `maxstepconstraintbdf` is `const`.
`maxstepconstraintbdf`	`auto` | `const` | `expr`	`auto`	Maximum time step for BDF: automatic (`auto`), constant (`const`), or an expression (`expr`).
`maxstepconstraintdopri5`	`auto` | `const` | `expr`	`auto`	Maximum time step for Dormand-Prince 5: automatic (`auto`), constant (`const`), or an expression (`expr`).
`maxstepconstraintgenalpha`	`auto` | `const` | `expr`	`auto`	Maximum time step for generalized alpha: automatic (`auto`), constant (`const`), or an expression (`expr`).
`maxstepdopri5`	positive scalar	`1e-1`	Maximum time step for Dormand-Prince 5, when `maxstepconstraintdopri5` is `const`.
`maxstepexpressionbdf`	String		Expression for the maximum time step for BDF, when `maxstepconstraintbdf` is `expr`.
`maxstepexpressiongendopri5`	String		Expression for the maximum time step for Dormand-Prince 5, when `maxstepconstraintdopri5` is `expr`.
`maxstepexpressiongenalpha`	String		Expression for the maximum time step for generalized alpha, when `maxstepconstraintgenalpha` is `expr`.
`maxstepgenalpha`	positive scalar	`1e-1`	Maximum time step for generalized alpha, when `maxstepconstraintgenalpha` is `const`.
`message`	String		The log message from the last solution process.
`minorder`	1 | 2	1	Minimum BDF order.
`nlsolver`	`automatic` | `manual`	`manual`	Nonlinear solver settings.
`plot`	`on` | `off`	`off`	Plot while solving.
`plotfreq`	`tsteps` | `tout`	`tout`	Times to update plot.
`plotgroup`	String		Name of plot group for plot while solving.
`probefreq`	`tsteps` | `tout`	`tsteps`	Times to update probe.
`probes`	vector of strings		Probed to use if `probesel=manual`.
`probesel`	`all` | `none` | `manual`	`all`	The probes to compute.

TABLE 6-67: VALID PROPERTIES FOR TIME

PROPERTY	VALUES	DEFAULT	DESCRIPTION
predictor	linear | constant	linear	Predictor type to use (linear or constant),
reacf	on | off	on	Compute reaction forces.
rhoinf	numeric	0.75	Amplification factor for high frequencies.
rkmethod	rk34 | ck5 | dopri5	rk34	Runge-Kutta method: RK34, Cash-Karp 5, or Dormand-Prince 5. Only available when timemethod is set to rk.
rkstiffcheck	on | off	on	Check for and stop if problem becomes numerically stiff for Runge-Kutta solvers.
rtol	numeric	0.01	Relative tolerance.
stabcntrl	on | off	off	Use a nonlinear controller for more efficient time-step control in the BDF method.
storeudot	on | off	on	Store time derivatives.
timemethod	bdf | rk | genalpha | init	bdf	Time-stepping method.
timestepbdf	numeric scalar | numeric vector | string with expression	0.01	Time step when manual time stepping using the BDF method.
timestepgenalpha	numeric scalar | numeric vector | string with expression	0.01	Time step when manual time stepping using the generalized alpha method.
tlist	numeric vector		Time list.
tout	tlist | tsteps	tlist	Output times.
tstepsbdf	free | intermediate | strict | manual	free	Time-stepping mode when rkmethod is set to bdf.
tstepsdopri5	free | intermediate | strict | manual	free	Time-stepping mode when rkmethod is set to dopri5.
tstepsgenalpha	free | intermediate | strict | manual	free	Time-stepping mode when rkmethod is set to genalpha.

By default, you can control the process of solving the linear or nonlinear system of equations in each time step manually. For a coupled problem, this is done through the properties Damp, Dtech, Hnlin, Initstep, Jtech, Maxiter, Minstep, and Rstep listed under femnlin. For a segregated problem, the properties listed under femstatic that are related to the segregated solver are available. When Timemethod is set to bdf it is possible to use the internal nonlinear solver of the time integrator. This can be achieved by setting Nlsolver to automatic.

The properties atol, atolmethod, atolglobal, atolglobalfactor, atolglobalmethod, atolglobalvaluemethod, atoludot, and atoludotactive require some additional explanation. The default value of the absolute tolerance for all fields is given by the property atolglobalfactor or atolglobal, depending on the setting for atolglobalvaluemethod. The modifier atolglobalmethod specifies whether the given value of atolglobal should be applied to scaled or unscaled variables. For variables where the automatic scaling does a good job, or where a manual scaling has been used, specifying the absolute tolerance in scaled variables is much easier. If either a different absolute value or scaling method than dictated by atolglobal and atolglobalmethod is wanted for one or several variables you can use the properties atol and atolmethod. Enter atol as a space separated string with alternating field names and tolerances (for example, "u 1e-3 v 1e-6"). Enter atolmethod as a space-separated string with alternating field names and one of the strings global, scaled, or unscaled (for example, "u unscaled v scaled"). By default atolmethod is equal to global for all fields. The lists atol and

`atolmethod` do not have to contain all fields. The ones not present get absolute tolerances as specified by `atolglobal` and `atolglobalmethod`. When solving wave-type equations with `timemethod` set to `bdf`, the time-derivatives of all fields are also treated as unknowns, and therefore absolute tolerances have to be specified also for these components. By default these tolerances are chosen automatically. In some situations it might be necessary to specify them manually with the properties `atoludot` and `atoludotactive`. To turn on manual specification for, say, the two fields `u` and `v`, set the property `atoludotactive` to the string `"u on v on"`. If `atoludot` is not specified, these two time-derivatives get the default absolute tolerance `1e-3`. To specify other absolute tolerances, set `atoludot` to, for instance, the string `"u 1e-4 v 1e-7"`. The absolute tolerance method for all time derivatives is the same as the method specified for the field itself.

The maximum allowed relative error in each time step (the local error) is specified using `rtol`. However, for small components of the solution vector U, the algorithm tries only to reduce the absolute local error in U below the given absolute tolerance.

There is no guarantee that the error tolerances are met strictly; that is, for hard problems they can be exceeded.

For the tolerance parameter in the convergence criterion for linear systems, the maximum of the numbers `rtol` and `itol` is used.

Use `complex=on` if complex numbers occur in the solution process.

The property `Consistent` controls the consistent initialization of a *differential algebraic equation* (DAE) system. The value `Consistent=off` means that the initial values are consistent (this is seldom the case because the initial value of the time derivative is 0). Otherwise, the solver tries to modify the initial values so that they become consistent. The value `consistent=on` can be used (when `timemethod=bdf` and `nlsolver=automatic`) for index-1 DAEs. Then the solver fixes the values of the differential DOFs and solves for the initial values of the algebraic DOFs and the time derivative of the differential DOFs. The value `Consistent=bweuler` can be used for both index-1 and index-2 DAEs. Then the solver perturbs the initial values of all DOFs by taking a backward Euler step.

For a DAE system, if `Estrat=exclude`, then the algebraic DOFs are excluded from the error norm of the time discretization error.

You can suggest a size of the initial time step using the property `initialstepbdf` when `timemethod` is set to `bdf` the property `initialstepdopri5` when `timemethod` is set to `dopri5`, and the property `initialstepgenalpha` when `timemethod` is set to `genalpha`. You also have to set one of the properties `initialstepbdfactive`, `initialstepdopri5active`, or `initialstepgenalphaactive` to `on` for the specified initial step to be active.

By default, the solver determines whether the system is differential-algebraic by looking after zero rows or columns in the mass matrix. If you have a DAE where the mass matrix has no zero rows or columns, put `masssingular=yes`.

The property `maxorder` gives the maximum degree of the interpolating polynomial in the BDF method (when `timemethod=bdf`).

If `timemethod=bdf` and `maxstepconstraintbdf=const`, then the property `maxstepbdf` put an upper limit on the time step size (this property is not allowed when `tstepsbdf=manual`). If instead `maxstepconstraintbdf=expr`, then the property `maxstepexpressionbdf` controls the maximum step size via an expression that is evaluated while solving. The same holds true for the associated `maxstep` properties if `timemethod=genalpha` or `timemethod=rk` and `rkmethod=dopri5`.

The `timemethod` property is used to select which time-stepping method to use:

- With `timemethod=bdf`, the IDA solver (which uses a variable order backward differentiation formula) is used.
- With `timemethod=rk`, a Runge-Kutta method is used, with the type determined by the `rkmethod` property: `rk34`, `ck5`, or `opri5`, representing the following Runge-Kutta methods: RK34, Cash-Karp 5, or Dormand-Prince 5.

- With `timemethod=genalpha`, the generalized-α method is used. With generalized-α, the numerical damping can be controlled by giving a value, $0 \le \rho_\infty \le 1$, by which the amplitude of the highest possible frequency is multiplied each time step (hence, a small value corresponds to large damping while a value close to 1 corresponds to little damping). This is done through the property `rhoinf`. Also, the initial guess for the solution at the next time step (needed by the nonlinear solver) can be controlled through the property `predictor` when generalized-α is used. With `predictor=linear`, linear extrapolation using the current solution and time-derivative is used. With `predictor=constant`, the current solution is used as initial guess.
- When `timemethod` is set to `init` the solver computes consistent initial values (for the start time, as defined by the property `tlist`) for the system and then stop. Time derivatives of algebraic variables and indicator functions might still be uninitialized after this operation. Such uninitialized quantities are represented by `NaN` (not a number) in the solution object.

The property `reacf` controls the computation and storage of the constraint reaction force. The value `reacf=on` (default) means that the solver stores the FEM residual vector L in the solution object. Because $L = N_F\Lambda$ for a converged solution, the residual is the same as the constraint force. Only the components of L that correspond to nonzero rows of N_F are stored. For each time for which the solution is requested an extra residual vector assembly is performed. The value `reacf=off` gives no computation or storage of the reaction force and can therefore save some computational time.

The property `tlist` must be a strictly monotone vector of real numbers. Commonly, the vector consists of a start time and a stop time. If more than two numbers are given, the intermediate times can be used as output times, or to control the size of the time steps (see below). If just a single number is given, it represents the stop time, and the start time is 0.

The property `tout` determines the times that occur in the output. If `tout=tsteps`, then the output contains the time steps actually taken by the solver. If `tout=tlist`, then the output contains interpolated solutions for the times in the `tlist` property. The default is `tout=tlist`.

The properties `tstepsbdf` (applicable when `timemethod=bdf`), `tstepsdopri5` (applicable when `timemethod=dopri5`), and `tstepsgenalpha` (applicable when `timemethod=genalpha`) control the selection of time steps. If either of these properties is set to `free`, the solver selects the time steps according to its own logic, disregarding the intermediate times in the `tlist` vector. If either of the properties is set to `strict`, then time steps taken by the solver contain the times in `tlist`. If either of the properties is set to `intermediate`, then there is at least one time step in each interval of the `tlist` vector. If `tstepsgenalpha` has been set to `manual`, the solver follows the time step specified in the property `timestepgenalpha`. If `timestepgenalpha` is a scalar value, this time step is taken in the entire simulation. When `timestepgenalpha` is a (strictly monotone) numeric vector, the solver computes the solution at the times in the vector. The start time and stop time is still obtained from `tlist`; the vector given in `timestepgenalpha` is truncated and/or expanded using the first and/or last time step in the vector so that the start time and stop time agrees with the values in `tlist`. Finally, an expression using variables with global scope and which results in a scalar can be used as `timestepgenalpha`.

For problems of wave type, the logic by which the solver selects the time step can sometimes result in a time step that oscillates in an inefficient manner. When `timemethod=genalpha` (the solver typically used for wave-type problems), you can avoid such oscillations in the time step using the properties `incrdelay` and `incrdelayactive`. When `incrdelayactive=on`, a counter keeps track of the number of consecutive time steps for which a time step increase has been warranted. When this counter exceeds the number given in the property `incrdelay`, the time step is increased and the counter is set to zero.

In structural mechanics models, the displacements are often quite small, and it is critical that a user-defined absolute tolerance value is chosen to be smaller than the actual displacements.

For more information about the Time-Dependent solver; see Time-Dependent Solver in the *COMSOL Multiphysics Reference Manual.*

TimeAdaption

Handle time-dependent adaptive mesh refinement parameters.

SYNTAX

```
model.sol(sname).feature(solv).create(fname,"TimeAdaption")
model.sol(sname).feature(solv).feature(fname).set(pname,value)
```

DESCRIPTION

Handles settings for time-dependent adaptive mesh refinement. This feature can be added to a solver of the Time Dependent type.

The `TimeAdaption` feature splits the overall time range into subintervals, and in each interval an adapted mesh is generated and used. The meshes for these intervals as well as the solutions are added to the model. The solutions are stored in one container node (`model.sol()`) to facilitate the result processing.

The feature `TimeAdaption` accepts the following property/value pairs

TABLE 6-68: VALID TIMEADAPTION PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`consistentrestart`	`on` | `off`	`off`	Consistent initialization after restart
`clist`	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
`cname`	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
`convertmesh`	`on` | `off`	`on`	Convert to simplex mesh
`eefuntime`	`user`	`user`	Error indicator function
`eefunctime`	String		Error indicator name (eefuntime=user)
`elfrac`	positive scalar	`0.2`	Fraction of maximum refinement if `tauto=automatic`
`elselect`	`globalmin` | `worst` | `elements`		Method for selecting elements to refine.
`elselectauto`	globalmin		Method for selecting elements to refine if `tauto=automatic`.
`gf`	positive scalar	2	Interval growth factor
`globalminpar`	positive scalar		Controls refinement if `elselect=globalmin`
`globalminparauto`	positive scalar		Controls refinement if `elselectauto=globalmin`
`initialsteprestart`	positive scalar	`0.001`	Initial time step size after restart
`initialsteprestart active`			
`message`	String		The log message from the last solution process.
`minti`	positive scalar	`0.01`	Minimal length of adaptation time intervals.
`ngenlocal`	scalar integer	2	Maximum number of element refinements.
`rf`	positive scalar	`0.5`	Interval reduction factor.

TABLE 6-68: VALID TIMEADAPTION PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
rmethod	regular | longest	longest	Refinement method.
samplepts	scalar | numeric vector	range(0,0.1,1)	Where to check the error in next subinterval.
tauto	manual | automatic	manual	Time interval control.
tfrac	positive scalar	0.1	Length of adaptation time intervals.
tfracauto	positive scalar	0.1	Length of initial adaptation time interval if tauto=automatic.
timeadapgeom	String		Name of geometry sequence.
worstpar	positive scalar		Controls refinement if elselect=worst.

TIME ADAPTATION

The TimeAdaption algorithm solves a sequence of problems on a sequence of adapted meshes. The first mesh, the base mesh, is obtained from the meshing sequence. The new adapted mesh is obtained by evaluating the mesh element error indicator, selecting a set of elements based on the element pick function, and then finally refining these elements. The solution to the problem on the previous mesh is then mapped to the new mesh and time integration continues until the next mesh adaptation takes place. The time of mesh adaptation can be determined manually or automatically.

The time adaptive solver works in one geometry at a time. You specify the name of the geometry sequence in the property timeadapgeom. The solver only supports simplex meshes, and if the base mesh is not simplex it can be converted by using the property convertmesh.

The length of the time interval using a fixed adapted spatial mesh can be controlled manually or automatically by the property tauto. If the time integrator runs into problems the computation is restarted at the beginning of the previous time interval. The length of the new interval is reduced to a fraction of the current interval length. This fraction is specified by the property rf. In the tauto=manual case the time interval length is given by property tfrac; if tauto=automatic the property tfracauto controls the initial interval length. For both cases the shortest possible interval length is given by the property minti.

If the property tauto is set to automatic the TimeAdaption algorithm tries to determine the length of the time interval according to the requested fraction of maximum refinement. The fraction is given by the value of the property elfrac. A value of zero means no refinement of the base mesh and a value of one means refinement everywhere with maximum element refinements (set through property ngenlocal). The algorithm strives to assume the given value of elfrac by controlling the size of the time interval. The shortening and lengthening of the interval is determined by the interval reduction and growth factors. These are the properties rf and gf, respectively.

The error indicator is specified using the property eefunctime. A solution on the coarse base mesh is computed in the next time interval and the error indicator is evaluated at the points given by property samplepts. In this way a new adapted mesh appropriate for the next time interval can be generated and the computation on this new mesh is then started. The sample points must be specified as a number between 0 and 1 because they are interpreted as being relative to the time interval under consideration. Entering a scalar value of 0.5 means that the error indicator is evaluated at the midpoint of the interval.

After each mesh adaptation the time integration is restarted and you can control the time stepping by the Time type analogous properties consistentrestart and initialsteprestart.

TimeDiscrete

Solve a time-discretized problem.

SYNTAX

```
model.sol(sname).create(fname,"TimeDiscrete")
model.sol(sname).feature(fname).set(pname,value)
```

DESCRIPTION

Operation feature.

The time interval and possible intermediate time values are given in the property `tlist`. The output times are controlled by the property `tout`.

The feature `TimeDiscrete` accepts the following property/values:

TABLE 6-69: VALID PROPERTIES FOR THE TIME-DISCRETE SOLVER

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`atol`	String	`empty`	Absolute tolerance per field. See below,
`atolmethod`	String	`empty`	How to interpret the atolfields value. See below.
`atolglobal`	positive scalar	`1e-3`	Global absolute tolerance, if `atolglobalvaluemethod` is `manual`.
`atolglobalfactor`	positive scalar	`0.1`	Global absolute tolerance as a factor of the relative tolerance, if `atolglobalvaluemethod` is `factor`.
`atolglobalmethod`	`scaled` | `unscaled`	`scaled`	How to interpret the atolglobal value.
`atolglobalvaluemethod`	`factor` | `manual`	`factor`	Use a factor of the relative tolerance or a user-defined value for the absolute tolerance.
`clist`	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
`cname`	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
`control`	String	`user`	Name of the controlling study step or `"user"` if the feature is controlled manually.
`keeplog`	`on` | `off`	`off`	Keep warnings in stored log.
`message`	String		The log message from the last solution process.
`plot`	`on` | `off`	`off`	Plot while solving.
`plotfreq`	`tsteps` | `tout`	`tout`	Times to update plot.
`plotgroup`	String		Name of plot group for plot while solving.
`prevlevels`	positive integer	2	Number of previous time levels to store.
`probefreq`	`tsteps` | `tout`	`tsteps`	Times to update probe.
`probes`	vector of strings		Probed to use if `probesel=manual`.
`probesel`	`all` | `none` | `manual`	`all`	The probes to compute.
`rtol`	numeric	`0.01`	Relative tolerance.
`timestepdiscrete`	numeric scalar | numeric vector | string with expression	`0.01`	Time step when manual time stepping.
`tlist`	numeric vector		Time list.
`tout`	`tlist` | `tsteps`	`tlist`	Output times.

The `TimeDiscrete` solver is used for solving time-dependent PDEs that have already been discretized in time using, for example, the `prev` operator or the `bdf` operator. Such discretization requires the solution at previous time steps. Different discretizations require different number of previous time steps. For example, the first order

accurate `bdf` method requires the solution at the previous time step, while the second-order accurate `bdf`-method requires the solution at the two preceding time steps. How many previous time steps should be accessible to the solver is controlled through the property `prevlevels`.

You can control the process of solving the linear or nonlinear system of equations in each time step manually. For a coupled problem, this is done through the properties `Damp`, `Dtech`, `Hnlin`, `Initstep`, `Jtech`, `Maxiter`, `Minstep`, and `Rstep` listed under `femnlin`. For a segregated problem, the properties listed under `femstatic` that are related to the segregated solver are available.

Because only manual time stepping is available, there is no estimation of the error made in a time step. However, the tolerances, specified through the properties `rtol`, `atol`, `atolmethod`, `atolglobal`, and `atolglobalmethod` are still important as tolerances when solving the nonlinear system of equations in each time step. For a description of these properties, see `Time`. They should in general be set to the desired accuracy in the final solution.

The property `tlist` must be a strictly monotone vector of real numbers. Commonly, the vector consists of a start time and a stop time. If more than two numbers are given, the intermediate times can be used as output times, or to control the size of the time-steps (see below). If just a single number is given, it represents the stop time, and the start time is 0.

The property `tout` determines the times that occur in the output. If `tout=tsteps`, then the output contains the time steps actually taken by the solver. If `tout=tlist`, then the output contains interpolated solutions for the times in the `tlist` property. The default is `tout=tlist`.

The size of the time step is controlled through the property `timestepdiscrete`. If `timestepdiscrete` is a scalar value, this time step is taken in the entire simulation. When `timestepdiscrete` is a (strictly monotone) numeric vector, the solver computes the solution at the times in the vector. The start time and stop time is still obtained from `tlist`; the vector given in `timestepdiscrete` is truncated and/or expanded using the first and/or last time step in the vector so that the start time and stop time agrees with the values in `tlist`. Finally, an expression using variables with global scope and which results in a scalar can be used as `timestepdiscrete`.

For more information about the time discrete solver; see Time Discrete Solver in the *COMSOL Multiphysics Reference Manual*.

TimeExplicit

Solve time-dependent problems with explicit time stepping.

SYNTAX

```
model.sol(sname).create(fname,"TimeExplicit")
model.sol(sname).feature(fname).set(pname,pvalue)
```

DESCRIPTION

Operation feature. The `TimeExplicit` solver is used for solving time-dependent PDEs using the classic Runge-Kutta or the Adams-Bashforth 3 explicit time-stepping schemes

TABLE 6-70: VALID TIMEEXPLICIT PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
`clist`	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
`cname`	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.

TABLE 6-70: VALID TIMEEXPLICIT PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
erkorder	integer between 1 and 4	4	Runge-Kutta order.
exprs	String		Expression for time stepping when tstepping=elemexprs.
keeplog	on | off	off	Keep warnings in stored log.
linsolver			Linear solver
message	String		The log message from the last solution process.
odesolver	erk | ab3 | ab3loc	erk	Time explicit solver.
plot	on | off	off	Plot while solving.
plotfreq	tsteps | tout	tout	Times to update plot.
plotgroup	String		Name of plot group for plot while solving.
probefreq	tsteps | tout	tsteps	Times to update probe.
probes	vector of strings		Probed to use if probesel=manual.
probesel	all | none | manual	all	The probes to compute.
rktimestep	positive scalar	1e-3	Time step.
storeudot	on | off	on	Store time-derivatives.
tlist	vector of strings		Specified time list.
tout	tsteps | tlist	tlist	Times to store in solution.
tstepping	manual | elemexprs	manual	Manual or from expressions time stepping.

The order of the Runge-Kutta method can be set by the erkorder property. The size of the time step is controlled through the property rktimestep and can be given as a single scalar value, a (strictly monotone) numeric vector, or an expression using variables with global scope, which results in a scalar. For Adams-Bashforth 3 only a scalar constant value of the time step is allowed. Time stepping from expressions tstepping=elemexprs is useful for the Wave form PDE interface. A local time-stepping version of Adams-Bashforth 3 is available for the Wave Form PDE interface by odesolver=ab3loc.

TimeParametric

Handle properties for parameter stepping for a time-dependent problem.

SYNTAX

```
model.sol(sname).create(fname,"Time")
model.sol(sname).feature(fname).create(parname,"TimeParametric")
model.sol(sname).feature(fname).feature(parname).set(pname,pvalue)
```

DESCRIPTION

Attribute feature.

TABLE 6-71: TIME PARAMETRIC PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
pdistrib	on | off	off	If the solver should distribute the parameter sweep.

TABLE 6-71: TIME PARAMETRIC PROPERTIES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plist	real array		List of parameter values. Obsolete, use plistarr instead.
plistarr	real matrix		Lists of parameter values. One row of values for each parameter name.
pname	vector of strings		Parameter names.
pwork	integer	1	Maximum number of distributed groups.
sweeptype	sparse | filled	sparse	Method for doing the parameter variation. For sweeptype=sparse, the parameter tuples defined by the columns in plistarr are solved for. This method requires equal length for the rows. For sweeptype=filled, all parameter combinations given by plistarr are solved for.

Variables

Handle initial data and scaling for variables solved, as well as how variables not solved for are computed. The methods are applied for the dependent variables present as Field or State subattributes. These attributes are automatically created and updated by this feature. So, if the Analysis (for the solver sequence) is altered or if a different Analysis is used in the sequence, then the Field attributes are changed accordingly.

SYNTAX

```
model.sol(sname).create(fname,'Variables')
model.sol(sname).feature(fname).set(pname,pval)
model.sol(sname).feature(fname).feature(varname).set(pname,pval)
```

DESCRIPTION

Operation feature. Computes the initial values for the variables that are solved for and how the variables not solved for are computed. The variables handled are the ones present as Field or State attributes. The feature also handles scaling and which variables to store in output.

Attribute feature.

TABLE 6-72: VALID VARIABLES PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
clist	String array		Provide values for constants as input parameters using a string array; for the corresponding constant names, use cname.
cname	String array		Provide names of constants as input parameters using a string array; for the corresponding constant values, use clist.
control	String	user	Name of the controlling study step or "user" if the feature is controlled manually.
initmethod	init | sol	init	Method used for initial value computation.
initsol	zero | solution object	zero	Initial value solution object.
initsoluse	current | solution store	current	Use current or stored values from the initial value solution object.
manualsolnum	positive integer		Identifies the solution used when solnum = manual.
notlistsolnum	vector of positive integers		List that identifies the solutions used when notsolnum = from_list.
notmanualsolnum	vector of positive integers		Identifies the solutions used when notsolnum = manual.

TABLE 6-72: VALID VARIABLES PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
notsol	zero | solution object	zero	Solution object for variables not solved for.
notsolmethod	init | sol	init	Method used for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Which solnums from other solution to use for variables not solved for.
notsoluse	current | solution store	current	Use current or stored values from the solution object for variables not solved for.
nott	double		The interpolation value used for values of variables not solved for when notsolnum = interp.
resscalemethod	auto | manual	auto	Method used for scaling of residual.
resscaleval	scalar	1	Residual scaling value, if resscalemethod is manual.
scalemethod	auto | init | none | manual	auto	Method used for scaling of variables.
scaleval	scalar	1	Global scaling value, if scalemethod is manual.
solnum	auto | first | last | interp | manual | positive integer	auto	The solnum from other solution to use for initial values of variables solved for.
t	double		The interpolation value used for initial values of variables solved for when solnum = interp.
useinitsol	on | off	off	Use user-controlled initial values of variables solved for.
usesol	on | off	off	Use user-controlled values of variables not solved for.

TABLE 6-73: VALID VARIABLE SUBATTRIBUTE FIELD/STATE PROPERTIES

PROPERTY	VALUES	DEFAULT	DESCRIPTION
comp	vector of strings		Field/State components
out	on | off	on	Store Field/State in output
reconstruct	String	none	Tag of a compatible reduced model to use for reconstruction when solvefor is off.
scalemethod	auto | init | none | manual | parent	parent	Method used for scaling of variables
scaleval	scalar	1	Scaling value
solvefor	on | off	on	Solve for this Field/State
storesel	Array of selection strings		Selections defining which field data to store.
usestoresel	all | selection	all	Store all field data or field data defined in selections in storesel.

The properties initmethod, initsol, and initsoluse determine the initial value for the solution components you solve for when useinitsol is set to on.

The properties notsolmethod, notsol, notsoluse, and notsolnum determine the value of solution components you do not solve when usesol is set to on.

Which variables to solve for, and which variables to store in the solution is controlled by the properties solvefor and out in the Field or State attributes.

The `reconstruct` property is only available when using model reduction and then to configure reconstruction for dependent variables not solved for.

The properties `scalemethod` and `scaleval` determine a scaling of the degrees of freedom that is applied in order to get a more well-conditioned system. The possible values of `scalemethod` are:

TABLE 6-74: VALUES FOR THE PROPERTY SCALEMETHOD

VALUE	MEANING
`auto`	The scaling is automatically determined.
`init`	The scaling is determined from the initial value. Use this if the sizes of the components of the initial value give a good estimate of the order of magnitude of the solution.
`none`	No scaling is applied.
`manual`	The scaling is user controlled by setting the property `scaleval`.
`parent`	Scaling method is inherited from the parent Variables feature (only for subattributes).

XmeshInfo

Get extended mesh information.

SYNTAX

```
SolverFeature step = model.sol(seqTag).feature(studyStepTag);
XmeshInfo xmi = step.xmeshInfo();
XmeshInfo xmi = step.xmeshInfo(meshCase);
SolverFeature var = model.sol(seqTag).feature(variablesTag);
XmeshInfo xmi = var.xmeshInfo();
XmeshInfo xmi = var.xmeshInfo(meshCase);
XmeshInfo xmi = model.sol(seqTag).xmeshInfo();
XmeshInfo xmi = model.sol(seqTag).xmeshInfo(meshCase);

String[] mcases = xmi.meshCases();

int nDofs = xmi.nDofs();
String[] fieldNames = xmi.fieldNames();
int[] fieldNDofs = xmi.fieldNDofs();
String[] geomTags = xmi.geoms();
String[] meshTypes = xmi.meshTypes();
String[] meshTypes = xmi.meshTypes(geomTag);

XmeshInfoDofs dofs = xmi.dofs();
int[] dofs.geomNums()
int[] dofs.nodes()
double[][] dofs.coords()
String[] dofs.dofNames()
int[] dofs.nameInds()
int[] dofs.solVectorInds()

XmeshInfoNodes nodes = xmi.nodes();
XmeshInfoNodes nodes = xmi.nodes(geomTag);
double[][] nodes.coords()
String[] nodes.dofNames()
int[][] nodes.dofs()

XmeshInfoElements elems = xmi.elements(meshType);
XmeshInfoElements elems = xmi.elements(meshType,geomTag);
double[][] elems.localCoords()
int[][] elems.nodes()
String[] elems.localDofNames()
double[][] elems.localDofCoords()
int[][] elems.dofs()

model.sol(seqTag).feature(studyStepTag).clearXmesh();
model.sol(seqTag).feature(variablesTag).clearXmesh();
```

DESCRIPTION

The Xmesh information methods provide information about the numbering of elements, nodes, and degrees of freedom (DOFs) in the extended mesh and in the matrices returned by `Assemble` and the solvers.

```
SolverFeature step = model.sol(seqTag).feature(studyStepTag);
XmeshInfo xmi = step.xmeshInfo();
```

returns information about all degrees of freedom in the given study step, for the main mesh case. This includes information about internal degrees of freedom.

```
XmeshInfo xmi = step.xmeshInfo(meshCase);
```

returns information about the given mesh case. The string `meshCase` can be `main`, `adaptionresidual`, or a multigrid level tag.

```
SolverFeature var = model.sol(seqTag).feature(variablesTag);
XmeshInfo xmi = var.xmeshInfo();
XmeshInfo xmi = var.xmeshInfo(meshCase);
```

returns information about the degrees of freedom solved for in the given variables feature. That is, the numbering of the degrees of freedom span over the DOFs solved for, which is the indexing used in the matrices and vectors assembled by the solver. Internal degrees of freedom are not included.

```
XmeshInfo xmi = model.sol(seqTag).xmeshInfo();
XmeshInfo xmi = model.sol(seqTag).xmeshInfo(meshCase);
```

is equivalent to calling `xmeshInfo` on the last study step feature in the sequence.

```
model.sol(seqTag).feature(studyStepTag).clearXmesh();
model.sol(seqTag).feature(variablesTag).clearXmes();
```

clears out the Xmesh object created by the call to `xmeshInfo`. After the required information has been obtained from the `XmeshInfo` object, this function should be called to release memory. When `xmeshInfo` is called on a solver sequence, an already existing `Xmesh` object is used, so there is no need to call `clearXmesh`.

General Information

`String[] mcases = xmi.meshCases()` returns a string vector containing tags of all mesh cases.

`int nDofs = xmi.nDofs()` returns the total number of DOFs.

`String[] fieldNames = xmi.fieldNames()` returns the field names, or the field names solved for.

`int[] fieldNDofs = xmi.fieldNDofs()` returns the number of DOFs for each field.

`String[] geomTags = xmi.geoms()` returns the tags of all geometries that exist in the xmesh.

`String[] meshTypes = xmi.meshTypes()` returns all mesh types.

`String[] meshTypes = xmi.meshTypes(geomTag)` returns all mesh types in geometry `geomTag` (a string). Possible mesh types are `vtx`, `edg`, `tri`, `quad`, `tet`, `hex`, `prism`, and `pyr`.

Information About Each DOF

`XmeshInfoDofs dofs = xmi.dofs()` returns information about each DOF.

The class `XmeshInfoDofs` has the following methods:

TABLE 6-75: XMESHINFODOFS METHODS

FIELD	CONTENTS
`int[] geomNums()`	1-based geometry numbers for all DOFs
`int[] nodes()`	0-based node numbers for all DOFs.
`double[][] coords()`	Global coordinates for all DOFs in the model length unit. The `k`th column of this matrix contains the coordinates of DOF number `k`.
`double[][] coords(xdGeomTag)`	For DOFs in an extra dimension product, return the coordinates of each DOF in the extra dimension geometry `xdGeomTag`. For DOFs that are not located in an extra dimension product containing `xdGeomTag`, the value NaN is returned.
`double[][] gCoords()`	Same as `coords()` except that coordinates are given in the geometry length unit. If there is more than one geometry, the coordinates of each DOF are given in the length unit of the geometry of that DOF.
`String[] dofNames()`	DOF names
`int[] nameInds()`	0-based indices into `dofNames()` for all DOFs.
`int[] solVectorInds()`	0-based indices into solution vector for all DOFs.

Information About Each Node Point

`XmeshInfoNodes nodes = xmesh.nodes()` returns information about nodes. This method throws an error if there is more than one geometry.

`XmeshInfoNodes nodes = xmesh.nodes(geomTag)` returns information about nodes in geometry `geomTag` (a string).

The class `XmeshInfoNodes` has the following methods:

TABLE 6-76: XMESHINFONODES CLASS METHODS

FIELD	CONTENTS
`double[][] coords()`	Global coordinates for all nodes. The `n`th column of the matrix `coords` contains the coordinates of node point number `n`
`double[][] gCoords()`	Same as `coords()` except that coordinates are given in the geometry length unit.
`String[] dofNames()`	DOF names in this geometry
`int[][] dofs()`	0-based DOF numbers for all nodes in this geometry. `dofs()[k][n]` is the DOF number for DOF name `dofNames()[k]` at node point `n`. A value of `-1` means that there is no DOF with this name at the node. Note: If there is a slit, only one of the DOFs is given for each node point.

Information about Each Mesh Element

`XmeshInfoElements[] elems = xmesh.elements(meshType)` returns information about mesh elements of type `meshType` (a string). This method throws an error if there is more than one geometry.

`XmeshInfoElements[] elems = xmesh.elements(meshType,geomTag)` returns information about mesh elements of type `meshType` in geometry `geomTag`.

The `XmeshInfoElements` class has the following methods:

TABLE 6-77: XMESHINFOELEMENTS CLASS NODES

FIELD	CONTENTS
`double[][] localNodes()`	Local coordinates of nodes. The `k`th column of the matrix `lnodes()` contains the coordinates of local node point number `k`.
`int[][] nodes()`	0-based node point indices for all mesh elements of type `type()`. `nodes()[k][el]` is the node point number within geometry `geomNum()` (see the output `xmi.nodes()`) for local node point `k` within mesh element `el`. A value `-1` means that there is no node point at this location.
`String[] localDofNames()`	The name for each local DOF.
`double[][] localDofCoords()`	The local coordinates for each local DOF (one column for each local DOF).
`int[][] dofs()`	0-baseed DOF numbers for all mesh elements of type `type()`. `dofs()[k][el]` is the DOF number for local DOF `k` within mesh element `el`. A value `-1` means that there is no DOF at this location.

Studies and Study Steps

Introduction

In the COMSOL Desktop, you create one or more *studies*, each with one or more *study steps* to compute the solution to a model. The studies generate a solver sequence with the solvers and other solver features that correspond to the study steps in the study.

Study and Study Step Types in the *COMSOL Multiphysics Reference Manual*.

CREATING A STUDY AND ADDING STUDY STEP

The following commands create a study `std1` and adds a Stationary study step to that study:

```
model.study().create("std1");
model.study("std1").create("stat", "Stationary");
```

RUNNING (COMPUTING) A STUDY

To run a study, use

```
model.study(<tag>).run();
```

The `run()` command corresponds to clicking **Compute** on a **Study** node in the COMSOL Desktop.

CREATING A REFERENCE TO A STUDY STEP

You can also create a reference to an existing study step from a solver sequence:

```
model.sol("sol1").create("st1", "StudyStep");
model.sol("sol1").feature("st1").set("study", "std1");
model.sol("sol1").feature("st1").set("studystep", "stat");
```

ATTACHING A STUDY

It is also possible to attach a study for making a solver sequence or batch feature part of the study sequence:

```
model.sol("sol1").attach("std1");
```

The `attach()` operation implies calling `study(`*`<tag>`*`)`(see below). You can only have one solver sequence attached to each study but you can have multiple batch features.

ASSOCIATING A SOLVER SEQUENCE WITH A STUDY

You can associate a solver sequence with a study using the following syntax:

```
model.sol("sol1").study("std1");
```

In contrast, `attach()` (see above) also makes the solver sequence part of the study sequence.

MAIN STUDY FEATURE SETTINGS

TABLE 6-78: METHODS FOR THE MAIN STUDY FEATURE SETTINGS

METHOD	DESCRIPTION
`isGenPlots(boolean)`	True if default results plots should be generated.
`isGenConv(boolean)`	True if convergence plots should be generated.
`setGenPlots(boolean)`	Set to true if default results plots should be generated.
`setGenConv(boolean)`	Set to true if convergence plots should be generated.

For example, use

```
model.study("std1").setGenConv(true);
```

to generate convergence plots when computing the solution.

The following table lists the major study steps with links to documentation of available properties for each study step:

- Batch
- Batch Sweep
- Bidirectionally Coupled Particle Tracing
- Bidirectionally Coupled Ray Tracing
- Cluster Computing
- Cluster Sweep
- Eigenfrequency
- Eigenvalue
- Frequency Domain and Frequency Domain Perturbation
- Frequency to Time FFT
- Function Sweep
- Material Sweep
- Model Reduction
- Multigrid Level
- Parametric Sweep
- Ray Tracing
- Sensitivity
- Stationary
- Time Dependent
- Time Discrete
- Time to Frequency FFT

Batch

Use a Batch study step to start a COMSOL Multiphysics batch process that solves the current study on your computer.

SYNTAX

```
model.study(stdname).create(fname, "Batch");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-79: PROPERTIES FOR BATCH SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`batchfile`	String	`batchmodel.mph`	Filename.
`extsolvergen`	`on` | `off`	`off`	Generate solver sequence in external process.

TABLE 6-80: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
graphics	on | off	off	Use graphics.
maxalive	Integer		Alive time (seconds).
maxallow	Integer		Maximum number of simultaneous jobs.
maxrestarts	Integer		Maximum number of job restarts.

Batch Sweep

Use the Batch Sweep study step to find the solution to a sequence of stationary or time-dependent simulations that arise when you vary some parameters of interest.

SYNTAX

```
model.study(stdname).create(fname, "BatchSweep");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-81: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type.

TABLE 6-82: PROPERTIES FOR OUTPUT WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
accumtable	String	new	Accumulated probe table.
accumtableall	on | off	on	Use all probes for the accumulated probe table
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
useaccumtable	on | off	on	Use accumulated probe table.

TABLE 6-83: PROPERTIES FOR BATCH SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
batchfile	String	batchmodel.mph	Name of batch model file.
clearmesh	on | off	on	Clear meshes.
clearsol	on | off	on	Clear solutions.
extsolvergen	on | off	off	Generate solver sequence in external process.
paramfilename	on | index	on	Add parameter names and values or shorter indices to the filename.
savefile	on | off	off	Output model to file.
serverdir	String		Server directory.
specserverdir	on | off	off	Specify server directory path.

TABLE 6-83: PROPERTIES FOR BATCH SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
sychaccumprobetable	on | off	on	Synchronize accumulated probe table.
synchsolutions	on | off	off	Synchronize solutions.

TABLE 6-84: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
graphics	on | off	off	Use graphics.
maxalive	Integer		Alive time (seconds).
maxallow	Integer	1	Maximum number of simultaneous jobs.
maxrestarts	Integer		Maximum number of job restarts.

Bidirectionally Coupled Particle Tracing

The Bidirectionally Coupled Particle Tracing study step is a special case of the Time Dependent study step that is used to model bidirectionally coupled particle-field or fluid-particle interactions. It is available with the Particle Tracing Module. It is similar to the Time Dependent study step but has an additional section called Iterations, which determines the behavior of the iterative solver loop for self-consistently modeling particle-field interactions in the default solver sequence.

SYNTAX

```
model.study(stdname).create(fname, "BidirectionallyCoupledParticleTracing");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-85: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
tlist	Numeric vector		Time list.
usertol	on | off	off	Physics-controlled or user-defined tolerance.
rtol	Positive scalar	0.01	Relative tolerance, if usertol is on.
tunit	String	s	Time unit.

TABLE 6-86: PROPERTIES FOR PLOT RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probefreq	pout | psteps	pout	Where to update probes.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
plotfreq	tout | tsteps	tout	Where to update plot.

TABLE 6-87: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-88: PROPERTIES FOR ITERATIONS SECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
expr	String	1	Global expression used to compute relative error when method=convergence.
iter	Positive integer	5	Number of iterations of the solver loop when method=iterations.
maxiter	Positive integer	25	Maximum number of iterations in the solver loop when method=convergence.
method	convergence | iterations	iterations	Choose whether termination of the solver loop is based on the convergence of a global variable or a fixed number of iterations.
miniter	Positive integer	1	Minimum number of iterations in the solver loop when method=convergence.
rtolterm	Positive real number	0.001	Relative tolerance for termination of the solver loop when method=convergence.
rtolthresh	Positive real number	1	Threshold used to avoid division by zero while computing the relative error when method=convergence.

TABLE 6-89: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initmethod	init | sol	init	Method for initial values for variables solved for.
initstudy	String		Reference to study or "zero" for zero solution.
manualsolnum	Vector of integers	[1]	Index to solution for initial value for variables solved for.
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.

TABLE 6-89: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
solnum	auto | first | last | interp | manual | positive integer	auto	Solution selection of initial values for variables solved for.
storesel	Vector of strings		Selections defining which field data to store.
t	String		Specify time for interpolated solution of initial value for variables solved for.
useinitsol	on | off	off	User-controlled initial values for variables solved for.
usesol	on | off	off	User-controlled values for variables not solved for.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-90: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-91: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapgeom	String		Name of geometry to use.
adaption	on | off	off	Adaptive mesh refinement.
autoremesh	on | off	off	Automatic remeshing.
autoremeshgeom	String		Name of geometry to use.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useparam	on | off	off	Auxiliary sweep.

Bidirectionally Coupled Ray Tracing

The Bidirectionally Coupled Particle Tracing study step is a special case of the Ray Tracing study step that is used to model bidirectionally coupled particle-field or fluid-particle interactions. It is available with the Ray Optics Module. It is similar to the Ray Tracing study step but has an additional section called Iterations, which determines the behavior of the iterative solver loop for self-consistently modeling ray-field interactions in the default solver sequence.

SYNTAX

```
model.study(stdname).create(fname, "BidirectionallyCoupledRayTracing");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-92: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
charvel	String	c_const or 343 m/s	Group velocity used to convert path lengths to solution times when timestepspec=specifylength.
llist	Numeric vector		List of path lengths when timestepspec=specifylength.
lunit	String	m	Length unit when timestepspec=specifylength.
numberofreflections	Positive integer	5	Maximum number of reflections per ray for automatic stop conditions when raystopcond=reflections.
raystopcond	nostop | noactive | rayintensity | reflections	nostop	Automatic stop condition in the default solver sequence.
rtol	Positive scalar	0.01	Relative tolerance, if usertol is on.
thresholdintensity	String	1[W/m^2]	Threshold intensity for automatic stop conditions when raystopcond=rayintensity.
timestepspec	specifytime | specifylength	specifytime	Determines whether the time intervals are entered directly or in terms of a path length.
tlist	Numeric vector		Time list when timestepspec=specifytime.
tunit	String	ns or ms	Time unit when timestepspec=specifytime.
usertol	on | off	off	Physics-controlled or user-defined tolerance.

TABLE 6-93: PROPERTIES FOR PLOT RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probefreq	pout | psteps	pout	Where to update probes.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
plotfreq	tout | tsteps	tout	Where to update plot.

TABLE 6-94: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-95: PROPERTIES FOR ITERATIONS SECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
expr	String	1	Global expression used to compute relative error when method=convergence.
iter	Positive integer	5	Number of iterations of the solver loop when method=iterations.
maxiter	Positive integer	25	Maximum number of iterations in the solver loop when method=convergence.
method	convergence | iterations	iterations	Choose whether termination of the solver loop is based on the convergence of a global variable or a fixed number of iterations.
miniter	Positive integer	1	Minimum number of iterations in the solver loop when method=convergence.
rtolterm	Positive real number	0.001	Relative tolerance for termination of the solver loop when method=convergence.
rtolthresh	Positive real number	1	Threshold used to avoid division by zero while computing the relative error when method=convergence.

TABLE 6-96: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initmethod	init | sol	init	Method for initial values for variables solved for.
initstudy	String		Reference to study or "zero" for zero solution.
manualsolnum	Vector of integers	[1]	Index to solution for initial value for variables solved for.
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.

TABLE 6-96: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
solnum	auto | first | last | interp | manual | positive integer	auto	Solution selection of initial values for variables solved for.
storesel	Vector of strings		Selections defining which field data to store.
t	String		Specify time for interpolated solution of initial value for variables solved for.
useinitsol	on | off	off	User-controlled initial values for variables solved for.
usesol	on | off	off	User-controlled values for variables not solved for.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-97: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-98: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapgeom	String		Name of geometry to use.
adaption	on | off	off	Adaptive mesh refinement.
autoremesh	on | off	off	Automatic remeshing.
autoremeshgeom	String		Name of geometry to use.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useparam	on | off	off	Auxiliary sweep.

Cluster Computing

Use the Cluster Computing study step when you want to submit COMSOL Multiphysics batch jobs to a job scheduler that in turn runs the batch job on a second computer or cluster.

SYNTAX

```
model.study(stdname).create(fname, "ClusterComputing");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-99: PROPERTIES FOR BATCH SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
batchfile	String	batchmodel.mph	Name of batch model file.
batchlic	on | off		Use batch license.
clustertype	general | whpc2008 | sge | slurm | pbs | none		The type of cluster job.
extsolvergen	on | off	off	Generate solver sequence in external process.
hostfile	String		Path to host file.
mpiargs	String		Additional MPI arguments.
mpibootstrap	String		Name of bootstrap server.
mpipath	String		Installation directory for MPI.
nn	Integer	1	Number of nodes.
rundir	String		The directory to store files used by the batch job.
scheduler	String		The scheduler for the batch job, if clustertype is whpc2008, slurm, or pbs.
serverdir	String		Server directory.
sgequeue	String		The name for the cluster queue, if clustertype is sge, slurm, or pbs.
specbatchdir	on | off		Specify different directory for batch process than used by the current process.
specserverdir	on | off	off	Specify server directory path.
user	String		User account for submitting the job if clustertype is whpc2008, slurm, or pbs.

TABLE 6-100: PROPERTY FOR CLUSTER SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
pdistrib	on | off	off	Distribute parametric sweep.

TABLE 6-101: PROPERTIES FOR REMOTE AND CLOUD ACCESS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
filecmd	String		File for commands when remotecmd is file.
filetransfercmd	none | scp | file | user	none	Command transfer file.
filetransferfrom	String		List of files to transfer from the other computer after the batch jobs have finished.
filetransferfromusercmd	String		Command to transfer files from remote location.
filetransferto	String		List of files to files to transfer to the other computer before running the batch job.
filetransfertousercmd	String		Command to transfer files to remote location.

TABLE 6-101: PROPERTIES FOR REMOTE AND CLOUD ACCESS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
remote	on | off		Run on remote server.
remotecmd	none | ssh | file | mpi | user		Command to use when invoking a command on a remote server.
remotehosts	String		List of remote hostnames.
remoteos	native | windows | linux		Command transfer file.
remoteusercmd	String		Command to use when invoking a command on a remote server.
scpkey	String		SCP key file.
scppath	String		Directory where SCP resides.
scpuser	String		Username used by SCP.
scpusercmd	String		Command for copying files to remote location.
sshcmd	ssh | putty | user		SSH command.
sshkey	String		SSH key file.
sshpath	String		Directory where SSH resides.
sshporthost	String		Port host.
sshports	String		Ports that should be forwarded by SSH.
sshuser	String		Username used by SSH.

TABLE 6-102: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
graphics	on | off	off	Use graphics.
maxalive	Integer		Alive time (seconds).
maxallow	Integer	1	Maximum number of simultaneous jobs.
maxrestarts	Integer		Maximum number of job restarts.

Cluster Sweep

Use the Cluster Sweep study step when you want to study to solve several models in parallel where each model has a different set of parameters.

SYNTAX

```
model.study(stdname).create(fname, "ClusterSweep");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-103: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type.

TABLE 6-104: PROPERTIES FOR OUTPUT WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
accumtable	String	new	Accumulated probe table.
accumtableall	on | off	on	Use all probes for the accumulated probe table.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
useaccumtable	on | off	on	Use an accumulated probe table.

TABLE 6-105: PROPERTIES FOR BATCH SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
batchfile	String	batchmodel.mph	Name of batch model file.
batchlic	on | off		Use batch license.
clearmesh	on | off	on	Clear meshes.
clearsol	on | off	on	Clear solutions.
clustertype	general | whpc2008 | sge | slurm | pbs | none		The type of cluster job.
extsolvergen	on | off	off	Generate solver sequence in external process.
hostfile	String		Path to host file.
mpiargs	String		Additional MPI arguments.
mpibootstrap	String		Name of bootstrap server.
mpipath	String		Installation directory for MPI.
nn	Integer	1	Number of nodes.
paramfilename	on | index	on	Add parameter names and values or shorter indices to the filename.
rundir	String		The directory to store files used by the batch job.
savefile	on | off	off	Output model to file.
serverdir	String		Server directory.
specbatchdir	on | off		Specify different directory for batch process than used by the current process.
specserverdir	on | off	off	Specify server directory path.
synchaccumprobetable	on | off	on	Synchronize accumulated probe table.
synchsolutions	on | off	off	Synchronize solutions.

TABLE 6-106: PROPERTIES FOR REMOTE AND CLOUD ACCESS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
filetransfercmd	none | scp | user	none	Command transfer file.
filetransferfromusercmd	String		Command to transfer files from remote location.
filetransfertousercmd	String		Command to transfer files to remote location.
remote	on | off		Run on remote server.
remotecmd	none | ssh | user		Command to use when invoking a command on a remote server.
remotehosts	String		List of remote hostnames.

TABLE 6-106: PROPERTIES FOR REMOTE AND CLOUD ACCESS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
remoteos	native | windows | linux		OS used on remote hosts.
remoteusercmd	String		Command to use when invoking a command on a remote server.
scpkey	String		SCP key file.
scppath	String		Directory where SCP resides.
scpuser	String		Username used by SCP.
scpusercmd	String		Command for copying files to remote location.
sshcmd	ssh | putty | user		SSH command.
sshkey	String		SSH key file.
sshpath	String		Directory where SSH resides.
sshporthost	String		Port host.
sshports	String		Ports that should be forwarded by SSH.
sshuser	String		Username used by SSH.

TABLE 6-107: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
graphics	on | off	off	Use graphics.
maxalive	Integer		Alive time (seconds).
maxallow	Integer	1	Maximum number of simultaneous jobs.
maxrestarts	Integer		Maximum number of job restarts.

Eigenfrequency

The Eigenfrequency study step is used to compute eigenmodes and eigenfrequencies of a linear or linearized model.

SYNTAX

```
model.study(stdname).create(fname, "Eigenfrequency");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-108: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
appnreigs	Integer	20	Approximate number of eigenfrequencies.
chkeigregion	on | off	on	Perform consistency check.
eigli	Real scalar	0	Largest imaginary part.
eiglr	Real scalar	0	Largest real part.
eigmethod	manual | region | all	manual	Eigenvalue search method; the all method finds all eigenvalues for a full matrix and can only be used for small eigenfrequency problems.
eigsi	Real scalar	0	Smallest imaginary part.
eigsr	Real scalar	0	Smallest real part.
eigwhich	lm | lr | sr | li | si	lm	Eigenfrequency search method around shift.

TABLE 6-108: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
maxnreigs	Integer	200	Maximum number of eigenfrequencies.
neigs	Integer	6	Desired number of eigenfrequencies.
neigsactive	on | off	off	Set desired number of eigenfrequencies.
shift	Complex scalar	0	Shift.
shiftactive	on | off	off	Use shift.

TABLE 6-109: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-110: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
storesel	Vector of strings		Selections defining which field data to store.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-111: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

For the adaptation and error estimates settings, see properties for Adaptation and Error Estimates.

Eigenvalue

The Eigenvalue study step is used to compute eigenmodes and eigenvalues of a linear or linearized model.

SYNTAX

```
model.study(stdname).create(fname, "Eigenvalue");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-112: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
appnreigs	Integer	20	Approximate number of eigenvalues.
chkeigregion	on | off	on	Perform consistency check.
eigli	Real scalar	0	Largest imaginary part.
eiglr	Real scalar	0	Largest real part.
eigmethod	manual | region | all	manual	Eigenvalue search method; the all method finds all eigenvalues for a full matrix and can only be used for small eigenvalue problems.
eigsi	Real scalar	0	Smallest imaginary part.
eigsr	Real scalar	0	Smallest real part.
eigwhich	lm | lr | sr | li | si	lm	Eigenfrequency search method around shift.
maxnreigs	Integer	200	Maximum number of eigenvalues.
neigs	Integer	6	Desired number of eigenvalues.
neigsactive	on | off	off	Set desired number of eigenvalues.
shift	Complex scalar	0	Shift.
shiftactive	on | off	off	Use shift.

TABLE 6-113: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-114: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
storesel	Vector of strings		Selections defining which field data to store.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-115: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2","mesh2"}.

For the adaptation and error estimates settings, see properties for Adaptation and Error Estimates.

Frequency Domain and Frequency Domain Perturbation

A Frequency Domain study step is used to compute the response of a linear or linearized model subjected to harmonic excitation for one or several frequencies. A Frequency-Domain Perturbation study step is used for studying small oscillations about a biased solution (small-signal analysis).

SYNTAX

```
model.study(stdname).create(fname, "Frequency");
model.study(stdname).create(fname, "Frequencylinearized");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-116: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
loadparameters	String		Load parameter values.
plist	Real vector		Frequencies.
preusesol	no | yes | auto	auto	Reuse solution from previous step.
punit	String	Hz	Frequency unit.

TABLE 6-117: PROPERTIES FOR RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.

TABLE 6-118: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-119: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initmethod	init | sol	init	Method for initial values for variables solved for.
initstudy	String		Reference to study or "zero" for zero solution.
manualsolnum	Vector of integers	[1]	Index to solution for initial value for variables solved for.
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
solnum	auto | first | last | interp | manual | positive integer	auto	Solution selection of initial values for variables solved for.
storesel	Vector of strings		Selections defining which field data to store.
t	String		Specify time for interpolated solution of initial value for variables solved for.

TABLE 6-119: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
useinitsol	on | off	off	User-controlled initial values for variables solved for.
usesol	on | off	off	User-controlled values for variables not solved for.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-120: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-121: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
awe	on | off	off	Use asymptotic waveform evaluation.
awefunc	Vector of strings		AWE expressions.
pcontinuation	String		Continuation parameter when pcontinuationmode = manual.
pcontinuationmode	no | last | manual	last	Determines if a continuation sweep should be performed for one of the parameters in pname.
pdistrib	on | off	off	Distribute parametric sweep.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	String		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useparam	on | off	off	Auxiliary sweep.

For the adaptation and error estimates settings, see properties for Adaptation and Error Estimates.

Frequency to Time FFT

A Frequency to Time FFT study step, which you can add to a time-dependent study, performs an inverse FFT (or, alternatively, the nonuniform Fourier transform) from the frequency domain (input) to the time domain (output). As the default solver it adds an FFT solver.

SYNTAX

```
model.study(stdname).create(fname, "FreqToTimeFFT");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-122: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
addstatsol	on | off	off	Add stationary solution.
fftoutrange	Numeric vector		Output times.
fftscaling	cont | discrete	cont	Use a discrete or continuous scaling for the Fourier transform.
fftwinalpha	Real scalar	0.5	Window parameter for a Tukey window.
fftwincenterinv	Real scalar	50	Window center for a Gaussian window function.
fftwincutoff	Real scalar	1	Cut-off fraction for window function in [0, 1].
fftwindev	Real scalar	1	Standard deviation for a Gaussian window function.
fftwindowinv	on | off	off	Use window function.
fftwinexpr	String	1	Expression for window function (when set to fromexpr). Can be expressed in terms of t, freq, niterFFTin, and niterFFTout (if applicable).
fftwinmaxinv	Real scalar	100	Maximum (end) value for window.
fftwinmininv	Real scalar	0	Minimum (start) value for window.
fftwintypeinv	fromexpr | cutoff | rectangle | gauss | hamming | hanning | blackman | tukey	fromexpr	Method for window function.
linpmethod	sol | init	sol	Prescribe the input values using a solution or an initial expression.
linpsol	String		Solution that defines input values for the FFT study step.
linpsoluse	String		Subsolution that defines the input values for the FFT study step/FFT solver.
linpstudy	String		Study that defines input values for the FFT study step.
statmanualsolnum	Integer	1	Index to stationary solution to add.
statmethod	sol | init	sol	For an added stationary solution, use a solution or initial expression.
statsolnum	auto | first | last | interp | manual | positive integer	auto	Selection method for stationary solution to add.
statstudy	String	zero	Study from which the added stationary solution is chosen.
statt	String		Specify time for interpolated solution to add.
tunit	String	s	Time unit.
winpunit	String	Hz	Frequency unit for window.

TABLE 6-123: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-124: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
storesel	Vector of strings		Selections defining which field data to store.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-125: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

Function Sweep

A Function Sweep study step is a special case of a Parametric Sweep study step, where the solver sweeps over functions defined under a Switch node in the Model Builder.

SYNTAX

```
model.study(stdname).create(fname, "FunctionSweep");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-126: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`plistarr`	Vector of integer vectors		Integer case numbers. One list of integers (for example, `range(1,1,10)`) per function switch.
`pname`	Vector of strings		Function switches.
`pcase`	Vector with entries `"all"` and `"user"`.	`["all"]`	Cases, one per function switch.

TABLE 6-127: PROPERTIES FOR OUTPUT WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`accumtable`	String	`new`	Accumulated probe table.
`accumtableall`	`on` | `off`	`on`	Use all probes for the accumulated probe table.
`filename`	String		Filename.
`keepsol`	`last` | `all`		Keep solutions in memory.
`plot`	`on` | `off`	`off`	Plot while solving.
`plotgroup`	String	`default`	Plot group to use for plot while solving.
`probes`	Vector of strings		Probes to use when `probesel=manual`.
`probesel`	`all` | `none` | `manual`	`all`	Probes to compute.
`save`	`on` | `off`		Save each solution as a model file.
`useaccumtable`	`on` | `off`	`on`	Use an accumulated probe table.

Material Sweep

A Material Sweep study step is a special case of a Parametric Sweep study step, where the solver sweeps over materials defined under a Switch node in the Model Builder.

SYNTAX

```
model.study(stdname).create(fname, "MaterialSweep");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-128: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`plistarr`	Vector of integer vectors		Integer case numbers. One list of integers (for example, `range(1,1,10)`) per material switch.
`pname`	Vector of strings		Material switches.
`pcase`	Vector with entries `"all"` and `"user"`.	`["all"]`	Cases, one per material switch.

TABLE 6-129: PROPERTIES FOR OUTPUT WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
accumtable	String	new	Accumulated probe table.
accumtableall	on | off	on	Use all probes for the accumulated probe table.
filename	String		Filename.
keepsol	last | all		Keep solutions in memory.
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
save	on | off		Save each solution as a model file.
useaccumtable	on | off	on	Use an accumulated probe table.

Model Reduction

Use a Model Reduction study step to perform simulations with reduced models or to produce reduced models.

A Model reduction study step will involve the following settings

1. Selecting the model reduction method to apply.
2. If applicable: Selecting the training data (Select or generate Study and Study step reference).
3. Defining the unreduced (source) model (Study and Study step reference).
4. If applicable: Defining the objective function representing a quality measure to minimize.
5. Selecting to create or update an instance of the reduced model under reduced models for online use.
6. If applicable: Specifying if the reduced model should be capable of reconstruction.
7. Defining reduced model control inputs.
8. Defining reduced model outputs.

SYNTAX

```
model.study(stdname).create(fname,"ModelReduction");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step for model reduction. The following general and common properties are available.

TABLE 6-130: GENERAL AND COMMON PROPERTIES FOR MODEL REDUCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
awefunc	String array		Error expressions, if reducedModelType is awe.
awefuncdesc	String array		Description of the error variables, if reducedModelType is awe.
awefuncscale	String array		Scale of the error variables, if reducedModelType is awe.
awefuncunit	String array		Unit of the error functions, if reducedModelType is awe.
awefuncuse	String array		Error expressions, if reducedModelType is awe.
awevar	String array		Model error/output variables, if reducedModelType is awe.

TABLE 6-130: GENERAL AND COMMON PROPERTIES FOR MODEL REDUCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initval	String array		Values for the model control inputs used for the simulation using the modal solver, if reducedModelType is modal.
reducedModelType	modal | awe	modal	Model reduction method to use.
romdata	String	new	Tag of the target container for the reduced model (new for a new reduced model).
romReconstruct	true | false	true	Enable reconstruction in the produced reduced model.
pname	String array		Model parameter names to use as model control input variables, if reducedModelType is modal.
qoidescr	String array		Descriptions for user-defined output expressions, if reducedModelType is modal.
qoiexpr	String array		Global expressions defining outputs, if reducedModelType is modal.
qoiname	String array		Variable names for outputs, if reducedModelType is modal.
qoiunit	String array		Units for user-defined output expressions, if reducedModelType is modal.
rtol	double	0.1	Relative tolerance for adaptation, if reducedModelType is awe
soltypemat	true | false	false	Store reduced matrices in the modal solver solution, if reducedModelType is modal.
soltypeonline	on | off	on	Create a reduced model.
unreducedModelStepAWE	String		Frequency domain study step, if reducedModelType is awe.
unreducedModelStudyAWE	String		Study containing at leas one compatible study step, if reducedModelType is awe.

For the modal model reduction method, the following methods are available..

TABLE 6-131: PROPERTIES FOR MODAL MODEL REDUCTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
trainingRecompute	initially | always	initially	Recomputation of the training study step.
trainingStep	String	auto	Study step compatible with the chosen model reduction method used to produce the basis of the reduced method.
trainingStudy	String	none	Study containing a study step compatible with training data for the chosen method.
unreducedModelStep	String	none	Study step compatible with the chosen model reduction method used to define the model to reduced.
unreducedModelStudy	String	none	Study containing a study step for reduction compatible with the chosen method.

The following properties are available for a time-dependent unreduced study (an unreducedModelStep).

TABLE 6-132: PROPERTIES FOR A TIME-DEPENDENT UNREDUCED STUDY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
romSolveTransient	on | off	off	Reduced model simulation using the modal solver.
tlist	double array	range(0,0.1,1)	Time list for the simulation with the modal solver.

The following properties are available for a frequency-dependent unreduced study (an `unreducedModelStep`).

TABLE 6-133: PROPERTIES FOR A FREQUENCY-DEPENDENT UNREDUCED STUDY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`romSolveFrequency`	`on` | `off`	`off`	Reduced model simulation using the modal solver.
`plist`	double array		Frequency list for the simulation with the modal solver. The first frequency is used as the linearization frequency for the second-order expansion of the matrices.

Physics and Variables Selection Properties

The following properties, in the physics and variables selection (common to many study steps) for variables not solved for reconstruction, can be used if available.

TABLE 6-134: PROPERTIES FOR A FREQUENCY-DEPENDENT UNREDUCED STUDY

PROPERTY	VALUE	DESCRIPTION
`activaterom`	Vector of strings	Store output DOFs produced by reduced model. In the vector, use alternating values of reduced model tags and `on` or `off`.
`disabledreduced`	Vector of strings	Disabled reduced models.
`reconstructors`	Vector of strings	Choose physics interfaces not solved for to reconstruct and which reduced model to use, with alternating values of physics tags and reduced model tags.

Multigrid Level

A Multigrid Level study substep specifies the geometric multigrid level used by the study step (a Stationary study step, for example).

SYNTAX

```
model.study(stdname).create(fname,"Stationary");
model.study(stdname).feature(fname).mglevel().create(mglname);
model.study(stdname).feature(fname).mglevel(mglname).set(pname,value);
```

DESCRIPTION

Study step attribute.

The following properties are available.

TABLE 6-135: PROPERTIES FOR PHYSICS SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`discretization`	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. Example value when two physics interfaces `g` and `c` are available is: `new String[]{"g", "disc1", "c", "disc2"}`.

TABLE 6-136: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

Parametric Sweep

Use the Parametric Sweep study step when you want to find the solution to a sequence of stationary or time-dependent problems that arise when you vary some parameters of interest.

SYNTAX

```
model.study(stdname).create(fname, "Parametric");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-137: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse | switch	sparse	Sweep type.

TABLE 6-138: PROPERTIES FOR OUTPUT WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
accumtable	String	new	Accumulated probe table.
accumtableall	on | off	on	Use all probes for the accumulated probe table.
filename	String		Filename.
keepsol	last | all		Keep solutions in memory.
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
save	on | off		Save each solution as a model file.
useaccumtable	on | off	on	Use an accumulated probe table.

TABLE 6-139: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
pdistrib	on | off	off	Distribute parametric sweep.
paramselect	auto | off	auto	Use parametric solver.

Ray Tracing

The Ray Tracing study step is a special case of the Time Dependent study step. It includes additional options for computing ray paths. The Ray Tracing study step is available with the Acoustics Module or the Ray Optics Module.

SYNTAX

```
model.study(stdname).create(fname, "RayTracing");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-140: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
charvel	String	c_const	Group velocity used to convert path lengths to solution times when timestepspec=specifylength.
llist	Numeric vector		List of path lengths when timestepspec=specifylength.
lunit	String	m	Length unit when timestepspec=specifylength.
raystopcond	nostop | noactive | rayintensity		Automatic stop condition in the default solver sequence.
rtol	Positive scalar	0.01	Relative tolerance, if usertol is on.
thresholdintensity	String	1[W/m^2]	Threshold intensity for automatic stop conditions when raystopcond=rayintensity.
timestepspec	specifytime | specifylength	specifytime	Determines whether the time intervals are entered directly or in terms of a path length.
tlist	Numeric vector		Time list when timestepspec=specifytime.
tunit	String	s	Time unit when timestepspec=specifytime.
usertol	on | off	off	Physics-controlled or user-defined tolerance.

TABLE 6-141: PROPERTIES FOR PLOT RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probefreq	pout | psteps	pout	Where to update probes.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
plotfreq	tout | tsteps	tout	Where to update plot.

TABLE 6-142: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features.
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-143: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initmethod	init | sol	init	Method for initial values for variables solved for.
initstudy	String		Reference to study or "zero" for zero solution.
manualsolnum	Vector of integers	[1]	Index to solution for initial value for variables solved for.
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
solnum	auto | first | last | interp | manual | positive integer	auto	Solution selection of initial values for variables solved for.
storesel	Vector of strings		Selections defining which field data to store.
t	String		Specify time for interpolated solution of initial value for variables solved for.
useinitsol	on | off	off	User-controlled initial values for variables solved for.
usesol	on | off	off	User-controlled values for variables not solved for.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-144: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-145: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapgeom	String		Name of geometry to use.
adaption	on | off	off	Adaptive mesh refinement.
autoremesh	on | off	off	Automatic remeshing.
autoremeshgeom	String		Name of geometry to use.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useparam	on | off	off	Auxiliary sweep.

Schrödinger-Poisson

The Schrödinger-Poisson study step is a special case of the Eigenfrequency study step that is used to model bidirectionally coupled Schrödinger-Poisson systems. It is available with the Semiconductor Module. It is similar to the Eigenvalue study step but has an additional section called Iterations, which determines the behavior of the iterative solver loop for self-consistently modeling of the Schrödinger-Poisson system.

SYNTAX

```
model.study(stdname).create(fname, "SchrodingerPoisson");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-146: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
appnreigs	Integer	20	Approximate number of eigenfrequencies.
chkeigregion	on | off	on	Perform consistency check.
eigli	Real scalar	0	Largest imaginary part.
eiglr	Real scalar	0	Largest real part.
eigmethod	manual | region | all	manual	Eigenvalue search method; the all method finds all eigenvalues for a full matrix and can only be used for small eigenfrequency problems.
eigsi	Real scalar	0	Smallest imaginary part.
eigsr	Real scalar	0	Smallest real part.
eigwhich	lm | lr | sr | li | si	lm	Eigenfrequency search method around shift.

TABLE 6-146: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
maxnreigs	Integer	200	Maximum number of eigenfrequencies.
neigs	Integer	6	Desired number of eigenfrequencies.
neigsactive	on | off	off	Set desired number of eigenfrequencies.
shift	Complex scalar	0	Shift.
shiftactive	on | off	off	Use shift.

TABLE 6-147: PROPERTIES FOR PLOT RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probefreq	pout | psteps	pout	Where to update probes.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
plotfreq	tout | tsteps	tout	Where to update plot.

TABLE 6-148: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-149: PROPERTIES FOR ITERATIONS SECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
atolterm	Positive real number	1E-6	Absolute tolerance for termination of the solver loop when method=minimization_of_global_variable.
expr	String	1	Global expression used to compute relative error when method!=iterations
iter	Positive integer	5	Number of iterations of the solver loop when method=iterations.
maxiter	Positive integer	25	Maximum number of iterations in the solver loop when method!=iterations.

TABLE 6-149: PROPERTIES FOR ITERATIONS SECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
method	minimization_of_global_variable | convergence_of_global_variable | iterations	iterations	Choose whether termination of the solver loop is based on the convergence of a global variable, minimization of a global variable or a fixed number of iterations.
miniter	Positive integer	1	Minimum number of iterations in the solver loop when method!=iterations.
rtolterm	Positive real number	0.001	Relative tolerance for termination of the solver loop when method=convergence_of_global_variable.
rtolthresh	Positive real number	1	Threshold used to avoid division by zero while computing the relative error when method=convergence_of_global_variable.

TABLE 6-150: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initmethod	init | sol	init	Method for initial values for variables solved for.
initstudy	String		Reference to study or "zero" for zero solution.
manualsolnum	Vector of integers	[1]	Index to solution for initial value for variables solved for.
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
solnum	auto | first | last | interp | manual | positive integer	auto	Solution selection of initial values for variables solved for.
storesel	Vector of strings		Selections defining which field data to store.
t	String		Specify time for interpolated solution of initial value for variables solved for.
useinitsol	on | off	off	User-controlled initial values for variables solved for.
usesol	on | off	off	User-controlled values for variables not solved for.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-151: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-152: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapgeom	String		Name of geometry to use.
adaption	on | off	off	Adaptive mesh refinement.
autoremesh	on | off	off	Automatic remeshing.
autoremeshgeom	String		Name of geometry to use.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useparam	on | off	off	Auxiliary sweep.

Sensitivity

Use a Sensitivity study step to add sensitivity analysis to a study.

SYNTAX

```
model.study(stdname).create(fname, "Sensitivity");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-153: PROPERTIES FOR SENSITIVITY METHOD

PROPERTY	VALUE	DEFAULT	DESCRIPTION
descr	String		Objective function description.
gradientMethod	adjoint | forward	adjoint	Gradient method.
gradientStep	String		Reference to study step.
objectiveActive	Vector with entries "on" and "off".	Vector with only "on".	Controls which objective functions from the physics interfaces that are active.
optobj	String		Objective function expression.

TABLE 6-154: PROPERTIES FOR CONTROL VARIABLES AND PARAMETERS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
controlVariableActive	Vector with entries "on" and "off".	Vector with only "on".	Controls which control variables from the physics interfaces that are active.
initval	Vector of scalars		Initial values, one per parameter.
pname	Vector of strings		Parameter names.

TABLE 6-154: PROPERTIES FOR CONTROL VARIABLES AND PARAMETERS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
scale	Vector of type valuetype		Scales, one per parameter.
valuetype	Vector with entries "real" and "complex"	Vector with only "real".	Value types, one per parameter.

Stationary

A Stationary study step is intended for a stationary or steady-state situation where you can use a stationary solver.

SYNTAX

```
model.study(stdname).create(fname, "Stationary");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-155: PROPERTIES FOR RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probefreq	pout | psteps	pout	Where to update probes.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.

TABLE 6-156: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features.
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-157: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
initmethod	init | sol	init	Method for initial values for variables solved for.
initstudy	String		Reference to study or "zero" for zero solution.
manualsolnum	Vector of integers	[1]	Index to solution for initial value for variables solved for.

TABLE 6-157: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
solnum	auto | first | last | interp | manual | positive integer	auto	Solution selection of initial values for variables solved for.
storesel	Vector of strings		Selections defining which field data to store.
t	String		Specify time for interpolated solution of initial value for variables solved for.
useinitsol	on | off	off	User-controlled initial values for variables solved for.
usesol	on | off	off	User-controlled values for variables not solved for.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-158: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-159: PROPERTIES FOR ADAPTATION AND ERROR ESTIMATES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapgeom	String		Adaptation in geometry.
adapsolnum	Array of integers>0	1	Indices.
adjppr	on | off	on	Adjoint solution error estimate (for adaptation).
allowcoarsening	on | off	on	Controls if the mesh can be coarsened by the general modification method (meshadaptmethod set to modify).
elementspar	Positive scalar	0.5	Element fraction (for adaptation).
elselect	globalmin | worst | elements	globalmin	Method for selecting elements to refine (for adaptation).
errestandadap	none | adaption | errest	none	Perform adaptation or error estimation (or none).

TABLE 6-159: PROPERTIES FOR ADAPTATION AND ERROR ESTIMATES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
errestim	l2errest | goalerrest	l2errest for adaption; goalerrest for errest	Error estimate.
goalfuncpredef	gfint | gfl2 | gfl1 | gflinf	gfint	Functional: integral (the default), L2 norm, L1 norm, or approximate max norm.
goalfunctype	gfpredef | gfman	gfpredef	Functional type: predefined (the default) or manual.
globalminpar	Positive scalar	1.7	Element growth rate (for adaptation).
l2scale	String	1	Scaling factor.
l2staborder	String	2	Stability estimate derivative order
maxscale	Double	3	Maximum coarsening factor (for adaptation).
maxt	Double	10,000,000	Maximum number of elements (for adaptation).
meshadaptmethod	modify | rebuild | regular | longest	longest	The refinement method for mesh adaptation (general mesh modification, rebuild mesh, regular refinement, or longest edge refinement)
ngen	Scalar integer	2	Maximum number of refinements (for adaptation).
resorder	String	0	Residual order.
savesolsref	true | false	true	Save solution on every refined mesh (for adaptation).
selection	first | last | all | manual	last	Solution selection: the first or last solution, a all solutions, or manual, using weights and solution number indices in adapsolnum. Eigenfrequency studies use all with weights set to 1, which then uses the first solution only.
weights	double[] (positive values)	1.0	Weight for each selected solution (for adaptation).
worstpar	positive scalar		Controls refinement if elselect=worst (for adaptation).

TABLE 6-160: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
constraintgroup	Matrix with "on"/ "off" entries	Matrix with only "off"	Constraint group status (active or not). One row per load case.
loadcase	Vector of strings		Load cases.
loadgroup	Matrix with "on"/ "off" entries	Matrix with only "off"	Load group status (active or not). One row per load case.
loadgroupweight	Real matrix	off	Weight of each load case (as a scalar number). One row per load case.
pcontinuation	String		Continuation parameter when pcontinuationmode = manual.

TABLE 6-160: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
pcontinuationmode	no | last | manual	last	Determines if a continuation sweep should be performed for one of the parameters in pname.
pdistrib	on | off	off	Distribute parametric sweep.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
preusesol	no | yes | auto	no	Determines how the converged solutions are reused in the parameter sweep.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useloadcase	on | off	off	Define load cases.
useparam	on | off	off	Auxiliary sweep.

Time Dependent

A Time Dependent study step is intended for simulations where field variables vary over time and you can use a time-dependent solver.

SYNTAX

```
model.study(stdname).create(fname, "Transient");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-161: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
tlist	Numeric vector		Time list.
usertol	on | off	off	Physics-controlled or user-defined tolerance.
rtol	Positive scalar	0.01	Relative tolerance, if usertol is on.
tunit	String	s	Time unit.

TABLE 6-162: PROPERTIES FOR PLOT RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probefreq	pout | psteps	pout	Where to update probes.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
plotfreq	tout | tsteps	tout	Where to update plot.

TABLE 6-163: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`activate`	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, `g` and `c`: `new String[]{"g", "on", "c", "off"}`.
`disabledcoupling`	Vector of strings		Disabled coupling features
`disabledphysics`	Vector of strings		Disabled physics interfaces.
`disabledvariables`	Vector of strings		Disabled variables.
`discretization`	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, `g` and `c`: `new String[]{"g", "disc1", "c", "disc2"}`.
`useadvanceddisable`	`on` | `off`	`off`	Modify physics tree and variables for study step.

TABLE 6-164: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`initmethod`	`init` | `sol`	`init`	Method for initial values for variables solved for.
`initstudy`	String		Reference to study or `"zero"` for zero solution.
`manualsolnum`	Vector of integers	`[1]`	Index to solution for initial value for variables solved for.
`notlistsolnum`	Vector of integers	`[1]`	Indices to selected solutions for values for variables not solved for.
`notmanualsolnum`	Vector of integers	`[1]`	Indices to solutions for values for variables not solved for.
`notsolmethod`	`init` | `sol`	`init`	Method for values for variables not solved for.
`notsolnum`	`auto` | `all` | `first` | `last` | `from_list` | `interp` | `manual` | positive integer	`auto`	Solution selection for values for variables not solved for.
`notstudy`	String		Reference to study or `"zero"` for zero solution.
`nott`	String		Specify time for interpolated solution of values for variables not solved for.
`solnum`	`auto` | `first` | `last` | `interp` | `manual` | positive integer	`auto`	Solution selection of initial values for variables solved for.
`storesel`	Vector of strings		Selections defining which field data to store.
`t`	String		Specify time for interpolated solution of initial value for variables solved for.
`useinitsol`	`on` | `off`	`off`	User-controlled initial values for variables solved for.
`usesol`	`on` | `off`	`off`	User-controlled values for variables not solved for.
`usestoresel`	`all` | `selection`	`all`	Store fields in output.

TABLE 6-165: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-166: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapgeom	String		Name of geometry to use.
adaption	on | off	off	Adaptive mesh refinement.
autoremesh	on | off	off	Automatic remeshing.
autoremeshgeom	String		Name of geometry to use.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useparam	on | off	off	Auxiliary sweep.

Time Discrete

A Time Discrete study step adds a Time Discrete Solver. Use it for performing time-dependent analysis using the projection method.

SYNTAX

```
model.study(stdname).create(fname, "TimeDiscrete");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-167: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
tlist	Numeric vector		Time list.
usertol	on | off	off	Physics-controlled or user-defined tolerance.
rtol	Positive scalar	0.01	Relative tolerance, if usertol is on.
tunit	String	s	Time unit.

TABLE 6-168: PROPERTIES FOR PLOT RESULTS WHILE SOLVING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
plot	on | off	off	Plot while solving.
plotgroup	String	default	Plot group to use for plot while solving.
probefreq	pout | psteps	pout	Where to update probes.
probes	Vector of strings		Probes to use when probesel=manual.
probesel	all | none | manual	all	Probes to compute.
plotfreq	tout | tsteps	tout	Where to update plot.

TABLE 6-169: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`activate`	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, `g` and `c`: `new String[]{"g", "on", "c", "off"}`.
`disabledcoupling`	Vector of strings		Disabled coupling features
`disabledphysics`	Vector of strings		Disabled physics interfaces.
`disabledvariables`	Vector of strings		Disabled variables.
`discretization`	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, `g` and `c`: `new String[]{"g", "disc1", "c", "disc2"}`.
`useadvanceddisable`	`on` | `off`	`off`	Modify physics tree and variables for study step.

TABLE 6-170: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`initmethod`	`init` | `sol`	`init`	Method for initial values for variables solved for.
`initstudy`	String		Reference to study or `"zero"` for zero solution.
`manualsolnum`	Vector of integers	`[1]`	Index to solution for initial value for variables solved for.
`notlistsolnum`	Vector of integers	`[1]`	Indices to selected solutions for values for variables not solved for.
`notmanualsolnum`	Vector of integers	`[1]`	Indices to solutions for values for variables not solved for.
`notsolmethod`	`init` | `sol`	`init`	Method for values for variables not solved for.
`notsolnum`	`auto` | `all` | `first` | `last` | `from_list` | `interp` | `manual` | positive integer	`auto`	Solution selection for values for variables not solved for.
`notstudy`	String		Reference to study or `"zero"` for zero solution.
`nott`	String		Specify time for interpolated solution of values for variables not solved for.
`solnum`	`auto` | `first` | `last` | `interp` | `manual` | positive integer	`auto`	Solution selection of initial values for variables solved for.
`storesel`	Vector of strings		Selections defining which field data to store.
`t`	String		Specify time for interpolated solution of initial value for variables solved for.
`useinitsol`	`on` | `off`	`off`	User-controlled initial values for variables solved for.
`usesol`	`on` | `off`	`off`	User-controlled values for variables not solved for.
`usestoresel`	`all` | `selection`	`all`	Store fields in output.

TABLE 6-171: PROPERTY FOR MESH SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

TABLE 6-172: PROPERTIES FOR STUDY EXTENSIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
adapgeom	String		Name of geometry to use.
adaption	on | off	off	Adaptive mesh refinement.
plistarr	Real matrix		List of parameter values. One row of values per parameter name.
pname	Vector of strings		Parameter names.
punit	Vector of strings		Parameter units.
sweeptype	filled | sparse	sparse	Sweep type: a filled or a sparse sweep.
useparam	on | off	off	Auxiliary sweep.

Time to Frequency FFT

A Time to Frequency FFT study step, which you can add to a frequency domain study, performs a forward FFT from the time domain (input) to the frequency domain (output). As the default solver it adds an FFT solver.

SYNTAX

```
model.study(stdname).create(fname, "TimeToFreqFFT");
model.study(stdname).feature(fname).set(pname,value);
```

DESCRIPTION

Study step.

The following properties are available.

TABLE 6-173: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
fftendtime	Real scalar	1.0	End time for the time interval.
fftmaxfreq	Real scalar	10	Maximum output frequency.
fftrealstore	on | off	on	Do not store negative frequencies for real input.
fftscaling	cont | discrete	cont	Use a discrete or continuous scaling for the Fourier transform.
fftstarttime	Real scalar	0.0	Start time for the time interval.
fftwinalpha	Real scalar	0.5	Window parameter for a Tukey window.
fftwincenterfw	Real scalar	0.5	Window center for a Gaussian window function.
fftwincutoff	Real scalar	1	Cut-off fraction for window function in [0, 1].
fftwindev	Real scalar	1	Standard deviation for a Gaussian window function.
fftwindowfw	on | off	off	Use window function.

TABLE 6-173: PROPERTIES FOR STUDY SETTINGS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
fftwinexpr	String	1	Expression for window function (when set to fromexpr). Can be expressed in terms of t, freq, niterFFTin, and niterFFTout (if applicable).
fftwinmaxfw	Real scalar	1	Maximum (end) value for window.
fftwinminfw	Real scalar	0	Minimum (start) value for window.
fftwintypefw	fromexpr | cutoff | rectangle | gauss | hamming | hanning | blackman | tukey	fromexpr	Method for window function.
linpmethod	sol | init	sol	Prescribe the input values using a solution or an initial expression.
linpsol	String		Solution that defines input values for the FFT study step.
linpsoluse	String		Subsolution that defines the input values for the FFT study step/FFT solver.
linpstudy	String		Study that defines input values for the FFT study step.
punit	String	Hz	Frequency unit.
tunit	String	s	Time unit.

TABLE 6-174: PROPERTIES FOR PHYSICS AND VARIABLES SELECTION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
activate	Vector of strings		Choose physics interfaces to solve for. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "on", "c", "off"}.
disabledcoupling	Vector of strings		Disabled coupling features
disabledphysics	Vector of strings		Disabled physics interfaces.
disabledvariables	Vector of strings		Disabled variables.
discretization	Vector of strings		Select discretizations for physics interfaces. The length of the vector is two times the number of physics interfaces. For example, with two physics interfaces, g and c: new String[]{"g", "disc1", "c", "disc2"}.
useadvanceddisable	on | off	off	Modify physics tree and variables for study step.

TABLE 6-175: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notlistsolnum	Vector of integers	[1]	Indices to selected solutions for values for variables not solved for.
notmanualsolnum	Vector of integers	[1]	Indices to solutions for values for variables not solved for.
notsolmethod	init | sol	init	Method for values for variables not solved for.
notsolnum	auto | all | first | last | from_list | interp | manual | positive integer	auto	Solution selection for values for variables not solved for.

TABLE 6-175: PROPERTIES FOR VALUES OF DEPENDENT VARIABLES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
notstudy	String		Reference to study or "zero" for zero solution.
nott	String		Specify time for interpolated solution of values for variables not solved for.
storesel	Vector of strings		Selections defining which field data to store.
usestoresel	all | selection	all	Store fields in output.

TABLE 6-176: PROPERTY FOR MESH SELECTION.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
mesh	Vector of strings		Select meshes for geometries. The length of the vector is two times the number of geometries. Example value when two geometries geom1 and geom2 are available is: new String[]{"geom1","mesh1","geom2", "mesh2"}.

7

Results

Detailed COMSOL API reference information is included for the results features and utility methods for extracting and plotting data from the simulations.

In this chapter:

About Results Commands

The commands in this chapter provide numerical results and plots for visualizing results. Note that `result` for the model object corresponds to Results in the Model Tree.

The following list includes the available commands for results evaluation and visualization (listed in alphabetical order):

- Animation
- Annotation
- AnnotationData
- Array 1D, Array 2D, Array3D
- ArrowData
- ArrowVolume, ArrowSurface, ArrowLine, ArrowPoint
- AvVolume, AvSurface, AvLine
- Average, Integral, Maximum, Minimum
- Color
- Contour
- Contour (Data Set)
- CoordSysLine, CoordSysSurface, CoordSysVolume
- CutLine2D, CutLine3D
- CutPlane
- CutPoint1D, CutPoint2D, CutPoint3D
- Data
- Deform
- Directivity
- Edge2D, Edge3D
- Eval
- EvalAberration
- EvalGlobal
- EvalGlobalMatrix
- EvalPoint
- EvalPointMatrix
- EvaluationGroup
- Export
- Extrude1D, Extrude2D
- Filter
- Filter (Particle Tracing, Point Trajectories, Ray Tracing,)
- Global (Numerical)
- Global (Plot)
- Grid1D, Grid2D, Grid3D
- Height, AberrationHeight, HistogramHeight, TableHeight
- Histogram
- Image1D, Image2D, Image3D
- ImpulseResponse
- InterferencePattern
- Interp
- IntersectionPoint2D, IntersectionPoint3D
- IntVolume, IntSurface, IntLine
- Isosurface
- Isosurface (Data Set)
- Join
- LayeredShell
- LayeredShellSlice
- Line
- LineData
- LineGraph
- MatrixHistogram
- MaxMinVolume, MaxMinSurface, MaxMinLine, MaxMinPoint
- MaxVolume, MaxSurface, MaxLine, MinVolume, MinSurface, MinLine
- Mesh
- Mesh (Data Set)
- Mesh (Export)
- Mirror2D, Mirror3D
- Multislice

- Nyquist
- OctaveBand
- OpticalAberration
- Parametric1D, Parametric2D
- ParCurve2D, ParCurve3D
- ParSurface
- Particle
- Particle (Data Set)
- Particle (Evaluation)
- ParticleBin
- ParticleMass
- ParticleTrajectories
- PhasePortrait
- Plot
- PlotGroup1D, PlotGroup2D, PlotGroup3D
- PoincareMap
- PointData
- PointGraph
- PointTrajectories
- PolarGroup
- PrincipalLine, PrincipalSurface, PrincipalVolume
- RadiationPattern
- Ray (1D Plot)
- Ray (Data Set)
- Ray (Evaluation)
- RayBin
- RayTrajectories
- Receiver2D, Receiver3D
- ReflectionGraph, ImpedanceGraph, AdmittanceGraph
- ResponseSpectrum2D, ResponseSpectrum3D
- Revolve1D, Revolve2D
- ScatterVolume, ScatterSurface
- Sector2D, Sector3D
- Selection
- Shell
- Slice
- SmithGroup
- Solution
- Streamline
- StreamlineSurface
- Surface
- Surface (Data Set)
- SurfaceData
- SurfaceSlit
- SystemMatrix
- Table
- Table (Export)
- Table (Plot)
- TableSurface
- TimeAverage, TimeIntegral
- ThroughThickness
- TubeData
- Volume
- Waterfall
- Whirl

Commands Grouped by Function

ATTRIBUTES

FUNCTION	PURPOSE
Color	Color expression.
Deform	Deformation.
Export	Export expressions.
Filter	Filter.

FUNCTION	PURPOSE
`Height`, `AberrationHeight`, `HistogramHeight`, `TableHeight`	Height for various plot types.
`Selection`	Selection for various plot types.

DATA SETS

FUNCTION	PURPOSE
`Array 1D, Array 2D, Array3D`	Array data sets
`Average, Integral, Maximum, Minimum`	Evaluation data sets
`Contour (Data Set)`	Contour data set
`CutLine2D, CutLine3D`	Cut line data sets
`CutPlane`	Cut plane data set
`CutPoint1D, CutPoint2D, CutPoint3D`	Cut point data sets
`Edge2D, Edge3D`	Edge data sets
`Extrude1D, Extrude2D`	Extrusion data sets
`Grid1D, Grid2D, Grid3D`	Grid data sets
`IntersectionPoint2D, IntersectionPoint3D`	Intersection point data sets
`Isosurface (Data Set)`	Isosurface data set
`Join`	Join data set for joining results from other data sets
`LayeredShell`	Layered shell data set for layered material.
`Mesh (Data Set)`	Mesh data set
`Mirror2D, Mirror3D`	Mirror data set
`Parametric1D, Parametric2D`	Extends another data set by using a parameter as dimension
`ParCurve2D, ParCurve3D`	Parameterized curve data sets
`ParSurface`	Parameterized face (surface) data set
`Particle (Data Set)`	Particle data set
`ParticleBin`	Particle bin data set
`Ray (Data Set)`	Ray data set
`RayBin`	Ray bin data set
`Receiver2D, Receiver3D`	Receiver data sets
`ResponseSpectrum2D, ResponseSpectrum3D`	Response spectrum data sets
`Revolve1D, Revolve2D`	Revolution data sets
`Sector2D, Sector3D`	Sector symmetry data sets
`Shell`	Shell data set for visualizing the top and bottom of a shell
`Solution`	Solution data set
`Surface (Data Set)`	Surface data set
`TimeAverage, TimeIntegral`	Time average and time integral data sets

EXPORT FEATURES

FUNCTION	PURPOSE
`Animation`	Animation export or player
`Data`	Data export from data sets
`Mesh (Export)`	Mesh export from data sets
`Image1D, Image2D, Image3D`	Image export
`Plot`	Plot export
`Table (Export)`	Table export

NUMERICAL RESULTS

FUNCTION	PURPOSE
AvVolume, AvSurface, AvLine	Average
Eval	Generic evaluation
EvalAberration	Aberration evaluation
EvalGlobal	Global evaluation
EvalGlobalMatrix	Global matrix evaluation
EvalPoint	Evaluation at points
EvalPointMatrix	Matrix evaluation at points
EvaluationGroup	Evaluation group
Global (Numerical)	Generic evaluation
Interp	Interpolation
IntVolume, IntSurface, IntLine	Integration
MaxVolume, MaxSurface, MaxLine, MinVolume, MinSurface, MinLine	Maximum and minimum
Particle (Evaluation)	Evaluation on particle trajectories
Ray (Evaluation)	Evaluation on ray trajectories
SystemMatrix	Evaluation of system matrix.

PLOTS

FUNCTION	PURPOSE
Annotation	Annotation plot
AnnotationData	Annotation data plot
ArrowData	Arrow data plot
ArrowVolume, ArrowSurface, ArrowLine, ArrowPoint	Arrow plots
Contour	Contour plot
CoordSysLine, CoordSysSurface, CoordSysVolume	Coordinate system plot
Directivity	Directivity plot
Filter	Far-field plot
Global (Plot)	Global plot
Histogram	Histogram plot
ImpulseResponse	Impulse response plot
InterferencePattern	Interference pattern plot
Isosurface	Isosurface plot
LayeredShellSlice	Layered shell slice plot
Line	Line plot
LineData	Line data plot
LineGraph	Line graph plot
MatrixHistogram	Matrix histogram plot
MaxMinVolume, MaxMinSurface, MaxMinLine, MaxMinPoint	Max/min marker plots
Mesh	Mesh plot
Multislice	Multislice plot
Nyquist	Nyquist plot

FUNCTION	PURPOSE
OctaveBand	Octave band plot
OpticalAberration	Optical aberration plot for rays.
Particle	Massless particle tracing plot
Particle (1D Plot)	Particle plot
ParticleMass	Particle tracing plot with mass
ParticleTrajectories	Plot the data from a particle data set
PhasePortrait	Phase portrait plot
PoincareMap	Plot a Poincaré map
PointData	Point data plot
PointGraph	Point graph plot
PointTrajectories	Point trajectories plot
PrincipalLine, PrincipalSurface, PrincipalVolume	Principal stress/strain plots
Ray (1D Plot)	Ray plot
RayTrajectories	Plot the data from a ray data set
ScatterVolume, ScatterSurface	Scatter plots
Slice	Slice plot
Streamline	Streamline plot
StreamlineSurface	Streamline plot on surfaces in 3D
Surface	Surface plot
SurfaceData	Surface data plot
SurfaceSlit	Surface slit plot
Table (Plot)	Table plot
TableSurface	Table surface plot
ThroughThickness	Though-thickness plot
TubeData	Tube data plot
Volume	Volume plot
Waterfall	Waterfall plot
Whirl	Whirl plot for rotordynamics

TABLES

FUNCTION	PURPOSE
Table	Table containing real and imaginary data.

Results Analysis and Plots in the *COMSOL Multiphysics Reference Manual*

Use of Data Sets

Table 7-1 shows applicability of data set output as data sets input for the most widely used data sets. Rows correspond to data set output and columns to data set input. Check marks appear if the row data set output is accepted as input to the column data set. *evaluation* indicates Average, Integral, Maximum, and Minimum data sets

TABLE 7-1: DATA SET INPUT VERSUS OUTPUT

DATA SETS Input vs. output	ARRAY 1D	ARRAY2D	ARRAY3D	CONTOUR	CUTLINE2D	CUTLINE3D	CUTPLANE	CUTPOINT1D	CUTPOINT2D	CUTPOINT3D	EVALUATION	INTERSECTION POINT	ISOSURFACE	JOIN	MESH	MIRROR2D	MIRROR3D	PARAMETRIC1D	PARAMETRIC2D	PARCURVE2D	PARCURVE3D	PARSURFACE	PARTICLE	RAY	REVOLVE1D	REVOLVE2D	SOLUTION
Array1D	√							√																			
Array2D		√		√	√				√		√			√		√									√	
Array3D			√								√		√	√			√										
Contour											√																
CutLine2D		√						√			√					√									√		
CutLine3D			√					√			√						√										
CutPlane		√	√	√	√				√		√					√	√			√						√	
CutPoint1D	√										√																
CutPoint2D		√									√					√											
CutPoint3D			√								√						√										
Edge2D		√														√											√
Edge3D			√														√										√
evaluation											√																
Intersection Point2D/3D											√																
Isosurface			√	√							√						√										
Join																											
Mesh		√	√	√	√	√	√	√	√	√	√		√			√	√			√	√	√			√	√	
Parametric1D																											√
Parametric2D																											√
ParCurve2D		√					√	√			√		√			√											
ParCurve3D			√					√			√						√										
ParSurface		√	√	√	√				√		√					√	√			√							
Particle							√				√	√															
Ray							√				√	√															
Revolve1D		√		√	√				√		√					√				√							
Revolve2D			√			√	√			√	√		√				√				√	√						
Sector2D		√			√		√							√		√									√		√
Sector3D			√			√	√						√	√			√									√	√

TABLE 7-1: DATA SET INPUT VERSUS OUTPUT

DATA SETS Input vs. output	ARRAY ID	ARRAY2D	ARRAY3D	CONTOUR	CUTLINE2D	CUTLINE3D	CUTPLANE	CUTPOINT1D	CUTPOINT2D	CUTPOINT3D	EVALUATION	INTERSECTION POINT	ISOSURFACE	JOIN	MESH	MIRROR2D	MIRROR3D	PARAMETRIC1D	PARAMETRIC2D	PARCURVE2D	PARCURVE3D	PARSURFACE	PARTICLE	RAY	REVOLVE1D	REVOLVE2D	SOLUTION
Solution		√	√	√	√	√	√	√	√	√	√		√	√		√	√	√	√	√	√	√	√	√	√	√	
Surface		√		√												√											

Table 7-2 shows applicability of data set output as input to plot features. Rows correspond to data set output and columns to plot features. Check marks appear if the data set output is accepted by the plot feature.

TABLE 7-2: DATA SET OUTPUT AS INPUT TO PLOT FEATURES (SOME SPECIAL PLOT TYPES ARE NOT INCLUDED)

DATA SET OUTPUT As input to plots	ARROW	CONTOUR	GLOBAL	HISTOGRAM	INTERFERENCEPATTERN	ISOSURFACE	LINE	LINEGRAPH	MESH	MULTISLICE	PARTICLE	PARTICLETRACING	PARTICLETRAJECTORIES	PHASEPORTRAIT	POINTGRAPH	POINTTRAJECTORIES	RADIATION PATTERN	RAY	RAYTRAJECTORIES	SCATTER	SLICE	STREAMLINE	SURFACE	VOLUME
Array2D	√	√		√			√													√		√	√	
Array3D	√			√		√	√			√										√	√	√	√	√
Contour	√			√			√																	
CutLine2D	√			√			√	√												√				
CutLine3D	√			√			√	√												√				
CutPlane	√	√		√	√		√													√		√	√	
CutPoint1D				√											√	√								
CutPoint2D				√											√	√								
CutPoint3D				√											√	√								
Edge2D				√			√	√																
Edge3D				√			√	√																
evaluation			√	√											√									
IntersectionPoint2D IntersectionPoint3D				√							√		√	√		√		√	√					
Isosurface	√	√		√			√																√	
Join	√	√		√		√	√	√		√					√					√	√	√	√	√
Mesh	√	√		√		√	√	√	√	√					√					√	√	√	√	√
Mirror2D	√	√		√			√													√		√	√	
Mirror3D	√			√		√	√			√										√	√	√	√	√
Parametric1D	√	√		√			√													√		√	√	
Parametric2D	√	√		√		√	√			√										√		√	√	√
Particle			√	√							√		√	√										
ParCurve2D	√			√			√	√																
ParCurve3D	√			√			√	√																
ParSurface	√	√		√			√													√		√	√	
Ray			√	√										√				√	√					

TABLE 7-2: DATA SET OUTPUT AS INPUT TO PLOT FEATURES (SOME SPECIAL PLOT TYPES ARE NOT INCLUDED)

DATA SET OUTPUT As input to plots	ARROW	CONTOUR	GLOBAL	HISTOGRAM	INTERFERENCEPATTERN	ISOSURFACE	LINE	LINEGRAPH	MESH	MULTISLICE	PARTICLE	PARTICLETRACING	PARTICLETRAJECTORIES	PHASEPORTRAIT	POINTGRAPH	POINTTRAJECTORIES	RADIATION PATTERN	RAY	RAYTRAJECTORIES	SCATTER	SLICE	STREAMLINE	SURFACE	VOLUME
Revolve1D	√	√		√			√													√		√	√	
Revolve2D	√	√		√		√	√			√										√	√	√	√	√
Sector2D	√	√		√			√													√		√	√	
Sector3D	√	√		√		√	√			√										√		√	√	√
Solution	√	√	√	√		√	√	√	√	√		√			√	√	√			√	√	√	√	√
Surface	√	√		√			√													√	√		√	

Extracting and Storing Plot Data

This section describes how to retrieve results or plot data and how to store and clear plot data from the model directly through the COMSOL API.

Retrieving Plot Data

Each plot is made up of one or more *groups* or parts. Most plots contain only one group, such as `Surface` or `Line` plots, whereas for example `Slice` plots contain one group per slice. Retrieve the number of groups with the method

```
plot.getGroups(<renderIndex>)
```

where `plot` is any plot feature.

Retrieving the groups requires that you specify a *render index* for which you want the number of groups. Each plot is made up of one or more internal, or rendering, plot types. For example, particle tracing can contain both lines and spheres, which are separate rendering types. Most plot have only a single rendering type, in which case you can safely use `0` as the render index. The *group index* property indicates groups or parts within the rendering group index.

Extract the data contained in any plot feature using the following methods:

`p = plot.getVertices(<renderIndex>, <groupIndex>)` returns a float matrix containing one row for each dimension and one column for each vertex.

`t = getElements(<renderIndex>, <groupIndex>)` returns the indices to columns in `p` of a simplex mesh, each column in `t` representing a simplex.

`d = getData(<renderIndex>, <groupIndex>, <dataType>)` returns a float array containing the data for each point in `p`. The type of data to retrieve is given by the String `<dataType>`:`"Color"`, `"Height"`, and so forth.

To retrieve the available data types, use:

`types = getDataTypes(<renderIndex>)`

which returns a string array with the data types currently present in the plot.

For plot features, you can retrieve the point normals using the following method:

`n = getNormals(<renderIndex>, <groupIndex>)`

which returns a floating-point matrix of point normals with each column corresponding to a single vertex.

EXAMPLE

```
int renderDataGroups = plot.getRenderGroups();

for (int ri = 0; ri < renderDataGroups; ri++) {

   String[] dataTypes = plot.getDataTypes(ri);
   int plotDataGroups = plot.getGroups(ri);
   for (int gi = 0; gi < plotDataGroups; gi++) {
      p = plot.getVertices(ri,gi);
      t = plot.getElements(ri,gi);
      //d = plot.getData(ri, gi, "Color");
```

```
        d = plot.getData(ri, gi, dataTypes[0]);
    }
}
```

RETRIEVING AXIS UNITS

Use `model.result(<feature>).getAxisUnits()` to return the units of the coordinate axes for the plot group to which the feature belong; null for 1D plot groups. This method returns a string array of length 2 or 3 containing LaTeX-formatted units.

Retrieving Numerical Results

It is possible to retrieve numerical results from any numerical feature, but there are a number of features especially designed for the COMSOL API that are not present in the COMSOL Desktop. These functions support multiple expressions, as well as some additional advanced properties, and a more convenient way to extract interpolated data. These two groups have slightly different access methods. Note that `numerical` in the model object corresponds to Derived Values in the Model Tree. In the API, code like `model.result().numerical(<ftag>)` returns objects of type NumericalFeature.

API-ONLY NUMERICAL FEATURES

TABLE 7-3: API-ONLY NUMERICAL FEATURE

FUNCTION	PURPOSE
`Eval`	Generic evaluation
`Global (Numerical)`	Generic evaluation
`Interp`	Interpolation

`result = model.result().numerical(<ftag>).getData()` returns the real part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][coordinates]`.

`model.result().numerical(<ftag>).getData(<expressionIndex>)` returns the real part of the result for one expression, equivalent to `result[expressionIndex]`.

`result = model.result().numerical(<ftag>).getImagData()` returns the imaginary part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][coordinates]`.

`model.result().numerical(<ftag>).getImagData(<expressionIndex>)` returns the imaginary part of the result for one expression, equivalent to `result[expressionIndex]`.

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. For models with outer solutions, `isComplex()` returns true if the result for the current value of `outersolnum` is complex.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution.

`model.result().numerical(<ftag>).getNData()` returns the number of points in the data vector.

`model.result().numerical(<ftag>).getCoordinates()` returns the coordinates of the evaluation or interpolation.

`model.result().numerical(<ftag>).getElements()` returns indices to columns in p of a simplex mesh.

`model.result().numerical(<ftag>).getVertexElements()` returns indices to mesh elements for each point.

More details can be found in the documentation for each feature type.

TABLE 7-4: STANDARD NUMERICAL FEATURES, ALSO PRESENT IN THE COMSOL MULTIPHYSICS GUI

FUNCTION	PURPOSE
`EvalGlobal`	Global evaluation
`EvalPoint`	Evaluation in points
`IntVolume, IntSurface, IntLine`	Integration

`model.result().numerical(`*`<ftag>`*`).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that one row contains data for all solution numbers. This is identical to `(`*`<columnwise>`*`)` when *`<columnwise>`* is `false`. If *`<columnwise>`* is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(`*`<ftag>`*`).getImag(`*`<allocate>`*`, `*`<columnwise>`*`)` returns the imaginary part of complex result, recomputing the feature if necessary. If *`<allocate>`* is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses *`<allocate>`* `true` and *`<columnwise>`* `false`.

`model.result().numerical(`*`<ftag>`*`).getComplex()` returns a complex-valued result (the real and imaginary values), as an array of length two, where the first element is the real part and the second element is the imaginary part. The second element is null if the return value is all-real. Data is ordered such that one row contains data for all solution numbers. This is identical to `(`*`<columnwise>`*`)` when *`<columnwise>`* is `false`. If *`<columnwise>`* is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(`*`<ftag>`*`).getComplex(`*`<columnwise>`*`)` returns the real and imaginary part of a complex-valued result. If the Boolean *`<columnwise>`* is `false`, data is ordered such that each row contains the values for all solution numbers. If `true`, one column contains the values for all solution numbers.

`model.result().numerical(`*`<ftag>`*`).getComplex(`*`<outersolnum>`*`)` returns the real and imaginary part of a complex-valued result for the given outer solution number (the 1-indexed integer *`<outersolnum>`*).

`model.result().numerical(`*`<ftag>`*`).getComplex(`*`<columnwise>`*`,`*`<outersolnum>`*`)` returns the real and imaginary part of a complex-valued result for the given outer solution number in *`<outersolnum>`* using an order determined by the Boolean *`<columnwise>`* (see above).

`model.result().numerical(`*`<ftag>`*`).isComplex()` returns true if the result is complex. For models with outer solutions, `isComplex()` returns true if the result is complex for any of the currently set `outersolnum`.

`model.result().numerical(`*`<ftag>`*`).isComplex(`*`<outersolnum>`*`)` returns true if the result is complex for the given outer solution (the 1-indexed integer *`<outersolnum>`*).

You can find more details in the documentation for each feature type.

Storing and Clearing Plot Data in the Model

To avoid recreating plot data in a model, the plot data can be stored in the model for a plot group using the following property:

```
model.result("pg1").set("savedatainmodel", true);
```

which saves the plot data in the model for the plot group `pg1`. It can be useful for data that takes a long time to recompute but is not very large (such as some 1D plots, for example).

`model.result().clearStoredPlotData()` removes all stored plot data from the model.

Solution Selection

In this section:

About Selecting Solutions

During the solution of, for example, time-dependent models or parametric sweep models, more than one solution is generated, and in order to do relevant postprocessing the correct set of solutions needs to be selected among them. How many solutions the result features can display vary, the main difference being between single-select and multi-select features. Single solution selection is available when only one solution at a time can be visualized, for example in 2D and 3D plots. In numerical features and 1D plots multi-select is used to be able to display plots relating to more than one parameter value at a time.

There are two ways to select solutions: by solution number and by solution level. COMSOL Multiphysics keeps them synchronized as far as possible.

Selecting solutions by solution number is a method that is tightly linked to the solution representation used by the solvers. The solution level method is structurally similar to the set up of the studies. Setting any one property belonging to either method triggers a synchronization in which all properties of that method are mapped to those of the other method. Mapping to the solution number method always works, since that case is the more general. If, on the other hand, mapping to the solution level method fails, its properties are set to their default settings.

The `solrepresentation` property is set to `"solnum"` automatically if the solution number method is the only one able to represent the selection made. On solving it is set to `"solutioninfo"` if the solution level method can be used to represent the previous selection. The `solutionrepresentation` property also decides which method is visible in the COMSOL Desktop.

Selecting Solutions by Solution Number

In the solution number method, the solutions are selected as a collection of inner and outer solutions. Inner solutions are generated by the solvers in one step. Outer solutions are generated by parametric sweeps wrapping the inner solutions. If there are more than one inner or outer parameter, they are represented and selected as tuples — that is, combinations of values of the different parameters. Depending on the setup of the studies the parameters can be either filled (all combinations) or sparse (a selection of combinations). In the single-selection case the properties used are solnum, `t` and `outersolnum`. In the multi-selection case the valid properties are `innerinput`, `solnum`, `solnumindices`, `t`, `outerinput`, `outersolnum`, and `outerindices`.

Selecting Solutions by Solution Level

In contrast, the solution level method handles all filled parameters — that is, parameters defined individually in the studies — in one level each, up to a maximum of three levels. If more levels than that exist in the study the outermost levels are combined in the third level. Parameters that together form sparse tuples in the studies are always presented on the same level. In the single-selection case the properties used are `looplevel` and `interp`. In the multiselection case the valid properties are `looplevelinput`, `looplevel`, `looplevelindices`, and `interp`.

Choosing Solution Selection Method

Whether selection is made using the solution level method or the solution number method, the ways of selecting solutions are the same. In the single-selection case, solutions are selected by parameter index or, if the solution is time-dependent, by value. In the multiselection case there are a number of selection input options all, first, last, by index from existing values, by manual indices, or, in time-dependent cases, by time.

Which method to use is not self-evident. The solution level method is perhaps the more intuitive of the two because it attempts to treat each individual level separately. The solution number method, however, is more general, and can pinpoint which tuples to use with more precision. The recommendation is to use the solution level method wherever possible, and resort to the solution number method only if its special characteristics are needed.

Results Commands

Animation

Create animations of plots, saved to a file or shown in a player in the COMSOL Desktop main window.

SYNTAX

```
model.result().export().create(<ftag>,"Animation");
model.result().export(<ftag>).set(property, <value>);
model.result().export(<ftag>).run();
```

DESCRIPTION

`model.result().export().create(<ftag>,"Animation")` creates an animation feature with the name *<ftag>*.

`result().export(<ftag>).set("plotgroup", <ptag>)` changes the source of the animation to the plot group named *<ptag>*.

The following properties are available:

TABLE 7-5: VALID PROPERTY/VALUE PAIRS FOR ANIMATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`allarray`	integer array	All solutions	The solutions to use, chosen from all combinations of outer and inner. Applicable when both inner and outer solutions exist and `solnumtype` is `all`.
`alwaysask`	`on` | `off`	`off`	Always ask for filename when saving. This property is ignored when running without a user interface.
`antialias`	`on` | `off`	`on`	Enable/disable antialiasing.
`avifilename`	String		The name of the AVI file produced if `movietype` is `avi`.
`aviqual`	double in [0,1]	`0.75`	The quality of the AVI file if `movietype` is `avi`; higher is better.
`axes`	`on` | `off`	`on`	If `options` is `on`; enable/disable display of the coordinate axes. Used for 1D and 2D animations.
`axisorientation`	`on` | `off`	`on`	If `options` is `on`; enable/disable display of the axis orientation indicator. Used for 3D animations.
`background`	`current` | `color`	`color`	The background color.
`bmpfilename`	String		The name of the output file if `imagetype` is `bmp`.
`const`	String array of property/ value pairs	Empty	Parameters to use in the expressions.
`customcolor`	double array	`{1, 1, 1}`	If background is color; the red, green, and blue components of the background color.
`cycletype`	`fullharm` | `halfharm` | `linear`	`fullharm`	The transformation of the solution that is performed if `sweeptype` is `dde`.

TABLE 7-5: VALID PROPERTY/VALUE PAIRS FOR ANIMATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`flashfilename`	String		The name of the Flash file produced if movietype is `flash`.
`flashinterp`	`on` | `off`	`on`	Enable/disable interpolation between frames in the generated Flash file if `movietype` is `flash`.
`flashopen`	`on` | `off`	`off`	Enable/disable opening of the generated Flash file in a browser if `movietype` is `flash`.
`fontsize`	integer	9	The font size.
`fps`	positive integer	10	The number of frames per second.
`framesel`	`all` | `number`	`number`	When sweeptype is solutions, framesel controls whether to look through all solutions or a specified number of frames.
`frametime`	positive double	0.1	The time in seconds that each frame is displayed when the target is set to player.
`giffilename`	String		The name of the GIF file produced if movietype is gif.
`gifopen`	`on` | `off`	`off`	Enable/disable opening of the generated GIF file in a browser if movietype is gif.
`globalpstart`	double	0	The parameter's start value if `sweeptype` is `globalparameter`.
`globalpstop`	double	1	The parameter's stop value if `sweeptype` is `globalparameter`.
`globalpunit`	String		The unit of the parameter if `sweeptype` is `globalparameter`.
`grid`	`on` | `off`	`on`	If `options` is `on`; enable/disable display of the coordinate grid. Used for 3D animations.
`height`	integer	480	The height in pixels of the frames of the animation.
`imagefilename`	String		The base name of generated images if type is movieseq; the generated images have names of the form base1.ext, base2.ext, ...
`interp`	double array	Empty	The times to use, for transient levels, that the `multilooplevel` property points to. Available when the underlying data is transient, `looplevelinput` is `interp`.
`legend`	`on` | `off`	`on`	If `options` is `on`; enable/disable display of the legend.
`logo`	`on` | `off`	`on`	If `options` is `on`; enable/disable display of the logotype.

TABLE 7-5: VALID PROPERTY/VALUE PAIRS FOR ANIMATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
looplevel	integer array	All solutions	The solutions to use. Applicable to the level that the multilooplevel property points to, when looplevelinput is manual.
looplevelindices	integer array or String	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable to the level that the multilooplevel property points to, when looplevelinput is manualindices.
looplevelinput	all | manual | manualindices | interp	all	How to input the solution to use, for the level that multilooplevel points to. manual indicates that looplevel is used for that level. manualindices indicates that looplevelindices is used for that level. interp indicates that interp is used for that level.
maxframes	integer >= 2	25	The number of frames.
movietype	gif | flash | avi | webm	gif	The movie format to use if type is movie: GIF, Flash, AVI, or WebM.
multilooplevel	1<=integer<=3	1	The loop level to animate over. Only applied if solnumtype is pointing to the same level and solrepresentation is solutioninfo
options	on | off	off	Enable/disable optional components of the image.
outerinnertype	first | last | all	last	When solnumtype is outer, outerinnertype controls whether to plot all, the first or the last inner solution. Applicable only for parametric sweep models.
outersolnumarray	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models when solnumtype is outer.
outersolnumsingle	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models when solnumtype is inner.
parameter	String		The model parameter that varies if sweeptype is parameter.
plotgroup	String		The name of the plot group to animate.
pstart	double	0	The parameter's start value if sweeptype is parameter.
pstop	double	1	The parameter's stop value if sweeptype is parameter.

TABLE 7-5: VALID PROPERTY/VALUE PAIRS FOR ANIMATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
punit	String		The unit of the parameter if sweeptype is parameter.
repeat	Boolean	false	Whether to repeat from the beginning when the end is reached when playing.
resolution	integer	96	The frame resolution in dots per inch.
reverse	true | false	false	Enable/disable reversal in time of the animation.
showframe	positive integer	1	The shown frame when playing,
singleinterp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels with the level pointed to by multilooplevel exempt. Available when the underlying data is transient.
singlelooplevel	array of nonnegative integers and strings	First solution for each level.	The index of the solution to use, per level with the level pointed to by multilooplevel exempt, or interp, but only when the underlying data is transient.
solnum	integer array	all	The solutions to animate if sweeptype is solutions.
solnumtype	level1 | level2 | level3 | all | inner | outer	all	Whether to sweep over a selected loop level or over all, inner or outer solutions, in a parametric sweep model.
sweeptype	solutions | parameter | globalparameter | dde	solutions	The parameter that varies during animation.
target	file | player	file	Save the animation in a file or show it in a player in a COMSOL graphics window.
timeinterp	on | off	off	Enable/disable sweep over interpolated times if sweeptype is solutions.
tint	double array		The interpolated times to animate if timeinterp is on.
title		on	If options is on; enable/disable display of the title.
type	imageseq | movie	movie	The kind of output that is produced.
webmadvanced	automatic | manual	automatic	Automatic or manual settings for advanced WebM settings.
webmcodec	vp8 | vp9	vp9	Codec, when movietype is webm.
webmcqlevel	0–1	0.6	Quality level, when movietype is webm.
webmdither	0–5	0	Use dithering for WebM format (0 means no dithering).

TABLE 7-5: VALID PROPERTY/VALUE PAIRS FOR ANIMATION

PROPERTY	VALUE	DEFAULT	DESCRIPTION
webmfilename	String		The name of the WebM file produced if movietype is webm.
webmlossless	on | off	off	Use lossless compression if movietype is webm.
webmparallelencoding	on | off	on	Parallel encoding for the WebM format.
webmparalleldecoding	on | off	off	Parallel decoding for WebM format (only available if parallel encoding is on).
webmquality	optimizeForQuality | optimizeForSpeed	optimizeForSpeed	Optimize the WebM quality for speed (faster encoding) or quality (slower encoding).
webmyuvmatrix	BT601Limited | BT601Full | BT709Limited | BT709Full	BT709Limited	YUV color space for WebM movies: BT.601 and BT.709 standards.
width	integer	640	The width in pixels of the frames of the animation.
zoomextents	true | false	false	Zoom to the extents of the plot's subject.

EXAMPLE

Create a 2D animation of a surface and contour plot:

Code for Use with Java

```
ExportFeature amim = model.result().export().create("c2","pg1","Animation");
anim.set("plotgroup", "pg1");
anim.run();
```

Code for Use with MATLAB

```
anim = model.result.export.create('c2','pg1','Animation');
anim.set('plotgroup', 'pg1');
anim.export('c2').run;
```

SEE ALSO

Image1D, Image2D, Image3D

Annotation

Add an annotation to a plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Annotation");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Annotation")` creates an annotation feature named *<ftag>* belonging to the plot group *<pgtag>*.

Annotations add text, including optional position coordinates, to plots.

The following properties are available:

TABLE 7-6: VALID PROPERTY/VALUE PAIRS FOR ANNOTATIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
allowexprs	on | off	off	Allow evaluation of expressions in the annotation's text using the eval(*expr*) and eval(*expr*,*unit*) syntax.
anchorpoint	upperright | uppermiddle | upperleft | middleright | center | middleleft | lowerright | lowermiddle | lowerleft	upperleft	The position of the annotation text relative to the anchor point at the position given by posexpr.
backgroundcolor	custom | black | blue | cyan | gray | green |magenta | red | white | yellow | none	none	The color to use for background rectangle.
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The color to use for the point where the annotation appears and the annotation text.
data	none | parent | data set name	parent	The data set this feature refers to.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
exprprecision	positive integer	6	Precision for the expressions used in annotations.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritbackgroundcolor	Boolean	true	If inheritplot is not none: Determines if the background color is inherited.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritframe	Boolean	true	If inheritplot is not none: Determines if the show frame property is inherited.
inheritplot	none | plot name	none	The plot that color is inherited from.
latexmarkup	on | off	off	Include LaTeX markup language in annotation.
level	fromdataset | global | line | point | surface | volume	fromdataset	The geometry level for evaluating expressions. The default is to take it from the data set. volume is only available in 3D.
orientation	horizontal | vertical	horizontal	Orient the annotation text horizontally or vertically.
plotonsecyaxis	Boolean	false	Plot on secondary y-axis if twoyaxes is set to true in the parent plot group. For 1D graph plots and annotations only. An array, using setIndex syntax.

TABLE 7-6: VALID PROPERTY/VALUE PAIRS FOR ANNOTATIONS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
posexpr	String array	{"0", "0"} (2D)	Position coordinates for the annotation (2 in 2D and 1D graph plots; 3 in 3D).
posprecision	positive integer	6	Precision for the position values.
prefixintitle	String	Empty	A prefix text in a custom title.
prependcoords	on | off	off	Include coordinates of annotation position before the annotation text.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
showframe	true | false	false	Whether to show a frame around the annotation or not.
showpoint	true | false	true	Whether to show the point for the position of the annotation or not.
suffixintitle	String	Empty	A suffix text in a custom title.
text	String	Empty	The text to display as an annotation.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	none	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

ATTRIBUTES

None.

SEE ALSO

MaxMinVolume, MaxMinSurface, MaxMinLine, MaxMinPoint

AnnotationData

Create an annotation data plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"AnnotationData");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"AnnotationData")` creates an annotation data plot feature named *<ftag>* belonging to the 2D or 3D plot group *<pgtag>*.

Annotation data plots are used to visualize raw annotation data given as points, text, and colors (see the example below). Annotation data plots can be added to 2D and 3D plot groups.

Set the `latexmarkup` property to `on` if you want to include mathematical symbols and Greek letters, for example, in the annotation. To include such symbols, surround the LaTeX syntax with `$` to indicate that the text inside of the `$` signs is LaTeX. For example, `$\alpha = \beta/\pi$` appears as $\alpha = \beta/\pi$. If the `latexmarkup` property is `on`, you can also add line breaks as `\\`. See Mathematical Symbols and Special Characters in the *COMSOL Multiphysics Reference Manual* for more information about available LaTeX symbols and characters (of which most but not all are applicable in this context).

The following properties are available:

TABLE 7-7: VALID PROPERTY/VALUE PAIRS FOR ANNOTATION DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`backgroundcolor`	`custom` | `black` | `blue` | `cyan` | `gray` | `green` |`magenta` | `red` | `white` | `yellow` | `none`	`none`	The color to use for background rectangle.
`color`	`custom` | `black` | `blue` | `cyan` | `gray` | `green` |`magenta` | `red` | `white` | `yellow`	`red`	The color to use for the point where the annotation appears and the annotation text.
`description`	String		A label showing a short description of the stored data.
`latexmarkup`	`true` | `false`	`false`	Include LaTeX markup language in annotation.
`showframe`	`true` | `false`	`false`	Whether to show a frame around the annotation or not.
`showpoint`	`true` | `false`	`true`	Whether to show the point for the position of the annotation or not.
`pos`	double array		The position coordinates for the annotation data plot (x and y coordinates in 2D and x, y, and z coordinates in 3D).
`text`	String		The text to display as an annotation.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `manual` | `none`	`none`	`auto` if the title contribution should be computed automatically. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.

ATTRIBUTES

None.

EXAMPLE

A method for creating letter in a circle in 2D.

Code for Use with Java

```
String pgTag = model.result().uniquetag("pg");
ResultFeature pg = model.result().create(pgTag, 2);

for (int i = 0; i < 26; i++) {
  double angle = 2*Math.PI*i/26;
```

```
  ResultFeature plot = pg.create("ann"+i, "AnnotationData");
  plot.set("pos", new double[]{Math.cos(angle), Math.sin(angle)})
    .set("text", "ABCDEFGHIJKLMNOPQRSTUVWXYZ".substring(i, i+1))
    .set("showpoint", false);
}
```

A method for adding Greek letters to the corners of a cube.

Code for Use with Java

```
String pgTag = model.result().uniquetag("pg");
ResultFeature pg = model.result().create(pgTag, 3);

String[] texts = {"\\alpha", "\\beta", "\\gamma", "\\delta", "\\epsilon", "\\zeta",
"\\eta", "\\theta"};
String[] colors = {"black", "blue", "cyan", "gray", "green", "magenta", "red", "yellow"};
for (int x = 0; x < 2; x++) {
  for (int y = 0; y < 2; y++) {
    for (int z = 0; z < 2; z++) {
      int index = x+2*y+4*z;
      ResultFeature plot = pg.create("ann"+index, "AnnotationData");
      plot.set("pos", new double[]{x, y, z})
        .set("text", "$"+texts[index]+"$")
        .set("latexmarkup", true)
        .set("color", colors[index]);
    }
  }
}
```

SEE ALSO

ArrowData, LineData, PointData, SurfaceData, TubeData

Array 1D, Array 2D, Array3D

Create array data sets.

SYNTAX

```
model.result().dataset().create(<dtag>,"Array1D");
model.result().dataset().create(<dtag>,"Array2D");
model.result().dataset().create(<dtag>,"Array3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(`*<dtag>*`,"Array1D")` creates a 1D array data set feature named *<dtag>*.

`model.result().dataset().create(`*<dtag>*`,"Array2D")` creates a 2D array data set feature named *<dtag>*.

`model.result().dataset().create(`*<dtag>*`,"Array3D")` creates a 3D array data set feature named *<dtag>*.

This data set takes data from another data set and adds an array of copies in cells as a linear, rectangular (2D), or three-dimensional (3D) array of cells.

The following properties are available for Array 1D, Array 2D, and Array 3D:

TABLE 7-8: VALID PROPERTY/VALUE PAIRS FOR ARRAY DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`base`	`corner` | `center`	`corner`	Base point for the position of the input cell if `inputmethod` is set to `manual`.
`celllinearvar`	String	Depends on the feature's tag	If `hasvar` is true: an integer variable that identify the current cell in the array.

TABLE 7-8: VALID PROPERTY/VALUE PAIRS FOR ARRAY DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
cellvars	String array	Depends on the feature's tag	If hasvar is true: an integer array that identify the current cell in the array.
checkoverlap	Boolean	true	Check for overlap between cells in the array.
data	none | data set name	First compatible data set	The data set this feature refers to.
displ	String array	{"0","0"} (2D); {"0","0","0"} (3D)	The displacement used to move each cell in the array if displmethod is set to manual.
displmethod	auto | manual	auto	Use automatic or manual definition of the displacement for the cells in the array.
floquetper	on | off	off	Include Floquet-Bloch periodicity.
fullsize	array (integer or string)	1 (1D); {1, 1} (2D); {1, 1,1} (3D)	Size of the array (number of cells in each direction) for a linear, rectangular, or three-dimensional array.
hasvars	Boolean	false	If true, space and cell indicator variables are defined.
inputmethod	auto | manual	auto	Use automatic or manual definition of the part of space that the array is created from,
linearsize	positive integer or string	1	Size of the linear array in number of cells.
pos	String array	{"0","0"} (2D); {"0","0","0"} (3D)	If inputmethod is manual: The coordinates (position) of the base point. If base is set to corner, it is the lower-left corner of the base cell.
size	String array	{"1","1"} (2D); {"1","1","1"} (3D)	If inputmethod is manual: The size of the input.
spacevars	String array	Depends on the feature's tag	If hasvar is true: The name of space variables, which evaluate to the coordinates in the data set's coordinate system.
type	linear | rectangular | three-dimensional	rectangular (2D); three-dimensional (3D)	The type of array: Linear, rectangular (2D only), or three-dimensional (3D only). Not available in 1D.
wavevector	String array		The wave vector for Floquet-Bloch periodicity as a 1-, 2-, or 3-element string array.

ArrowData

Create an arrow data plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ArrowData");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"ArrowData")` creates an arrow data plot feature named *<ftag>* belonging to the 2D or 3D plot group *<pgtag>*.

Arrow data plots are used to visualize raw vector data given as points, vectors, and colors (see the example below). Arrow data plots can be added to 2D and 3D plot groups.

The following properties are available:

TABLE 7-9: VALID PROPERTY/VALUE PAIRS FOR ARROW DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
arrowbase	heat | tail | center	head	Whether the head, tail, or center of the arrow is located at the arrow position.
arrowlength	normalized | proportional | logarithmic	proportional	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
arrowtype	arrow | arrowhead | cone	arrow	The type of arrow to draw.
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
colordata	double 1D array		The color data for the arrow data plot as a real N-vector.
coloring	colortable | uniform	uniform	How to color the points.
colorlegend	on | off	on	Whether to show color legend when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
description	String		A label showing a short description of the stored data.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
pointdata	double 2D array		The point data for the arrows' starting points in the arrow data plot, as x and y coordinates in 2D and x, y, and z coordinates in 3D in an sdim-by-N real matrix.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.

TABLE 7-9: VALID PROPERTY/VALUE PAIRS FOR ARROW DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`rangedatactive`	`on` | `off`	`off`	Whether to use the manual data range specified in `rangedatamin` and `rangedatamax`. Values outside the data range are not plotted.
`rangedatamax`	double	Plot-dependent	The maximum data value. Active when `rangedataactive` is on.
`rangedatamin`	double	Plot-dependent	The minimum data value. Active when `rangedataactive` is on.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `manual` | `none`	`none`	`auto` if the title contribution should be computed automatically. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`vectordata`	double 2D array		The vector data for the arrow data plot, as sign and length of the arrows in the x and y directions in 2D and in the x, y, and z directions in 3D in an sdim-by-N real matrix.

ATTRIBUTES

None.

EXAMPLE

A method for creating an arrow circle in 2D.

Code for Use with Java

```
String pgTag = model.result().uniquetag("pg");
ResultFeature pg = model.result().create(pgTag, 2);
ResultFeature plot = pg.create("arrow1", "ArrowData");
int N = 17;
double[][] p = new double[2][N];
double[][] vec = new double[2][N];
double len = 0.2;
for (int i = 0; i < N; i++) {
  double angle = 2*Math.PI*i/N;
  p[0][i] = Math.cos(angle);
  p[1][i] = Math.sin(angle);
  vec[0][i] = -len*p[0][i];
  vec[1][i] = -len*p[1][i];
}
plot.set("pointdata", p).set("vectordata", vec);
```

A method for creating a 3D logarithmic arrow spiral.

Code for Use with Java

```
String pgTag = model.result().uniquetag("pg");
ResultFeature pg = model.result().create(pgTag, 3);
ResultFeature plot = pg.create("arrow1", "ArrowData");
int N = 1000;
double[][] p = new double[3][N];
double[][] vec = new double[3][N];
double[] color = new double[N];
for (int i = 0; i < N; i++) {
  double par = 0.005*i;
  p[0][i] = Math.exp(par)*Math.cos(10*par);
```

```
    p[1][i] = Math.exp(par)*Math.sin(10*par);
    p[2][i] = 0.1*i;
    double len = Math.sqrt(p[0][i]*p[0][i]+p[1][i]*p[1][i]+p[2][i]*p[2][i]);
    for (int j = 0; j < 3; j++) {
      vec[j][i] = 4*p[j][i]/len;
    }
    color[i] = i;
  }
  plot.set("pointdata", p)
    .set("vectordata", vec)
    .set("colordata", color)
    .set("coloring", "colortable");
```

SEE ALSO

AnnotationData, LineData, PointData, SurfaceData, TubeData

ArrowVolume, ArrowSurface, ArrowLine, ArrowPoint

Create volume, surface, line, or point arrow plots.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ArrowVolume");
model.result(<pgtag>).create(<ftag>,"ArrowSurface");
model.result(<pgtag>).create(<ftag>,"ArrowLine");
model.result(<pgtag>).create(<ftag>,"ArrowPoint");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Arrow...")` creates an arrow plot feature named *<ftag>*.

Arrow plots are available in 2D and 3D. `ArrowPoint` plots arrows at points in 2D or 3D. `ArrowLine` plots arrows on lines in 2D or 3D such as geometry boundaries in 2D or cut plane edges in 3D. `ArrowSurface` plots arrows on surfaces in 2D or 3D. `ArrowVolume` plots arrows in a 3D volume.

The following properties are available:

TABLE 7-10: VALID PROPERTY/VALUE PAIRS FOR ARROW PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`arrowbase`	`heat`|`tail`|`center`	`head`	Whether the head, tail, or center of the arrow is located at the arrow position.
`arrowcount`	positive integer	200	If placement is uniform: The approximate number of arrows. Available for ArrowEdge in 2D and 3D and for ArrowSurface in 3D.
`arrowlength`	`normalized` | `proportional` | `logarithmic`	`proportional`	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
`arrowtype`	`arrow` | `arrowhead` | `cone`	`arrow`	The type of arrow to draw.
`arrowxmethod`	`number` | `coord`	`number`	Indicates whether the x-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for `ArrowSurface` in 2D and `ArrowVolume` in 3D.

TABLE 7-10: VALID PROPERTY/VALUE PAIRS FOR ARROW PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
arrowymethod	number | coord	number	Indicates whether the y-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for ArrowSurface in 2D and ArrowVolume in 3D.
arrowzmethod	number | coord	number	Indicates whether the z-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for ArrowVolume in 3D.
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The color to use.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expressions in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array of length 2 in 2D and 3 in 3D	Mode-dependent	The components of the vector to plot as arrows.
gporder	poitive integer	1	If placement is gausspoints: The Gauss point order.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if arrow scale is inherited.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritplot	none | plot name	none	The plot that arrow scale, color, and deformation scale are inherited from.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.

TABLE 7-10: VALID PROPERTY/VALUE PAIRS FOR ARROW PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`logrange`	double > 1	100	If `arrowlength` is `logarithmic`: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
`looplevel`	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or `interp`, but only for transient solutions. Available when `data` is not `parent` and the underlying data has multiple solutions.
`outersolnum`	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
`placement`	`elements` | `uniform` | `uniformanis` | `gausspoints`	`uniform`	If `uniform`, then the arrows are distributed uniformly. If `uniformanisotropic`, then the arrows are distributed uniformly with weights taken from the weight property. If `elements`, then arrows are drawn in the mesh nodes for each element. If `gausspoints`, then the arrows are drawn in the Gauss points (of order set as `gporder`). Available for ArrowEdge in 2D and 3D and for ArrowSurface in 3D.
`planecoordsys`	`cutplane` | `cartesian`	`cartesian`	Coordinate system for arrow vectors. Only available for plots that use a cut plane data set that points to a 3D solution or mesh data set.
`plotcomp`	`all` | `normal` | `tangential`	`all`	Choose to plot arrows that represent all components of the vector in `expr` or only its normal or tangential components. Available for ArrowSurface in 3D.
`prefixintitle`	String	Empty	Added prefix to contribution to title.
`revcoordsys`	`cylindrical` | `cartesian`	`cartesian`	Coordinate system for arrow vectors. Only available for plots that use a 1D or 2D revolution data set that has default axis settings and points to a solution or mesh data set for an axisymmetric geometry.
`scale`	positive double	1	If `scaleactive` is true: The length scale factor.
`scaleactive`	Boolean	false	Whether to use manual scaling.
`solnum`	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when `data` is not `parent` and the underlying data has multiple solutions.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active
`suffixintitle`	String	Empty	Added suffix to contribution to title
`t`	double	Time corresponding to last selected `solnum`.	The time to use, for transient problems. Available when `data` is not `parent` and the underlying data is transient.

TABLE 7-10: VALID PROPERTY/VALUE PAIRS FOR ARROW PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
weight	double array	1	If placement is uniformani: The weights given to the different axis directions.
xnumber	nonnegative integer	15 (3D), 7 (2D)	Number of points in the x-direction. Active when arrowxmethod is set to number. Available for ArrowSurface in 2D and ArrowVolume in 3D.
xcoord	String array	Empty	Absolute coordinates in the x-direction, active when arrowxmethod is set to coord. Available for ArrowSurface in 2D and ArrowVolume in 3D.
ynumber	integer	15 (3D), 7 (2D)	Number of points in the y-direction. Active when arrowymethod is set to number. Available for ArrowSurface in 2D and ArrowVolume in 3D.
ycoord	String array	Empty	Absolute coordinates in the z-direction, active when arrowymethod is set to coord. Available for ArrowSurface in 2D and ArrowVolume in 3D.
znumber	integer	15 (3D), 7 (2D)	Number of points in the z-direction. Active when arrowzmethod is set to number. Available for ArrowVolume in 3D.
zcoord	String array	Empty	Absolute coordinates in the z-direction, active when arrowzmethod is set to coord. Available for ArrowVolume in 3D.

ATTRIBUTES

Color, Deform, Filter

SEE ALSO

Line, ScatterVolume, ScatterSurface, Surface, Volume

AvVolume, AvSurface, AvLine

Compute a volume average, surface average, or line average.

SYNTAX

```
model.result().numerical().create(<ftag>,"AvVolume");
model.result().numerical().create(<ftag>,"AvSurface");
model.result().numerical().create(<ftag>,"AvLine");
model.result().numerical(<ftag>).selection(...);
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace `numerical(<ftag>)` with `evaluationGroup(<ftag>)`.

DESCRIPTION

`model.result().numerical().create(<ftag>,"AvVolume")` creates a volume average feature with the name *<ftag>*.

`model.result().numerical().create(<ftag>,"AvSurface")` creates a surface average feature with the name *<ftag>*.

`model.result().numerical().create(<ftag>,"AvLine")` creates a line average feature with the name *<ftag>*.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that one row contains data for all solution numbers. This is identical to `(columnwise)` when `columnwise` is `false`. If `columnwise` is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(allocate, columnwise)` returns the imaginary part of complex result, recomputing the feature if necessary. If `allocate` is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses `allocate true` and `columnwise false.`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).selection()` returns the selection of the geometry for the computation of the volume average, surface average, or line average. See Selections for more information about the available selection methods.

`model.result().numerical(<ftag>).set(property,<value>)` sets the value of a property of the volume average, surface average, or line average.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-11: VALID PROPERTY/VALUE PAIRS FOR AVERAGES

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`dataseries`	`average` | `integral` | `maximum` | `minimum` | `none` | `rms` | `stddev` | `variance`	none	The operation that is applied to the data series formed by the evaluation.
`dataseriesmethod`	`auto` | `integration` | `summation`	`auto`	The method to use for the data series: automatic, integration, or summation.
`const`	String array of property/value pairs	`Empty`	Parameters to use in the expressions.
`descr`	String array	Model-dependent	The descriptions of the expression in `expr`. Is used in the automatic title.
`differential`	`on` | `off`	on	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String array	Model-dependent	The expressions to plot.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels	The times to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`intorder`	positive integer	`4`	The integration order.
`intorderactive`	`on` | `off`	`off`	Whether to use manually specified integration order
`intsurface`	`on` | `off`	`off`	Compute surface integral. Available for line integration features of axisymmetric models.
`intvolume`	`on` | `off`	`off`	Compute volume integral. Available for surface integration features of axisymmetric models.
`looplevel`	integer row matrix	All solutions on all levels	The solutions to use, per level

TABLE 7-11: VALID PROPERTY/VALUE PAIRS FOR AVERAGES

NAME	VALUE	DEFAULT	DESCRIPTION
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
maximumobj	abs | real	real	The value being maximized if dataseries is maximum.
method	auto | integration | summation	auto	The integration method.
minimumobj	abs | real	real	The value being minimized if dataseries is minimum.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
solnum	nonnegative integer array	All solutions	The solutions to use.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
t	double array	Empty	The times to use. Available when the underlying solution is transient.
table	new | table name	new	The table to use when calling setResult() or appendResult(). new indicates that a new table is created.

TABLE 7-11: VALID PROPERTY/VALUE PAIRS FOR AVERAGES

NAME	VALUE	DEFAULT	DESCRIPTION
`tablecols`	`inner` | `outer` | `data` | `level`*1*	`data`	Whether to use inner or outer solutions as columns in the table when calling `setResult()` or `appendResult()`. Applicable only for parametric sweep models. The level values (`level1`, `level2`, and so on) are the levels in the parametric sweep.
`unit`	String array	Model-dependent	The units to use for the expressions in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`IntVolume, IntSurface, IntLine`

Average, Integral, Maximum, Minimum

Create average. integral, maximum, and minimum evaluation data sets.

SYNTAX

```
model.result().dataset().create(<dtag>,"Average");
model.result().dataset().create(<dtag>,"Integral");
model.result().dataset().create(<dtag>,"Maximum");
model.result().dataset().create(<dtag>,"Minimum");
model.result().dataset(<dtag>).set(property, <value>);
model.result().dataset(<dtag>).selection(...);
```

DESCRIPTION

`model.result().dataset().create(`*`<dtag>`*`,"Average")` creates a data set named *`<dtag>`* that computes the average of another data set.

`model.result().dataset().create(`*`<dtag>`*`,"Integral")` creates a data set named *`<dtag>`* that computes the integral of another data set.

`model.result().dataset().create(`*`<dtag>`*`,"Maximum")` creates a data set named *`<dtag>`* that computes the maximum of another data set.

`model.result().dataset().create(`*`<dtag>`*`,"Minimum")` creates a data set named *`<dtag>`* that computes the minimum of another data set.

`model.result().dataset(`*`<dtag>`*`).selection()` returns the selection of the geometry for the data set, which by default is the selected geometry in the data set that this data set refers to. See Selections for more information about the available selection methods.

`model.result().dataset(`*`<dtag>`*`).set(`*`property`*`,`*`<value>`*`)` sets the value of a property of the data set.

The following common properties are available:

TABLE 7-12: COMMON PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`level`	`fromdataset` | `volume` | `surface` | `edge` | `point`	fromdataset	The element dimension; if `fromdataset`, then the highest dimension supported by the data set is used.

The following additional properties are available for some of the evaluation data sets:

TABLE 7-13: ADDITIONAL PROPERTY/VALUE PAIRS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`intorderactive`	`on` | `off`	`off`	For Average and Integral: Whether to use manually specified integration order.
`intorder`	Positive integer	4	For Average and Integral: The manually set integration order.
`intsurface`	Boolean	false	For Average and Integral: Compute surface integral for 1D axisymmetric data.
`intvolume`	Boolean	false	For Average and Integral: Compute volume integral for 2D axisymmetric data.
`method`	`auto` | `integration` | `summation`	auto	For Average and Integral: The integration method.
`refine`	nonnegative integer	1	For Maximum and Minimum: The element refinement to use. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.

Color

Add a color expression attribute to add a coloring to the shapes defined by a plot.

SYNTAX

```
model.result(<pgtag>).feature(<ftag>).create(<atag>,"Color");
model.result(<pgtag>).feature(<ftag>).feature(<atag>).set(property, <value>);
```

DESCRIPTION

`model.result(<pgtag>).feature(<ftag>).create(<atag>,"Color")` creates a color expression attribute named *<atag>* belonging to the plot feature *<ftag>*.

Use color expressions to add a coloring to the shapes defined by a plot. Color expressions can be added to surface plots, line plots, volume plots, arrow plots, contour plots, isosurface plots, particle tracing plots, and streamline plots.

The following properties are available:

TABLE 7-14: VALID PROPERTY/VALUE PAIRS FOR COLOR

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`colorlegend`	`on` | `off`	`on`	Whether to show a color legend.
`colortable`	color table name	`Rainbow`	The color table to use. See Color Tables for a list of color tables.
`colortablerev`	`on` | `off`	`off`	Whether to reverse to color table.
`colortablesym`	`on` | `off`	`off`	Whether to symmetrize the color range around 0.
`descr`	String	Model-dependent.	The description of the expression in `expr`. Is used in the automatic title.
`descriptionintitle`	`on` | `off`	`on`	Whether the title contribution should contain the description when `titletype` is `custom`.

TABLE 7-14: VALID PROPERTY/VALUE PAIRS FOR COLOR

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`differential`	`on` | `off`	on	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String	Model-dependent.	The expression to plot.
`expressionintitle`	`on` | `off`	`off`	Whether the title contribution should contain the expression when `titletype` is `custom`.
`prefixintitle`	String	Empty	Added prefix to contribution to title.
`rangecoloractive`	`on` | `off`	`off`	Whether to use the manual color range specified in `rangecolormin` and `rangecolormax`. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
`rangecolormax`	double	Plot-dependent	The maximum color range value. Active when `rangecoloractive` is on.
`rangecolormin`	double	Plot-dependent	The minimum color range value. Active when `rangecoloractive` is on.
`rangedatactive`	`on` | `off`	`off`	Whether to use the manual data range specified in `rangedatamin` and `rangedatamax`. Values outside the data range are not plotted.
`rangedatamax`	double	Plot-dependent	The maximum data value. Active when `rangedataactive` is on.
`rangedatamin`	double	Plot-dependent	The minimum data value. Active when `rangedataactive` is on.
`suffixintitle`	String	Empty	Added suffix to contribution to title.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title contribution should be computed automatically, possibly using the group's customization. `custom` if the title contribution should be computed automatically, but customized. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution should contain the type when `titletype` is `custom`.
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution should contain the unit when `titletype` is `custom`.

COLOR TABLES

The following color tables are available for use with the `colortable` property here and in other types of plots: `AuroraAustralis`, `AuroraBorealis`, `Cividis`, `Cyclic`, `Disco`, `DiscoLight`, `GrayPrint`, `GrayScale`, `HeatCamera`, `HeatCameraLight`, `JupiterAuroraBorealis`, `Rainbow`, `RainbowLight`, `Spectrum`, `Thermal`, `ThermalEquidistant`, `ThermalLight`, `Traffic`, `TrafficLight`, `Twilight`, `Wave`, and `WaveLight`. See the *COMSOL Multiphysics Reference Manual* for more information about the color tables.

SEE ALSO

`Deform`, `Height`, `AberrationHeight`, `HistogramHeight`, `TableHeight`, `ArrowVolume`, `ArrowSurface`, `ArrowLine`, `ArrowPoint`, `Contour`, `Isosurface`, `Particle`, `ParticleMass`, `Streamline`

Contour

Create a contour plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Contour");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Contour")` creates a contour plot feature named *<ftag>* belonging to the plot group *<pgtag>*. Contour plots are available in 2D and 3D plot groups. Contour lines are colored by their level. Add a color expression attribute to color them by an arbitrary expression.

The following properties are available:

TABLE 7-15: VALID PROPERTY/VALUE PAIRS FOR CONTOUR

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`color`	`custom` | `black` | `blue` | `cyan` | `gray` | `green` | `magenta` | `red` | `white` | `yellow`	`red`	The uniform color to use. Active when `coloring` is `uniform`.
`coloring`	`colortable` | `uniform`	`colortable`	How to color the contours.
`colorlegend`	`on` | `off`	`on`	Whether to show a color legend.
`colortable`	color table name	`Rainbow`	The color table to use when `coloring` is set to `colortable`. See Color Tables for a list of color tables.
`colortablerev`	`on` | `off`	`off`	Whether to reverse to color table when `coloring` is set to `colortable`.
`colortablesym`	`on` | `off`	`off`	Whether to symmetrize the color range around 0 when `coloring` is set to `colortable`.
`const`	String array of property/value pairs	Empty	Parameters to use in the expressions.
`contourlabels`	`on` | `off`	`off`	Whether to display labels next to the contour lines. Only applicable if `contourtype` is `lines`.
`contourtype`	`lines` | `filled` | `tubes`	`lines`	Whether to display lines for each level or a surface with bands of color.

TABLE 7-15: VALID PROPERTY/VALUE PAIRS FOR CONTOUR

PROPERTY	VALUE	DEFAULT	DESCRIPTION
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
customlabelcolor	RGB-triplet	{1,0,0} or last used color.	If contourlabels is on and labelcolor is custom: The label color to use.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
includeoutside	on | off	on	Fill surfaces outside of contour levels if contourtype is filled.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that color and deformation scale are inherited from.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
levelmethod	number | levels	number	How to specify contour levels.
labelcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black	If contourlabels is on: The label color to use.
labelprec	positive	integer	If contourlabels is on: The number of significant digits in the labels.
legendtype	auto | filled | lines	auto	Whether to show the color legend as a filled legend or using lines. The auto setting provides a filled legend for filled contours and a line legend for line and tube contours.

TABLE 7-15: VALID PROPERTY/VALUE PAIRS FOR CONTOUR

PROPERTY	VALUE	DEFAULT	DESCRIPTION
levels	String array		The specific levels to plot. Active when levelmethod equals levels.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
number	positive integer	20	Total number of contour levels. Active when levelmethod equals number.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title.
radiusexpr	String	1	Expression for the tube radius, when the contour type is set to tubes.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.

TABLE 7-15: VALID PROPERTY/VALUE PAIRS FOR CONTOUR

PROPERTY	VALUE	DEFAULT	DESCRIPTION
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
tuberadiusscale	double	Computed automatically	The scale factor for the tube radius when the contour type is set to tubes.
tuberadiusscaleactive	Boolean	false	Whether the tube radius scaling is active or not. By default, the tube radius scaling is automatic.
tubescale	Boolean	true	Whether the style inheritance of tube radius scale factor is active or not.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

ATTRIBUTES

Color, Deform, Filter

SEE ALSO

Contour (Data Set), Surface

Contour (Data Set)

Create a contour data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Contour");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

model.result().dataset().create(*<dtag>*,"Contour") creates a contour data set feature named *<dtag>*.

Contour lines are in general not parametrizable, and this limits the set of plots and transformations that can be applied to them.

The following properties are available:

TABLE 7-16: VALID PROPERTY/VALUE PAIRS FOR CONTOUR DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`descr`	String		Description of expr
`differential`	`on` | `off`	on	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String	u	Expression to find constant level for
`level`	double	0	Level that defines the data set. Active when `levelmethod` is level.
`levelmethod`	`number` | `levels`	`number`	How to specify contour levels
`number`	positive integer	20	Total number of contour levels. Active when `levelmethod` is `number`.
`unit`	String		Unit of expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`Contour`

CoordSysLine, CoordSysSurface, CoordSysVolume

Create a coordinate system line, surface, or volume plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"CoordSysVolume");
model.result(<pgtag>).create(<ftag>,"CoordSysSurface");
model.result(<pgtag>).create(<ftag>,"CoordSysLine");

model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"CoordSysVolume")` creates a coordinate system plot named *<ftag>* belonging to the plot group *<pgtag>*.

The following properties are available:

TABLE 7-17: VALID PROPERTY/VALUE PAIRS FOR COORDINATE SYSTEM PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
arrowcount	positive integer	200	If placement is uniform: The approximate number of points to display coordinate systems in. Available for CoordSysLine in 2D and 3D and for CoordSysSurface 3D.
arrowlength	normalized | proportional | logarithmic	proportional	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
arrowtype	arrow | cone	arrow	The type of arrow to draw
arrowxmethod	number | coord	number	Indicates whether the x-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for CoordSysSurface in 2D and CoordSysVolume in 3D.
arrowymethod	number | coord	number	Indicates whether the y-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for CoordSysSurface in 2D and CoordSysVolume in 3D.
arrowzmethod	number | coord	number	Indicates whether the z-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for CoordSysVolume in 3D.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String		If mode is matrix: The description of the matrix expression to plot. Available for CoordSysSurface in 2D and CoordSysVolume in 3D.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String		If mode is matrix: The matrix expression to plot. Available for CoordSysSurface in 2D and CoordSysVolume in 3D.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if arrow scale is inherited.
inherit color	Boolean	true	If inheritplot is not none: Determines if the color is inherited.

TABLE 7-17: VALID PROPERTY/VALUE PAIRS FOR COORDINATE SYSTEM PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
inheritplot	none | plot name	none	The plot that arrow scale, color, and deformation scale are inherited from.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
mode	system | matrix	system	Chooses whether what's plotted is taken from a coordinate system or a matrix variable. Available for CoordSysSurface in 2D and CoordSysVolume in 3D.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
placement|	elements | uniform | uniformani	uniform	If uniform, then the arrows are distributed uniformly. If uniformanisotropic, then the arrows are distributed uniformly with weights taken from the weight property. If elements, then arrows are drawn in each element. Available for CoordSysLine in 2D and 3D and for CoordSysSurface 3D.
scale	positive double	1	If scaleactive is true: The length scale factor.
scaleactive	Boolean	false	Whether to use manual scaling.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
sys	none | coordinate system name	none	The coordinate system to plot.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. manual if the manual title should be used (the title property). none if no title should be displayed.

TABLE 7-17: VALID PROPERTY/VALUE PAIRS FOR COORDINATE SYSTEM PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`type`	`stress` | `strain`	`stress`	Selection between principal stress and principal strain plot.
`weight`	double array	1	If placement is uniformani: The weights given to the different axis directions.
`xnumber`	nonnegative integer	15 (3D), 7 (2D)	Number of points in the x-direction. Active when `arrowxmethod` is set to `number`. Available for `CoordSysSurface` in 2D and `CoordSysVolume` in 3D.
`xcoord`	double array	Empty	Absolute coordinates in the x-direction, active when `arrowxmethod` is set to `coord`. Available for `CoordSysSurface` in 2D and `CoordSysVolume` in 3D.
`ynumber`	integer	15 (3D), 7 (2D)	Number of points in the y-direction. Active when `arrowymethod` is set to `number`. Available for `CoordSysSurface` in 2D and `CoordSysVolume` in 3D.
`ycoord`	double array	Empty	Absolute coordinates in the z-direction, active when `arrowymethod` is set to `coord`. Available for `CoordSysSurface` in 2D and `CoordSysVolume` in 3D.
`znumber`	integer	15 (3D), 7 (2D)	Number of points in the z-direction. Active when `arrowzmethod` is set to `number`. Available for `CoordSysVolume` in 3D.
`zcoord`	double array	Empty	Absolute coordinates in the z-direction, active when `arrowzmethod` is set to `coord`. Available for `CoordSysVolume` in 3D.

CutLine2D, CutLine3D

Create a 2D or 3D cut line data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"CutLine2D");
model.result().dataset().create(<dtag>,"CutLine3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"CutLine2D")` creates a 2D cut line data set feature named *<dtag>*.

`model.result().dataset().create(<dtag>,"CutLine3D")` creates a 3D cut line data set feature named *<dtag>*.

The following properties are available:

TABLE 7-18: VALID PROPERTY/VALUE PAIRS FOR CUTLINE DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
bndsnap	Boolean	false	If true, each point is snapped to the closest boundary. For Cut Line 3D data sets only.
bounded	on | off	on	Active when method equals twopoint, this property specifies if the line should be bounded by the two points or extend infinitely.
data	none | data set name	First compatible data set	The data set this feature refers to.
genparaactive	on | off	off	Decides if parallel lines should be drawn.
genparadist	double array	{}	Active when genparaactive is on, this property contains the distances from the extra parallel lines to the base line.
genpoints	double matrix	{{0, 0, 0}, {1,0,0}}	Active when method equals twopoint, this property contains the coordinates of the two points in the two rows of the matrix.
method	twopoint | pointdir	twopoint	Decides if the line should be specified by two points or through one point and a direction.
normal	String array of length 2	{"cln1nx", "cln1ny"} for the first Cut Line 2D data set.	For Cut Line 2D data sets only: Variables for the normals to the cut line.
orthvec	String array of length 3	{"0","1","0"}	Used in 3D when genparaactive is true: The direction that together with the cut line's direction spans the plane that contains the parallel lines.
pddir	String array	Zero string vector	Active when method equals pointdir, this property contains the direction.
pdpoint	String array	Zero string vector	Active when method equals pointdir, this property contains the coordinates of the point.
spacevars	String array of length 1	Created from the feature tag.	The name of the variable that evaluates to the line's parameterization.

SEE ALSO

LineGraph

CutPlane

Create a cut plane data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"CutPlane");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"CutPlane")` creates a cut plane data set with the name *<dtag>*.

The following properties are available:

TABLE 7-19: VALID PROPERTY/VALUE PAIRS FOR CUT PLANE DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
data	none | data set name	First compatible data set	The data set this feature refers to.
genparaactive	on | off	off	Decides if parallel lines should be drawn.
genparadist	double array	{}	Active when genparaactive is on, this property contains the distances from the extra parallel planes to the base plane.
genmethod	threepoint | pointnormal	threepoint	Active when planetype equals general, this property indicates whether the plane should be specified by three points or through one point and a normal.
genpoints	double matrix	{{0, 0, 0}, {1,0,0}, {0,1,0}}	Active when method equals threepoint, this property contains the coordinates of the three points in the rows of the matrix.
genpnpoint	String array of length three	Zero string vector	Active when genmethod equals pointnormal, this property contains the coordinates of the point.
genpnvec	String array of length three	Zero string vector	Active when genmethod equals pointnormal, this property contains the normal vector.
normal	String array of length three	Created from the feature tag.	The names of the variables that can be used to evaluate the plane's normal.
planetype	quick | general	quick	Specify plane type.
quickplane	xy | yz | zx | yx | zy | xz	yz	Specify quick plane type. Active when planetype is quick.
quickx	String	"0"	x-coordinate, if planetype is yz or zy.
quicky	String	"0"	y-coordinate, if planetype is zx or xz.
quickz	String	"0"	z-coordinate, if planetype is xy or yx.
spacevars	String array of length 2	Created from the feature tag.	The names of the variables that evaluate to the plane's parameterization.

EXAMPLES

This example creates a cut plane and plots a surface plot and a contour plot on it.

Create a solution data set and set it to point to the named solution Sol1 from a solver sequence:

Code for Use with Java

```
DatasetFeature ds = model.result().dataset().create("dset1", "Solution");
ds.set("solution", "sol1");
```

Code for Use with MATLAB

```
ds = model.result.dataset.create('dset1', 'Solution');
ds.set('solution', 'sol1');
```

Create 3D plot group:

Code for Use with Java

```
ResultFeature pg = result().create("pg1",3);
DatasetFeature ds = result().dataset().create("cutp1","CutPlane");
ds.set("data", "dset1");

pg.create("surf1","Surface");
```

```
pg.feature("surf1").set("data","cutp1");

pg.create("cont1","Contour");
pg.feature("cont1").set("data","cutp1");
```

Code for Use with MATLAB

```
pg = result.create('pg1',3);
ds = result.dataset.create('cutp1','CutPlane');
ds.set('data', 'dset1');

pg.create('surf1','Surface');
pg.feature('surf1').set('data','cutp1');

pg.create('cont1','Contour');
pg.feature('cont1').set('data','cutp1');
```

SEE ALSO

Surface

CutPoint1D, CutPoint2D, CutPoint3D

Create a 1D, 2D, or 3D cut point data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"CutPoint1D");
model.result().dataset().create(<dtag>,"CutPoint2D");
model.result().dataset().create(<dtag>,"CutPoint3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"CutPoint1D")` creates a 1D cut point data set with the name *<dtag>*.

`model.result().dataset().create(<dtag>,"CutPoint2D")` creates a 2D cut point data set with the name *<dtag>*.

`model.result().dataset().create(<dtag>,"CutPoint3D")` creates a 3D cut point data set with the name *<dtag>*.

A cut point is the 0D analog of cut lines and cut planes. A difference compared to cut lines and cut planes is that a cut point feature can contain an arbitrary number of points. Cut points can exist in 1D, 2D, and 3D.

The following properties are available:

TABLE 7-20: VALID PROPERTY/VALUE PAIRS FOR CUT POINT DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`bndsnap`	Boolean	`false`	If true, each point is snapped to the closest boundary.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`gridx`	double array		If method is grid: The grid x-coordinates
`filename`	String		If method is file: The file that contains the point coordinates in a spreadsheet format.
`gridy`	double array		If method is grid: The grid y-coordinates. (Only for CutPoint2D and CutPoint3D)
`gridz`	double array		If method is grid: The grid z-coordinates. (Only for CutPoint3D)

TABLE 7-20: VALID PROPERTY/VALUE PAIRS FOR CUT POINT DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
method	coords | file | grid | regulargrid	coords	The method used for defining the points
pointvar	String	cpt1n (for the first cut point data set)	Point number variable for the points defined by the cut point data set.
pointx	String array	{}	If method is coords: The point x-coordinates.
pointy	String array	{}	If method is coords: The point y-coordinates. (Only for CutPoint2D and CutPoint3D)
pointz	String array	{}	If method is coords: The point z-coordinates. (Only for CutPoint3D)
regulargridx	String	10	If method is regulargrid: The number of grid points in the x-direction.
regulargridy	String	10	If method is regulargrid: The number of grid points in the y-direction. (Only for CutPoint2D and CutPoint3D)
regulargridz	String	10	If method is regulargrid: The number of grid points in the z-direction. (Only for CutPoint3D)

SEE ALSO

PointGraph

Data

Export data to a file.

SYNTAX

```
model.result().export().create(<ftag>,"Data");
model.result().export().create(<ftag>,<dtag>,"Data");
model.result().export(<ftag>).set(property, <value>);
model.result().export(<ftag>).run();
```

DESCRIPTION

`model.result().export().create(<ftag>,"Data")` creates a data export feature with the name *<ftag>*.

`model.result().export().create(<ftag>,<dtag>,"Data")` creates a data export feature with the name *<ftag>* for the data set *<dtag>*.

The following properties are available:

TABLE 7-21: VALID PROPERTY/VALUE PAIRS FOR DATA EXPORT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
alwaysask	on | off	off	Always ask for filename when saving. This property is ignored when running without a GUI.
coordfilename	String		If location is file: The file that contains coordinates to evaluate in.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
data	none | data set name	First compatible data set	The name of the data set to export.
descr	String array		Descriptions of the expressions in expr.

TABLE 7-21: VALID PROPERTY/VALUE PAIRS FOR DATA EXPORT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
exporttype	text | vtu	text	File type for the export: a text file or a VTU file.
expr	String array		The expressions to evaluate and export.
filename	String		The output file.
fullprec	on | off	on	If on, floating-point numbers are written in full precision, otherwise they are written with six significant digits.
gporder	poitive integer	1	If pattern is gauss: The Gauss point order.
gridstruct	grid | spreadsheet	spreadsheet	If location is grid or regulargrid: The format of the exported data.
gridx1	double array		If location is grid and the data set is 1D: x-coordinates to evaluate in.
gridx2	double array		If location is grid and the data set is 2D: x-coordinates to evaluate in.
gridy2	double array		If location is grid and the data set is 2D: y-coordinates to evaluate in.
gridx3	double array		If location is grid and the data set is 3D: x-coordinates to evaluate in.
gridy3	double array		If location is grid and the data set is 3D: y-coordinates to evaluate in.
gridz3	double array		If location is grid and the data set is 3D: z-coordinates to evaluate in.
header	on | off	off	Enable/disable a data header in the output file.
ifexists	append | overwrite	overwrite	If the file exists, append to or overwrite the file contents.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
lagorder	integer	1	The Lagrange point order to use if resolution is custom.
level	fromdataset | volume | surface | line | point	fromdataset	The geometry level to evaluate on.
location	fromdataset | file | grid | regulargrid	fromdataset	The points evaluated in.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level

TABLE 7-21: VALID PROPERTY/VALUE PAIRS FOR DATA EXPORT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
pattern	gauss | lagrange	lagrange	If the data set is a solution: Specifies if evaluation takes place in Lagrange points or in Gauss points.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
regulargridx1	String	10	If location is regulargrid and the data set is 1D: The number of grid points along the x-axis.
regulargridx2	String	10	If location is regulargrid and the data set is 2D: The number of grid points along the x-axis.
regulargridy2	String	10	If location is regulargrid and the data set is 2D:The number of grid points along the y-axis.
regulargridx3	String	10	If location is regulargrid and the data set is 3D: The number of grid points along the x-axis.
regulargridy3	String	10	If location is regulargrid and the data set is 3D: The number of grid points along the y-axis.
regulargridz3	String	10	If location is regulargrid and the data set is 3D: The number of grid points along the z-axis.
resolution	normal | fine | finer | custom		The evaluation resolution.
sdim	fromdataset | 0 | 1 | 2 | 3	fromdataset	The space dimension to evaluate the underlying data set in.
solnum	integer array		Solution number to take values from.

TABLE 7-21: VALID PROPERTY/VALUE PAIRS FOR DATA EXPORT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
sort	on | off	off	Enable/disable sorting of the points with respect to the coordinates.
struct	sectionwise | spreadsheet		If location is fromdataset: Format of the exported data.
t	double array	Empty	The times to use. Available when the underlying solution is transient.

SEE ALSO

Height, AberrationHeight, HistogramHeight, TableHeight

Deform

Add a deformation attribute to a plot.

SYNTAX

```
model.result(<pgtag>).feature(<ftag>).create(<atag>,"Deform");
model.result(<pgtag>).feature(<ftag>).feature(<atag>).set(property, <value>);
```

DESCRIPTION

model.result(*<pgtag>*).feature(*<ftag>*).create(*<atag>*,"Deform") creates a deformation attribute feature with the name *<atag>*, belonging to the feature *<ftag>*.

Deformation attributes deform the coordinates of a plot feature according to an expression (typically, the displacement in a structural mechanics model). The deformation attribute can be added to arrow plots, contour plots, isosurface plots, particle plots, slice plots, streamline and streamline surface plots, surface plots, volume plots, and mesh plots.

The following properties are available:

TABLE 7-22: VALID PROPERTY/VALUE PAIRS FOR DEFORM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
descr	String	Model-dependent	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent	The expression to plot.
maxreldeformexpr	String	"0,1"	Maximum relative deformation as a fraction of the mean size of the geometry's bounding box.
prefixintitle	String	Empty	Added prefix to contribution to title.

TABLE 7-22: VALID PROPERTY/VALUE PAIRS FOR DEFORM

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`revcoordsys`	`cylindrical` | `cartesian`	`cartesian`	Coordinate system for the deformation vector. Available for plots that use a Revolution 1D or Revolution 2D data set that has default axis settings and points to a solution or mesh data set for an axisymmetric geometry and for plots using a Mirror data set applied to a Revolution 2D data set.
`scale`	positive double	Model-dependent	The scale factor for the deformation.
`scaleactive`	`on` | `off`	off	Whether to use the automatically computed scale, or the scale in the `scale` property.
`suffixintitle`	String	Empty	Added suffix to contribution to title.
`title`	String	The auto-title	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title contribution should be computed automatically, possibly using the group's customization. `custom` if the title contribution should be computed automatically, but customized. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution should contain the type when `titletype` is `custom`.
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`Color`, `Height`, `AberrationHeight`, `HistogramHeight`, `TableHeight`, `ArrowVolume`, `ArrowSurface`, `ArrowLine`, `ArrowPoint`, `Contour`, `Contour`, `Isosurface`, `Line`, `Mesh`, `Particle`, `ParticleMass`, `ScatterVolume`, `ScatterSurface`, `Slice`, `Streamline`, `StreamlineSurface`, `Surface`, `Volume`.

Directivity

Create a directivity plot. A directivity plot is an extension of far-field plots and is a common acoustic plot for speakers. This plot collects spatial information across frequencies and shows this data as a contour plot.

Directivity plots are available with the Acoustics Module.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Directivity");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Directivity")` creates a directivity plot feature named *<ftag>* belonging to the plot group *<pgtag>*. Directivity plots are available in 2D plot groups.

The following properties are available:

TABLE 7-23: VALID PROPERTY/VALUE PAIRS FOR DIRECTIVITY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
anglerestr	manual | none	none	Use no angle restriction or a user-defined start angle and range.
centerz	double	0	z-coordinate for center of evaluation.
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color the contours.
colorlegend	on | off	on	Whether to show color legend.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
contourlabels	on | off	off	Whether to display labels next to the contour lines. Only applicable if contourtype is lines.
contourtype	lines | filled	lines	Whether to display lines for each level or a surface with bands of color.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
customlabelcolor	RGB-triplet	{1,0,0} or last used color.	If contourlabels is on and labelcolor is custom: The label color to use.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.

TABLE 7-23: VALID PROPERTY/VALUE PAIRS FOR DIRECTIVITY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
filledlegend	on | off	on	Whether to show the color legend as a filled legend.
frequencyscale	logarithmic | linear	logarithmic	Whether to use a logarithmic or linear frequency scale in the plot.
includeoutside	on | off	on	Fill surfaces outside of contour levels if contourtype is filled.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritplot	none | plot name	none	The plot that color is inherited from.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
layout	frequencyx | frequencyy	frequencyx	Plot the frequency on the x-axis or on the y-axis.
levelmethod	number | levels	number	How to specify contour levels.
labelcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	If contourlabels is on: The label color to use.
labelprec	positive integer	4	If contourlabels is on: The number of significant digits in the labels.
levels	String array		The specific levels to plot. Active when levelmethod equals levels.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
normal	double array of length 3	{0, 1, 0}	The normal direction for the evaluation.
normalization	angle | max | none	angle	Normalization of the expression values with respect to the angle (the default), with respect to the maximum value, or no normalization.
number	positive integer	20	Total number of contour levels. Active when levelmethod equals number.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
phidisc	integer >= 2	50	The angular discretization (resolution) in the phi direction.
phimin	double	0	If anglerestr is manual: The minimum phi angle in degrees.

TABLE 7-23: VALID PROPERTY/VALUE PAIRS FOR DIRECTIVITY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
phirange	double	360	If anglerestr is manual: The phi angle's range in degrees.
prefixintitle	String	Empty	Added prefix to contribution to title.
radius	double	1	Radius of evaluation distance.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refdir	double array of length 3	{0, 0, 1}	The reference direction for the evaluation.
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.

TABLE 7-23: VALID PROPERTY/VALUE PAIRS FOR DIRECTIVITY

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution should contain the unit when `titletype` is `custom`.

ATTRIBUTES

None.

SEE ALSO

`Contour`

Edge2D, Edge3D

Create a 2D or 3D edge data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Edge2D");
model.result().dataset().create(<dtag>,"Edge3D");

model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Edge2D")` creates a 2D edge data set with the name *<dtag>*.

The edge data set makes it possible to evaluate edge of a model in 1D or the model's dimension.

The following properties are available:

TABLE 7-24: VALID PROPERTY/VALUE PAIRS FOR EDGE DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The solution data set this feature refers to.

Eval

Evaluate expressions in domains from data sets that directly map to a solution.

SYNTAX

```
model.result().numerical().create(<ftag>,"Eval");
model.result().numerical(<ftag>).selection(...);
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getData();
model.result().numerical(<ftag>).getData(<expressionIndex>);
model.result().numerical(<ftag>).getImagData();
model.result().numerical(<ftag>).getImagData(<expressionIndex>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).getNData();
model.result().numerical(<ftag>).getCoordinates();
model.result().numerical(<ftag>).getElements();
model.result().numerical(<ftag>).getVertexElements();
model.result().numerical(<ftag>).run();
```

DESCRIPTION

`model.result().numerical().create(<ftag>,"Eval")` creates an evaluation feature with the name *<ftag>*.

`Eval` is a feature made specifically for users of the COMSOL API and does not appear in the COMSOL Multiphysics GUI. It is used to evaluate results directly on the solution.

`result = model.result().numerical(<ftag>).getData()` returns the real part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][coordinates]`.

`model.result().numerical(<ftag>).getData(<expressionIndex>)` returns the real part of the result for one expression, equivalent to `result[expressionIndex]`.

`result = model.result().numerical(<ftag>).getImagData()` returns the imaginary part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][coordinates]`.

`model.result().numerical(<ftag>).getImagData(<expressionIndex>)` returns the imaginary result for one expression, equivalent to `result[expressionIndex]`.

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).getNData()` returns the number of points in the data vector.

`model.result().numerical(<ftag>).getCoordinates()` returns node point coordinates.

`model.result().numerical(<ftag>).getElements()` returns indices to columns in `p` of a simplex mesh.

`model.result().numerical(<ftag>).getVertexElements()` returns indices to mesh elements for each point.

The following properties are available:

TABLE 7-25: VALID PROPERTY/VALUE PAIRS FOR EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/value pairs	Empty	Parameters to use in the expressions.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to. Only `Solution`, `Particle`, `Shell`, and `Ray` data sets are supported.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String array	Model-dependent	The expressions to evaluate.
`complexfun`	`on` | `off`	`on`	Use complex-valued functions with real input.
`gporder`	poitive integer	1	If `pattern` is `gauss`: The Gauss point order.
`matherr`	`on` | `off`	`off`	Error for undefined operation or variable.

TABLE 7-25: VALID PROPERTY/VALUE PAIRS FOR EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
refine	auto | integer	auto	Refinement of elements for evaluation points.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
pattern	gauss | lagrange	lagrange	Specifies if evaluation takes place in Lagrange points or in Gauss points.
phase	double	0	Evaluate solution at this angle, given in degrees.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
t	double array	Empty	The times to use. Available when the underlying solution is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
phase	double	0	Evaluate solution at this angle, given in degrees.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

Interp, Global (Numerical), EvalPoint, EvalGlobal

EvalAberration

Optical aberration evaluations to compute a list of Zernike coefficients for Zernike polynomials that correspond to various types of monochromatic aberration that arise when electromagnetic rays are focused by a system of lenses and mirrors. An Intersection Point 3D data set (see IntersectionPoint2D, IntersectionPoint3D) pointing to a Ray (Data Set) data set must be used.

The EvalAberration optical aberration evaluation requires a license for the Ray Optics Module.

SYNTAX

```
model.result().numerical().create(<ftag>,"EvalAberration");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace `numerical(<ftag>)` with `evaluationGroup(<ftag>)`.

DESCRIPTION

`model.result().numerical().create(<ftag>,"EvalAberration")` creates a optical aberration evaluation feature with the name *<ftag>*.

`model.result().numerical(<ftag>).getReal()` returns the real-valued Zernike coefficients. Data is ordered so that there is one row with length equal to the number of Zernike polynomials up to the specified order.

`model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>)` always returns null because the Zernike coefficients are always real-valued.

`model.result().numerical(<ftag>).isComplex()` always returns false because the Zernike coefficients are real-valued.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data containing the real and imaginary parts of the Zernike coefficients; the latter is always null.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluate the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-26: VALID PROPERTY/VALUE PAIRS FOR OPTICAL ABERRATION EVALUATIONS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The intersection 3D data set this feature refers to
`lunit`	Any length unit	\u00b5m (micron)	Length unit for computing Zernike coefficients
`maxorder`	2, 3, 4, or 5	5	Maximum polynomial order for the Zernike coefficients calculation,

EvalGlobal

Evaluate global quantities.

SYNTAX

```
model.result().numerical().create(<ftag>,"EvalGlobal");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace `numerical(<ftag>)` with `evaluationGroup(<ftag>)`.

DESCRIPTION

`model.result().numerical().create(<ftag>,"EvalGlobal")` creates an evaluation feature with the name *<ftag>*.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that one row contains data for all solution numbers. This is identical to (*<columnwise>*) when `columnwise` is `false`. If `columnwise` is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>)` returns the imaginary part of complex result, recomputing the feature if necessary. If `allocate` is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses *<allocate>* `true` and *<columnwise>* `false.`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluate the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-27: VALID PROPERTY/VALUE PAIRS FOR GLOBAL EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/value pairs	Empty	Parameters to use in the expressions.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.

TABLE 7-27: VALID PROPERTY/VALUE PAIRS FOR GLOBAL EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
dataseries	average | integral | maximum | minimum | none | rms | stddev | variance	none	The operation that is applied to the data series formed by the evaluation.
dataseriesmethod	auto | integration | summation	auto	The method to use for the data series: automatic, integration, or summation.
descr	String array	Model-dependent	The descriptions of the expressions in expr. Is used in the automatic title.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array	Model-dependent	The expressions to plot.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
maximumobj	abs | real	real	The value being maximized if dataseries is maximum.
minimumobj	abs | real	real	The value being minimized if dataseries is minimum.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.

TABLE 7-27: VALID PROPERTY/VALUE PAIRS FOR GLOBAL EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`outersolnum`	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the `solnum` property is not used.
`outersolnumindices`	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `outerinput` is `manualindices`.
`solnum`	nonnegative integer array	`All solutions`	The solutions to use.
`solnumindices`	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active.
`t`	double array	Empty	The times to use. Available when the underlying solution is transient.
`table`	`new` | table name	new	The table to use when calling `setResult()` or `appendResult()`. `new` indicates that a new table is created.
`tablecols`	`inner` | `outer` | `data` | `level`*`1`	`data`	Whether to use inner or outer solutions as columns in the table when calling `setResult()` or `appendResult()`. Applicable only for parametric sweep models. The level values (`level1`, `level2`, and so on) are the levels in the parametric sweep.
`unit`	String array	Model-dependent	The units to use for the expressions in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`EvalGlobalMatrix`, `Eval`, `EvalPoint`

EvalGlobalMatrix

Evaluate global matrix quantities.

SYNTAX

```
model.result().numerical().create(<ftag>,"EvalGlobalMatrix");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

DESCRIPTION

`model.result().numerical().create(<ftag>,"EvalGlobalMatrix")` creates an evaluation feature with the name *<ftag>*.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that one row contains data for all solution numbers. This is identical to (*<columnwise>*) when `columnwise` is `false`. If `columnwise` is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>)` returns the imaginary part of complex result, recomputing the feature if necessary. If `allocate` is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses *<allocate>* `true` and *<columnwise>* `false.`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-28: VALID PROPERTY/VALUE PAIRS FOR GLOBAL MATRIX EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/ value pairs	Empty	Parameters to use in the expressions.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`dataseries`	`average` | `none` | `sum`	`none`	The operation that is applied to the data series formed by the evaluation over inner solutions.
`descr`	String	Model-dependent	The description of the expression in `expr`. Is used in the automatic title.

TABLE 7-28: VALID PROPERTY/VALUE PAIRS FOR GLOBAL MATRIX EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String	Model-dependent	The matrix variable to plot.
`ignorenan`	`on` | `off`	`on`	When on, NaN is ignored when taking the average in the inner or outer data series. If all entries are NaN for a given component, however, you get NaN as output.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels	The times to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	integer row matrix	All solutions on all levels	The solutions to use, per level.
`looplevelindices`	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `looplevelinput` is `manualindices` on a level.
`looplevelinput`	String array with `all` | `first` | `last` | `manual` | `manualindices` | `interp` on each level	`all` on all levels	How to input the solution to use, per level. `manual` on a level indicates that `looplevel` is used on that level. `manualindices` on a level indicates that `looplevelindices` is used on that level. `interp` on a level indicates that `interp` is used on that level.
`outerdataseries`	`average` | `none` | `sum`	`none`	The operation that is applied to the data series formed by the evaluation over outer solutions.
`outerinput`	`all` | `first` | `last` | `manual` | `manualindices`	`all`	How to input the outer solutions to use. Applicable only for parametric sweep models. `manual` indicates that `outersolnum` is used. `manualindices` indicates that `outersolnumindices` is used.
`outersolnum`	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the `solnum` property is not used.

TABLE 7-28: VALID PROPERTY/VALUE PAIRS FOR GLOBAL MATRIX EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
solnum	nonnegative integer array	All solutions	The solutions to use.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
t	double array	Empty	The times to use. Available when the underlying solution is transient.
table	new | table name	new	The table to use when calling setResult() or appendResult(). new indicates that a new table is created.
tablerows	inner | outer	inner	Whether to use inner or outer solutions as rows in the table when calling setResult() or appendResult(). Applicable only for parametric sweep models.
trans	none | inverse | sy | sz | ys | yz | zs | zy | maxwellmutual | mutualmaxwell | invmaxwellmutual	none	The transformation to apply to the matrix. sy means a transformation from S to Y, and so on. The maxwellmutual mutualmaxwell, and invmaxwellmutual transformations are from Maxwell to mutual capacitance, and vice versa, and from an inverse Maxwell to mutual capacitance.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
y0	double array	Taken from the physics interfaces.	If trans is sy or ys: The characteristic admittance.
z0	double array	Taken from the physics interfaces.	If trans is sz or zs: The characteristic impedance.

SEE ALSO

EvalGlobal, Eval, EvalPoint, EvalPointMatrix

EvalPoint

Evaluate quantities in points.

SYNTAX

```
model.result().numerical().create(<ftag>,"EvalPoint");
model.result().numerical(<ftag>).selection(...);
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace `numerical(<ftag>)` with `evaluationGroup(<ftag>)`.

DESCRIPTION

`model.result().numerical().create(<ftag>,"EvalPoint")` creates a point evaluation feature with the name *<ftag>*. Point evaluations can be performed both on points in a geometry or on cut points.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that there is one row per point, with one row containing data for all solution numbers. This is identical to `(<columnwise>)` when *<columnwise>* is `false`. If *<columnwise>* is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>)` returns the imaginary part of complex result, recomputing the feature if necessary. If *<allocate>* is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses *<allocate>* `true` and *<columnwise>* `false.`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-29: VALID PROPERTY/VALUE PAIRS FOR EVALUATION IN POINTS.

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/value pairs	`Empty`	Parameters to use in the expressions.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.

TABLE 7-29: VALID PROPERTY/VALUE PAIRS FOR EVALUATION IN POINTS.

NAME	VALUE	DEFAULT	DESCRIPTION
dataseries	average | integral | maximum | minimum | none | rms | stddev | variance	none	The operation that is applied to the data series formed by the evaluation.
dataseriesmethod	auto | integration | summation	auto	The method to use for the data series: automatic, integration, or summation.
descr	String array	Model-dependent	The descriptions of the expressions in expr. Is used in the automatic title.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array	Model-dependent	The expressions to plot.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
maximumobj	abs | real	real	The value being maximized if dataseries is maximum.
minimumobj	abs | real	real	The value being minimized if dataseries is minimum.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.

TABLE 7-29: VALID PROPERTY/VALUE PAIRS FOR EVALUATION IN POINTS.

NAME	VALUE	DEFAULT	DESCRIPTION
`outersolnum`	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the `solnum` property is not used.
`outersolnumindices`	String or integer array	`Empty`	An alternative way to specify the outer solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `outerinput` is `manualindices`.
`solnum`	nonnegative integer array	All solutions	The solutions to use.
`solnumindices`	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active.
`summethod`	`none` | `sum` | `average`	`none`	Summation method to compute the sum or average for the expressions at all selected points.
`t`	double array	Empty	The times to use. Available when the underlying solution is transient.
`table`	`new` | table name	new	The table to use when calling `setResult()` or `appendResult()`. `new` indicates that a new table is created.
`tablecols`	`inner` | `outer` | `data` | `level`*`1`*	`data`	Whether to use inner or outer solutions as columns in the table when calling `setResult()` or `appendResult()`. Applicable only for parametric sweep models. The level values (`level1`, `level2`, and so on) are the levels in the parametric sweep.
`unit`	String array	Model-dependent	The units to use for the expressions in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`EvalGlobal`

EvalPointMatrix

Evaluate matrix quantities at points in the geometry.

SYNTAX

```
model.result().numerical().create(<ftag>,"EvalPointMatrix");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
model.result().numerical(<ftag>).selection();
```

DESCRIPTION

`model.result().numerical().create(<ftag>,"EvalPointMatrix")` creates an evaluation feature with the name *<ftag>*.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that one row contains data for all solution numbers. This is identical to (*<columnwise>*) when `columnwise` is `false`. If `columnwise` is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>)` returns the imaginary part of complex result, recomputing the feature if necessary. If `allocate` is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses *<allocate>* `true` and *<columnwise>* `false.`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

`model.result().numerical(<ftag>).selection()` selects the points where the matrix quantity should be evaluated. `model.result().numerical(<ftag>).selection().all();` selects all points in the geometry.

The following properties are available:

TABLE 7-30: VALID PROPERTY/VALUE PAIRS FOR GLOBAL MATRIX EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/ value pairs	Empty	Parameters to use in the expressions.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.

TABLE 7-30: VALID PROPERTY/VALUE PAIRS FOR GLOBAL MATRIX EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`dataseries`	`average` | `none` | `sum`	`none`	The operation that is applied to the data series formed by the evaluation over inner solutions.
`descr`	String	Model-dependent	The description of the expression in `expr`. Is used in the automatic title.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String	Model-dependent	The matrix variable to plot.
`ignorenan`	`on` | `off`	`on`	When on, NaN is ignored when taking the average in the inner or outer data series. If all entries are NaN for a given component, however, you get NaN as output.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels	The times to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	integer row matrix	All solutions on all levels	The solutions to use, per level.
`looplevelindices`	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `looplevelinput` is `manualindices` on a level.
`looplevelinput`	String array with `all` | `first` | `last` | `manual` | `manualindices` | `interp` on each level	`all` on all levels	How to input the solution to use, per level. `manual` on a level indicates that `looplevel` is used on that level. `manualindices` on a level indicates that `looplevelindices` is used on that level. `interp` on a level indicates that `interp` is used on that level.
`outerdataseries`	`average` | `none` | `sum`	`none`	The operation that is applied to the data series formed by the evaluation over outer solutions.
`outerinput`	`all` | `first` | `last` | `manual` | `manualindices`	`all`	How to input the outer solutions to use. Applicable only for parametric sweep models. `manual` indicates that `outersolnum` is used. `manualindices` indicates that `outersolnumindices` is used.

TABLE 7-30: VALID PROPERTY/VALUE PAIRS FOR GLOBAL MATRIX EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`outersolnum`	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the `solnum` property is not used.
`outersolnumindices`	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `outerinput` is `manualindices`.
`solnum`	nonnegative integer array	All solutions	The solutions to use.
`solnumindices`	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active.
`t`	double array	Empty	The times to use. Available when the underlying solution is transient.
`table`	`new` | table name	`new`	The table to use when calling `setResult()` or `appendResult()`. `new` indicates that a new table is created.
`tablerows`	`inner` | `outer`	inner	Whether to use inner or outer solutions as rows in the table when calling `setResult()` or `appendResult()`. Applicable only for parametric sweep models.
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`EvalGlobal`, `Eval`, `EvalPoint`, `EvalGlobalMatrix`

EvaluationGroup

Create an evaluation group for grouping related evaluation nodes and presenting the result in an evaluation group table.

SYNTAX

```
model.result().evaluationGroup().create(<egtag>,<eglabel>);
model.result().evaluationGroup(<egtag>).set(property, <value>);
model.result().evaluationGroup(<egtag>).run();
```

DESCRIPTION

`model.result().evaluationGroup().create(<egtag>,<egname>)` creates an evaluation group named *<egtag>* with a label *<eglabel>*. An evaluation group is a group of evaluation nodes (derived values) that are evaluated and displayed in an evaluation group table.

The following properties are available for evaluation groups:

TABLE 7-31: VALID PROPERTY/VALUE PAIRS FOR EVALUATION GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to. This is the default data set for all plots in the group.
`includeparameters`	`auto` | `true` | `false`	`auto`	Include the parameter value columns from the first evaluation feature (`auto`), all parameter value columns (`true`), or no parameter value column (`false`).
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels	The times to use, for transient levels. Available when `data` is not `none` and the underlying data is transient.
`looplevel`	integer row matrix	`All solutions` on all levels	The solutions to use, per level.
`looplevelindices`	integer row matrix	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `looplevelinput` is `manualindices` on a level.
`looplevelinput`	String array with `all` | `first` | `last` | `manual` | `manualindices` | `interp` on each level	`all` on all levels	How to input the solution to use, per level. `manual` on a level indicates that `looplevel` is used on that level. `manualindices` on a level indicates that `looplevelindices` is used on that level. `interp` on a level indicates that `interp` is used on that level.
`outerinput`	`all` | `first` | `last` | `manual` | `manualindices`	`all`	How to input the outer solutions to use. Applicable only for parametric sweep models. `manual` indicates that `outersolnum` is used. `manualindices` indicates that `outersolnumindices` is used.
`outersolnum`	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the `solnum` property is not used.
`outersolnumindices`	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `outerinput` is `manualindices`.
`solnum`	Integer array	All solutions	The solutions to plot. Available when the underlying data has multiple solutions.
`solnumindices`	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.

TABLE 7-31: VALID PROPERTY/VALUE PAIRS FOR EVALUATION GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
storetable	inmodel | inmodelandonfile | onfile	inmodel	Controls whether evaluation group table is stored in model(inmodel) or on file(onfile), or both(inmodelandonfile).
tablebuffersize	Positive integer	Taken from buffer size preference. The default of which is 10000.	The size of the in-memory buffer size where the evaluation group table is stored, used when storetable is set to inmodel or inmodelandonfile. In the second case only the last tablebuffersize rows are kept in the model; the rest is read from file when necessary.

SEE ALSO

AvVolume, AvSurface, AvLine, EvalAberration, EvalGlobal, Eval, EvalPoint, MaxVolume, MaxSurface, MaxLine, MinVolume, MinSurface, MinLine, PlotGroup1D, PlotGroup2D, PlotGroup3D

Export

Add an export expressions attribute to a plot.

SYNTAX

```
model.result(<pgtag>).feature(<ftag>).create(<atag>,"Export");
model.result(<pgtag>).feature(<ftag>).feature(<atag>).set(property, <value>);
```

DESCRIPTION

`model.result(<pgtag>).feature(<ftag>).create(<atag>,"Export")` creates an export expressions attribute named *<atag>* belonging to the plot feature *<ftag>*.

Use export expressions to include additional quantities in plot data export.

Export expressions can be added to streamline and streamline surface, radiation pattern, particle trajectories, point trajectories, and ray trajectories plots.

The following properties are available:

TABLE 7-32: VALID PROPERTY/VALUE PAIRS FOR EXPORT EXPRESSIONS ATTRIBUTES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
descr	String array		The description of the expressions in expr.
expr	String array		The expressions to export in addition to the plot data.
unit	String		The unit to use for the expression in expr.

Extrude1D, Extrude2D

Create a 1D or 2D extrude data set for extruding data in postprocessing from 1D to 2D and from 2D to 3D.

SYNTAX

```
model.result().dataset().create(<dtag>,"Extrude1D");
model.result().dataset().create(<dtag>,"Extrude2D");

model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(`*`<dtag>`*`,"Extrude2D")` creates a 2D extrude data set with the name *`<dtag>`*.

The extrude data set makes it possible to postprocess a 1D or 2D solution that is extruded into 2D or 3D.

The following properties are available:

TABLE 7-33: VALID PROPERTY/VALUE PAIRS FOR EXTRUDE DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The solution data set this feature refers to.
`res`	integer, at least 2	10	The resolution as the number of layers in the extrusion.
`ymin`	double	0	The minimum for the extrusion 1D range.
`ymax`	double	1	The maximum for the extrusion 1D range.
`yvar`	string	`extr1y`	The name of the variable for the extrusion direction for a 1D extrusion.
`zmin`	double	0	The minimum for the extrusion 2D range.
`zmax`	double	1	The maximum for the extrusion 2D range.
`zvar`	string	`extr1z`	The name of the variable for the extrusion direction for a 2D extrusion.

Filter

Add a filter attribute to a plot.

SYNTAX

```
model.result(<pgtag>).feature(<ftag>).create(<atag>,"Filter");
model.result(<pgtag>).feature(<ftag>).feature(<atag>).set(property, <value>);
```

DESCRIPTION

`model.result(`*`<pgtag>`*`).feature(`*`<ftag>`*`).create(`*`<atag>`*`,"Filter")` creates an element filter attribute named *`<atag>`* belonging to the plot feature *`<ftag>`*.

Use filters to limit plots to elements satisfying a condition.

Filters can be added to arrow plots, contour plots, global plots, isosurface plots, line graphs, line plots, mesh plots (in 2D and 3D), point graphs, slice plots, surface plots, and volume plots.

The following properties are available:

TABLE 7-34: VALID PROPERTY/VALUE PAIRS FOR FILTER ATTRIBUTES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`expr`	String	1	The logical expression that must be satisfied for an element to be included in the plot.
`nodespec`	`all` | `any` | `xor` | `smooth`	`smooth`	The set of nodes in an element that have to satisfy the logical expression for it to be included in the plot. The `smooth` option creates smooth edges by "cutting" through elements. Available in 2D and 3D only.

Filter (Particle Tracing, Point Trajectories, Ray Tracing,)

Add a filter attribute to a particle trajectories or particle, point trajectories, or ray or ray tracing plot.

SYNTAX

```
model.result(<pgtag>).feature(<ftag>).create(<atag>,"ParticleTrajectoriesFilter");
model.result(<pgtag>).feature(<ftag>).create(<atag>,"PointTrajectoriesFilter");
model.result(<pgtag>).feature(<ftag>).create(<atag>,"RayTrajectoriesFilter");
model.result(<pgtag>).feature(<ftag>).feature(<atag>).set(property, <value>);
```

DESCRIPTION

`model.result(<pgtag>).feature(<ftag>).create(<atag>,"ParticleTrajectoriesFilter")` creates a filter attribute named *<atag>* belonging to the plot feature *<ftag>*.

Use filters to plot a subset of particles, points, or rays in a data set.

Filters can be added to particle trajectories plots and particle plots; point trajectories plots; and ray trajectories plots and ray plots.

The following properties are available:

TABLE 7-35: VALID PROPERTIES FOR THE FILTERS FOR PARTICLE TRAJECTORIES, POINT TRAJECTORIES, AND RAY TRACING

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`evaluate`	`all|fraction|number`	`all`	Determines which particles are rendered when creating the plot.
`fraction`	Double	1	Fraction of particles that are rendered. Active when `evaluate` is set to `fraction`.
`logical`	Double	1	Logical statement that must be true for a particle, point, or ray to be included in the plot. Active when `type` is set to `logical`.
`number`	Integer	100	Number of particles, points, or rays that are rendered. Active when `evaluate` is set to `number`.
`type`	`all | primary| secondary| logical`	`all`	Determines which particles, points, or rays that are included when creating the plot. `primary` and `secondary` are not available for point trajectories.

Global (Numerical)

Evaluate global quantities.

SYNTAX

```
model.result().numerical().create(<ftag>,"Global");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getData();
model.result().numerical(<ftag>).getData(<expressionIndex>);
model.result().numerical(<ftag>).getImagData();
model.result().numerical(<ftag>).getImagData(<expressionIndex>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).getNData();
model.result().numerical(<ftag>).run();
```

DESCRIPTION

`model.result().numerical().create(<ftag>,"Global")` creates an evaluation feature with the name *<ftag>*.

`Global` is a feature made specifically for users of the COMSOL API and does not appear in the COMSOL Desktop. `Global` features support multiple expressions as well as some additional advanced properties not available in `EvalGlobal`.

`result = model.result().numerical(<ftag>).getData()` returns the real part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][value]`.

`model.result().numerical(<ftag>).getData(<expressionIndex>)` returns the real part of the result for one expression, equivalent to `result[expressionIndex].`

`result = model.result().numerical(<ftag>).getImagData()` returns the imaginary part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][value]`.

`model.result().numerical(<ftag>).getImagData(<expressionIndex>)` returns the imaginary part of the result for one expression, equivalent to `result[expressionIndex].`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).getNData()` returns the number of points in the data vector.

The following properties are available:

TABLE 7-36: VALID PROPERTY/VALUE PAIRS FOR GLOBAL EVALUATION

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/value pairs	`Empty`	Parameters to use in the expressions.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`descr`	String array		Descriptions for the expressions to evaluate.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String array	Model-dependent	The expressions to evaluate.
`complexfun`	`on` | `off`	`on`	Use complex-valued functions with real input.
`matherr`	`on` | `off`	`off`	Error for undefined operation or variable.
`outersolnum`	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
`phase`	double	0	Evaluate solution at this angle, given in degrees.
`solnum`	nonnegative integer array	`All solutions`	The solutions to use.
`t`	double array	Empty	The times to use. Available when the underlying solution is transient.
`units`	String array	Model-dependent	The units to use for the expressions in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

Eval, Interp, EvalPoint, EvalGlobal

Global (Plot)

Create a global plot for 1D plot groups and polar plot groups.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Global");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Global")` creates a plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Global plot is used to visualize defined variables, such as solutions to ODEs or coupling operators with a destination. Global plots can be added to 1D and polar plot groups.

The following properties are available:

TABLE 7-37: VALID PROPERTY/VALUE PAIRS FOR GLOBAL PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`autodescr`	`on` | `off`	Model dependent	Whether the automatic legends should include the expression descriptions.
`autoexpr`	`on` | `off`	Model dependent	Whether the automatic legends should include the expressions.
`autolegends`	`on` | `off`	`on`	Whether to use the automatically computed legends or the legends defined in the `legends` property. The automatic legends display the description and expression for each line.
`autounit`	`on` | `off`	`off`	Whether the automatic legends should include the unit.
`const`	String array of property/value pairs	`Empty`	Parameters to use in the expressions.
`customlinecolor`	RGB-triplet	`{0,0,1}` or last used `edgecolor`.	The color to use for the lines. Active when `linecolor` is set to `custom`.
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to.
`descr`	String array	Model-dependent.	The description of the expressions in `expr`. Is used in the automatic legends.
`descriptionintitle`	`on` | `off`	`on`	Whether the title contribution should contain the description when `titletype` is `custom`.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.

TABLE 7-37: VALID PROPERTY/VALUE PAIRS FOR GLOBAL PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array	Model-dependent.	The expressions to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
freqmax	integer		If xaxisdata is spectrum and freqrangeactive is true: The upper frequency bound.
freqmin	integer		If xaxisdata is spectrum and freqrangeactive is true: The lower frequency bound.
freqrangeactive	on | off	false	If xaxisdata is spectrum: Controls whether a manual frequency range is used.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
legend	on | off	off	Whether to show legends.
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legendprefix	String		A prefix added to the automatic legend.
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
legendsuffix	String		A suffix added to the automatic legend.
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
linewidth	double	0.5	The line width.
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.

TABLE 7-37: VALID PROPERTY/VALUE PAIRS FOR GLOBAL PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
nfreqs	integer	1	If xaxisdata is spectrum and nfreqsactive is true: The number of frequencies to plot.
nfreqsactive	Boolean	false	If xaxisdata is spectrum: Controls whether the number of frequencies is set manually.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
plotonsecyaxis	Boolean	true	Plot on secondary y-axis, if twoyaxes is set to true in the parent plot group.
prefixintitle	String	Empty	Added prefix to contribution to title.
scale	Boolean	false	If xaxisdata is spectrum: The frequency spectrum is transformed so that it has the same scale as the original data.

TABLE 7-37: VALID PROPERTY/VALUE PAIRS FOR GLOBAL PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`solnum`	nonnegative integer array	All solutions	The solutions to plot. Available when `data` is not `parent` and the underlying data has multiple solutions.
`solnumindices`	String or integer array	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active.
`suffixintitle`	String	Empty	Added suffix to contribution to title.
`t`	double array	Empty	The times to plot. Available when `data` is not `parent` and the underlying solution is transient.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title contribution should be computed automatically, possibly using the group's customization. `custom` if the title contribution should be computed automatically, but customized. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution should contain the type when `titletype` is `custom`.
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution should contain the unit when `titletype` is `custom`.
`xdata`	`expr` | `solution` | `spectrum` | `phase`	`solution`	x-axis data. `expr` uses the expression in `xdataexpr`. `solution` uses the available solutions in the underlying data set, such as time steps. `phase` uses a phase range, and rearranged phase plots.
`xdataexpr`	String	Model-dependent	Expression for x-axis data.
`xdatadescr`	String	Model-dependent	Description of expression in `xdataexpr`.
`xdataphaserange`	double array	`range(0, 0.5, 2π)`	The phases for which the expressions should be evaluated when `xdata` is `phase`.
`xdataphaseunit`	String	`rad`	The unit in which `xdataphaserange` is described.

TABLE 7-37: VALID PROPERTY/VALUE PAIRS FOR GLOBAL PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
xdatasolnumtype	all | inner | outer | valid level	outer	Whether the expression should be evaluated for every inner or every outer solution, or for a specific level (level1, level2, and so on). Applicable only for models containing multiple levels.
xdataunit	String	Model-dependent	The unit to use for the expression in xdataexpr. If the old unit is not valid when the expression changes, the unit property is reset to default.

ATTRIBUTES

None.

SEE ALSO

LineGraph

Grid1D, Grid2D, Grid3D

Create a data set that can evaluate 1D, 2D, or 3D functions or other data sets on a domain with a grid. For example, you can use these data sets to evaluate BEM and far-field operators.

SYNTAX

```
model.result().dataset().create(<dtag>,"Grid1D");
model.result().dataset().create(<dtag>,"Grid2D");
model.result().dataset().create(<dtag>,"Grid3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Grid1D")` creates a 1D grid data set feature named *<dtag>*.

This data set provides support for evaluation of functions or other data sets on a domain with a grid. All functions in the same function list as the selected function can also be evaluated. The domain is an interval for Grid1D, a rectangle for Grid2D, and a block for Grid3D. The domain does not need to have the same dimension as the number of arguments to the function.

The following properties are available:

TABLE 7-38: VALID PROPERTY/VALUE PAIRS FOR GRID DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | data set tag	none	The data set this feature refers to.
function	none | all | function tag	none	The function this feature refers to.
par*i*	String	Model-dependent	The name of the parameter. par1, par2, and par3 for Grid3D, for example.
parmin1	double	0	Lower bound for the first dimension of the domain.
parmax1	double	1	Upper bound for the first dimension of the domain.
parmin2	double	0	Lower bound for the second dimension of the domain. (For Grid2D and Grid3D.)

TABLE 7-38: VALID PROPERTY/VALUE PAIRS FOR GRID DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
parmax2	double	1	Upper bound for the second dimension of the domain. (For Grid2D and Grid3D.)
parmin3	double	0	Lower bound for the third dimension of the domain. (For Grid3D.)
parmax3	double	1	Upper bound for the third dimension of the domain. (For Grid3D.)
res*i*	integer >= 2	1000 for 1D, 100 for 2D, and 30 for 3D	The number of points into which each dimension is discretized. res1, res2, and res3 for Grid 3D, for example.
source	function | data	function	Use a function or a data set as the source.

Height, AberrationHeight, HistogramHeight, TableHeight

Add a height attribute for 2D line and surface plots, for 2D optical aberration plots, for 2D histogram plots, and for 2D table surface plots.

SYNTAX

```
model.result(<pgtag>).feature(<ftag>).create(<atag>,"Height");
model.result(<pgtag>).feature(<ftag>).create(<atag>,"AberrationHeight");
model.result(<pgtag>).feature(<ftag>).create(<atag>,"HistogramHeight");
model.result(<pgtag>).feature(<ftag>).create(<atag>,"TableHeight");
model.result(<pgtag>).feature(<ftag>).feature(<atag>).set(property, <value>);
```

DESCRIPTION

`model.result(<pgtag>).feature(<ftag>).create(<atag>,"Height")` creates a `Height` attribute feature with the name *<atag>*, belonging to the feature *<ftag>*.

Height attributes are available for 2D line and surface plots, and with slightly different sets of properties, for 2D optical aberration, histogram and table surface plots. Adding a height attribute changes the rendered view to 3D. The plot group, however, still remains a 2D plot group. Any other plots in the group that do not have a height attribute are rendered at $z = 0$.

The following properties are available:

TABLE 7-39: VALID PROPERTIES FOR HEIGHT ATTRIBUTES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
coldata	integer		Table data for the height for a table surface with the columns table format. An integer that specifies the column number to use.
data	none | filled table data	none	Table data for the height for a table surface with the filled table format.
descr	String	Model-dependent	The description of the expression in expr. It is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.

TABLE 7-39: VALID PROPERTIES FOR HEIGHT ATTRIBUTES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent	The expression to plot. For Height attributes only.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
heightdata	parent | expr or parent | data	parent	parent uses the expression and description in the plot the height feature has been added to. expr uses the expr and descr properties (for Height attributes only). data uses some specified data from the data or coldata properties (for TableHeight attributes only).
imagplot	on | off	off	Plot the imaginary part of the height data (for TableHeight attributes only).
offset	double	0	The offset along the z-axis where to place the height plot.
prefixintitle	String	Empty	Added prefix to contribution to title.
preprocz	none | linear	none	Preprocess the height data with a scaling factor and a shift, if set to linear (for TableHeight attributes only).
scale	positive double	1	If scaleactive is true: The scale factor for the height.
scaleactive	Boolean	false	Whether to use manual scaling.
scalingz	double	1	The scaling factor for the preprocessing, if preprocz is set to linear (for TableHeight attributes only).
shiftz	double	0	The shift for the preprocessing, if preprocz is set to linear (for TableHeight attributes only).
suffixintitle	String	Empty	Added suffix to contribution to title.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used. custom is available for Height attributes only.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.

TABLE 7-39: VALID PROPERTIES FOR HEIGHT ATTRIBUTES

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution should contain the unit when `titletype` is `custom`.

SEE ALSO

`Color`, `Deform`, Histogram, Table, TableSurface

Histogram

Create a histogram plot for 1D and 2D plot groups.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Histogram");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Histogram")` creates a histogram plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Histograms are used to visualize the distribution of the range of an expression. The result is a plot with the expression's range on the *x*-axis and element length, area, or volume on the *y*-axis. Such histogram plots can be added to 1D plot groups. In 2D histograms, which you can add to 2D plot groups, the *x*-axis and *y*-axis represent the values of two quantities (as a number of bins or a range of values), and the color surface represents the count of the total element volume in each "bin".

2D Histogram plots require a license for the Particle Tracing Module, Ray Optics Module, or Acoustics Module.

The following properties are available:

TABLE 7-40: VALID PROPERTY/VALUE PAIRS FOR HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/ value pairs	Empty	Parameters to use in the expressions.
`cumulative`	Boolean	`false`	Plot a cumulative histogram.
`customlinecolor`	RGB-triplet	`{0,0,1}` or last used edgecolor.	The color to use for the lines. Active when `linecolor` is set to `custom`.
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to.
`descr`	String	Model-dependent.	The description of the expression in `expr`. Is used in the automatic title.
`descriptionintitle`	`on` | `off`	`on`	Whether the title contribution should contain the description when `titletype` is `custom`.

TABLE 7-40: VALID PROPERTY/VALUE PAIRS FOR HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal|lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
function	continuous | discrete	continuous	Use a continuous function or a discrete function (that is, using a constant level in each bin) for the histogram.
innerinput	all | first | last | manual|manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
level	fromdataset | volume | surface | line | point	fromdataset	The geometry level to evaluate on.
limits	double array	0 1	The bin limits if method is limits.
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
linewidth	double	0.5	The line width.
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.

TABLE 7-40: VALID PROPERTY/VALUE PAIRS FOR HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
measure	auto | integral | count	auto	The measure for evaluation of the histogram data. Choose integral for volume-based data; choose count of element-based data. auto is count for Mesh data sets; integral otherwise.
method	limit | number	number	The method used to specify the bins in which the expression's range is split
normalization	integral | none | peak	none	The normalization of the values plot on the y-axis.
number	nonnegative integer	10	The number of bins if method is number.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
plotonsecyaxis	Boolean	true	Plot on secondary y-axis, if twoyaxes is set to true in the parent plot group for 1D histogram plots.
prefixintitle	String	Empty	Added prefix to contribution to title

TABLE 7-40: VALID PROPERTY/VALUE PAIRS FOR HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`rangecoloractive`	`on` | `off`	`off`	Whether to use the manual color range specified in `rangecolormin` and `rangecolormax`. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values. This and other range settings are available for 2D Histogram plots.
`rangecolormax`	double	Plot-dependent	The maximum color range value. Active when `rangecoloractive` is `on`.
`rangecolormin`	double	Plot-dependent	The minimum color range value. Active when `rangecoloractive` is `on`.
`rangedatactive`	`on` | `off`	`off`	Whether to use the manual data range specified in `rangedatamin` and `rangedatamax`. Values outside the data range is not plotted.
`rangedatamax`	double	Plot-dependent	The maximum data value. Active when `rangedataactive` is `on`.
`rangedatamin`	double	Plot-dependent	The minimum data value. Active when `rangedataactive` is `on`.
`refine`	nonnegative integer	1	The element refinement to use, if `resolution` is set to `manual`. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
`resolution`	`norefine` | `coarse` | `normal` | `fine` | `finer` | `extrafine` | `custom`	`normal`	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use `custom` to enter your own refinement in the `refine` property.
`sdim`	`fromdataset` | 0 | 1 | 2 | 3	`fromdataset`	The space dimension to evaluate the underlying data set in
`solnum`	integer array	All solutions	The solutions to plot. Available when `data` is not `parent` and the underlying data has multiple solutions
`solnumindices`	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active
`suffixintitle`	String	Empty	Added suffix to contribution to title
`t`	double array	Empty	The times to plot. Available when `data` is not `parent` and the underlying solution is transient.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.

TABLE 7-40: VALID PROPERTY/VALUE PAIRS FOR HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
type	curve | solid	curve	Use a filled histogram (solid) or a histogram drawn using lines (curve). This property is only available when function is discrete.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

SEE ALSO

MatrixHistogram

Image1D, Image2D, Image3D

Export an image.

SYNTAX

```
model.result().export().create(<ftag>,"Image1D");
model.result().export().create(<ftag>,"Image2D");
model.result().export().create(<ftag>,"Image3D");
model.result().export().create(<ftag>,<pgtag>,"Image1D");
model.result().export().create(<ftag>,<pgtag>,"Image2D");
model.result().export().create(<ftag>,<pgtag>,"Image3D");
model.result().export(<ftag>).set(property, <value>);
model.result().export(<ftag>).run();
```

DESCRIPTION

`model.result().export().create(<ftag>,"Image1D")` creates a 1D image feature with the name *<ftag>*.

`model.result().export().create(<ftag>,<pgtag>,"Image1D")` creates a 1D image feature with the name *<ftag>* for the plot group *<pgtag>*.

`result().export(<ftag>).set("plotgroup", <ptag>)` changes the source of the image to the plot group named *<ptag>*.

Image features can be used both to export images and to have ready-made views of plot groups.

The following properties are available:

TABLE 7-41: VALID PROPERTY/VALUE PAIRS FOR IMAGE EXPORT

NAME	VALUE	DEFAULT	DESCRIPTION
alwaysask	on | off	off	Always ask for filename when saving. This property is ignored when running without a GUI.
antialias	on | off	on	Enable/disable antialiasing.
axes	on | off	on	If options is on; enable/disable display of the coordinate axes. Used for 1D and 2D plots.
axisorientation	on | off	on	If options is on; enable/disable display of the axis orientation indicator. Used for 3D plots.
background	current | color | transparent	color	The background color.
bmpfilename	String		The name of the output file if imagetype is bmp.
customcolor	double array	{1, 1, 1}	If background is color; the red, green, and blue components of the background color.
epsfilename	String		The name of the output file if imagetype is eps.
fontsize	integer	9	The font size.
gltffilename	String		The name of the output file if imagetype is gltf.
grid	on | off	on	If options is on; enable/disable display of the coordinate grid. Used for 3D plots.
height	double	600	The height of the image.
imagetype	png | eps | jpeg | bmp | gltf	png	The type of image to export. eps can only be used for 1D plots. gltf can only be used for 3D plots.
jpegfilename	String		The name of the output file if imagetype is jpeg.
legend	on | off	on	If options is on; enable/disable display of the legend.
lockratio	Boolean	false	If true, then the aspect ratio of the image is preserved when the width or the height is changed.
logo	on | off	on	If options is on; enable/disable display of the logotype.
options	on | off	off	Enable/disable optional components of the image.
pngfilename	String		The name of the output file if imagetype is png.
qualityactive	on | off	off	If a quality level (quantitylevel) should be active when imagetype is jpeg.
quantitylevel	integer	92	The quality level when imagetype is jpeg.
resolution	integer	96	The frame resolution in dots per inch.

TABLE 7-41: VALID PROPERTY/VALUE PAIRS FOR IMAGE EXPORT

NAME	VALUE	DEFAULT	DESCRIPTION
`plotgroup`	String		The plot group to export.
`title`	`on` | `off`	`on`	If options is on; enable/disable display of the title.
`unit`	`px` | `mm` | `in`	mm	The unit for the dimensions of the image.
`width`	double	800	The width of the image.

The default values listed are valid before any image has been exported successfully. After that, the settings from the last successful image export are used as default values the next time an image export feature is created.

Changing plot group after creation does not reset plot group-dependent default settings (`title`, `colorlegend`).

SEE ALSO

Animation

ImpulseResponse

Create an impulse response plot for 1D plot groups. This plot type requires the Acoustics Module.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ImpulseResponse");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"ImpulseResponse")` creates an impulse response plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Impulse response plots are primarily used for postprocessing of acoustics simulations. Impulse response plots can be added to 1D plot groups.

The following properties are available:

TABLE 7-42: VALID PROPERTY/VALUE PAIRS FOR IMPULSE RESPONSE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`autodescr`	`on` | `off`	Model dependent	Whether the automatic legends should include the expression descriptions.
`autoexpr`	`on` | `off`	Model dependent	Whether the automatic legends should include the expressions.
`autolegends`	`on` | `off`	`on`	Whether to use the automatically computed legends or the legends defined in the `legends` property. The automatic legends display the description and expression for each line.
`autounit`	`on` | `off`	`off`	Whether the automatic legends should include the unit.
`customlinecolor`	RGB-triplet	`{0,0,1}` or last used `edgecolor`.	The color to use for the lines. Active when `linecolor` is set to `custom`.
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to.

TABLE 7-42: VALID PROPERTY/VALUE PAIRS FOR IMPULSE RESPONSE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
density	String		The density of the frequency expression.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
freqmax	integer		If transform is spectrum and freqrangeactive is true: The upper frequency bound.
freqmin	integer		If transform is spectrum and freqrangeactive is true: The lower frequency bound.
freqrangeactive	on | off	false	If transform is spectrum: Controls whether a manual frequency range is used.
frequency	String		The frequency expression.
freqtype	octave | octave3 | octave6	octave	The frequency interpretation: octave, 1/3 octave, or 1/6 octave.
legend	on | off	off	Whether to show legends.
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legendprefix	String		A prefix added to the automatic legend.
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
legendsuffix	String		A suffix added to the automatic legend.
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
linewidth	double	0.5	The line width.
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.

TABLE 7-42: VALID PROPERTY/VALUE PAIRS FOR IMPULSE RESPONSE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`markers`	integer	8	The number of markers to show. Markers are visible when `linemarker` is set.
`nfreqs`	integer	1	If transform is spectrum and nfreqsactive is true: The number of frequencies to plot.
`nfreqsactive`	Boolean	`false`	If transform is spectrum: Controls whether the number of frequencies is set manually.
`passbandslope`	double	1.03	The passband slope factor.
`prefixintitle`	String		Added prefix to contribution to title.
`power`	String		The power of the frequency expression.
`ripplefactor`	double	0.05	The ripple factor.
`scale`	Boolean	`false`	If transform is spectrum: The frequency spectrum is transformed so that it has the same scale as the original data.
`solnum`	nonnegative integer array	All solutions	The solutions to plot. Available when `data` is not `parent` and the underlying data has multiple solutions.
`solnumindices`	String or integer array	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active.
`soundspeed`	String		The speed of sound.
`suffixintitle`	String	Empty	Added suffix to contribution to title.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title contribution should be computed automatically, possibly using the group's customization. `custom` if the title contribution should be computed automatically, but customized. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`transform`	`none` | `spectrum`	`none`	Transformation of x-axis date.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution should contain the type when `titletype` is `custom`.

TABLE 7-42: VALID PROPERTY/VALUE PAIRS FOR IMPULSE RESPONSE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

ATTRIBUTES

None.

SEE ALSO

LineGraph

InterferencePattern

Plot the interference pattern resulting from the intersection of rays with a cut plane.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"InterferencePattern");
model.result(<pgtag>).feature(<ftag>).selection(...);
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

model.result(*<pgtag>*).create(*<ftag>*,"InterferencePattern") creates an interference pattern plot feature named *<ftag>* belonging to the plot group *<pgtag>*. The interference pattern plot is used to visualize the interference of multiple rays as they intersect a cut plane. Interference pattern plots can be added to 2D plot groups.

The following properties are available:

TABLE 7-43: VALID PROPERTY/VALUE PAIRS FOR INTERFERENCE PATTERN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this surface
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.

TABLE 7-43: VALID PROPERTY/VALUE PAIRS FOR INTERFERENCE PATTERN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to.
`inheritcolor`	Boolean	`true`	If `inheritplot` is not `none`: Determines if the color is inherited.
`inheritplot`	`none` | plot name	`none`	The plot that color and color range are inherited from.
`inheritrange`	Boolean	`true`	If `inheritplot` is not `none`: Determines if the color and data ranges are inherited.
`interp`	double array	Time corresponding to last selected `solnum` for transient levels.	The time to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or `interp`, but only for transient solutions. Available when `data` is not `parent` and the underlying data has multiple solutions.
`originspec`	`manual` | `index` | `intensity`	manual	Determines how the origin of the interference plot is defined.
`originx`	double	0	If `originspec` is `manual`, determines the x-coordinate of the origin.
`originy`	double	0	If `originspec` is `manual`, determines the y-coordinate of the origin.
`originz`	double	0	If `originspec` is `manual`, determines the z-coordinate of the origin.
`outersolnum`	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
`rangecoloractive`	`on` | `off`	`off`	Whether to use the manual color range specified in `rangecolormin` and `rangecolormax`. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
`rangecolormax`	double	Plot-dependent	The maximum color range value. Active when `rangecoloractive` is on.
`rangecolormin`	double	Plot-dependent	The minimum color range value. Active when `rangecoloractive` is on.
`rangedatactive`	`on` | `off`	`off`	Whether to use the manual data range specified in `rangedatamin` and `rangedatamax`. Values outside the data range is not plotted.
`rangedatamax`	double	Plot-dependent	The maximum data value. Active when `rangedataactive` is on.
`rangedatamin`	double	Plot-dependent	The minimum data value. Active when `rangedataactive` is on.

TABLE 7-43: VALID PROPERTY/VALUE PAIRS FOR INTERFERENCE PATTERN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
rangexactive	on | off	off	Whether to use a manual range of x-coordinates for the grid points.
rangexmax	double	Plot-dependent	The maximum x-coordinate in the local coordinate system of the interference pattern plot. Active when rangexactive is on.
rangexmin	double	Plot-dependent	The minimum x-coordinate in the local coordinate system of the interference pattern plot. Active when rangexactive is on.
rangeyactive	on | off	off	Whether to use a manual range of y-coordinates for the grid points.
rangeymax	double	Plot-dependent	The maximum y-coordinate in the local coordinate system of the interference pattern plot. Active when rangeyactive is on.
rangeymin	double	Plot-dependent	The minimum y-coordinate in the local coordinate system of the interference pattern plot. Active when rangeyactive is on.
rayindex	int	1	The index of the ray used to define the location of the origin of the interference pattern plot. The origin is located at the intersection of the specified ray with the cut plane. Active when originspec is index.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.

TABLE 7-43: VALID PROPERTY/VALUE PAIRS FOR INTERFERENCE PATTERN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
xyresolution	int	200	The number of grid points in each direction to use when rendering the interference pattern. Cannot be greater than 1000.

Interp

Evaluate expressions in arbitrary points or data sets using interpolation.

SYNTAX

```
model.result().numerical().create(<ftag>,"Interp");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getCoordinates();
model.result().numerical(<ftag>).getData();
model.result().numerical(<ftag>).getData(<expressionIndex>);
model.result().numerical(<ftag>).getImagData();
model.result().numerical(<ftag>).getImagData(<expressionIndex>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).getElements();
model.result().numerical(<ftag>).getNData();
model.result().numerical(<ftag>).run();
model.result().numerical(<ftag>).setInterpolationCoordinates(<value>);
```

DESCRIPTION

`model.result().numerical().create(<ftag>,"Interp")` creates an interpolation feature with the name *<ftag>*.

`Interp` is a feature made specifically for users of the COMSOL API and does not appear in the COMSOL Multiphysics GUI. `Interp` combines cut points and evaluation features, as well as allowing evaluation of arbitrary data sets. It supports multiple expressions and some additional advanced properties not available when using cut points and `EvalPoint` features.

`result = model.result().numerical(<ftag>).getData()` returns the real part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][coordinates]`.

`model.result().numerical(<ftag>).getData(<expressionIndex>)` returns the real part of the result for one expression, equivalent to `result[expressionIndex].`

`result = model.result().numerical(<ftag>).getImagData()` returns the imaginary part of the result, recomputing the feature if necessary. `result` is a three-dimensional double matrix ordered `result[expression][solnum][coordinates]`.

`model.result().numerical(<ftag>).getImagData(<expressionIndex>)` returns the imaginary part of the result for one expression, equivalent to `result[expressionIndex].`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. `<outersolnum>` is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).getElements()` returns indices to columns in `p` of a simplex mesh.

`model.result().numerical(<ftag>).getNData()` returns the number of points in the data vector.

`model.result().numerical(<ftag>).getCoordinates()` returns the coordinates of the interpolation.

`model.result().numerical(<ftag>).setInterpolationCoordinates(<value>)` is identical to `model.result().numerical(<ftag>).set(coord, <value>)`, when value is of type double[ ][ ].

The columns of the `coord` property are the coordinates for the evaluation points. If the number of rows in `coord` equals the space dimension, then `coord` are global coordinates, and the selection (or the property `edim`) determines the dimension in which the expressions are evaluated. For instance, dimension 2 means that the expressions are evaluated on boundaries in a 3D model. If the dimension to evaluate on is less than the space dimension, then the points in `coord` are projected onto the closest point on a domain of that dimension. It is further possible to select a single geometric entity of a given dimension. If so, then the closest point on that domain in the given dimension is used.

If the number of rows in `coord` is less than the space dimension, then these coordinates are parameter values on a geometry face or edge. In that case, the domain number for that face or edge must be specified in the selection.

For data sets that do not support selections, the `edim` property must always be used, and no selections are possible.

The following properties are available:

TABLE 7-44: VALID PROPERTY/VALUE PAIRS FOR INTERP

NAME	VALUE	DEFAULT	DESCRIPTION
`complexfun`	`on` | `off`	`on`	Use complex-valued functions with real input
`const`	String array of property/value pairs	`Empty`	Parameters to use in the expressions.
`coord`	double matrix	`Empty`	The coordinates to evaluate in. Data sets that define an interpolation in themselves, such as cut planes, revolve and so forth, can be evaluated directly in the coordinates that define their shapes, without specifying coord.
`coorderr`	`on` | `off`	`on`	If on, evaluating for a set of points that all fall outside the geometry results in an error being reported.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`edim`	`auto` | `0` | `1` | `2` | `3`	`auto`	Element dimension. This is used for arbitrary data sets. Solution data sets use selections as usual to specify where to perform the evaluation, and ignore the value of the `edim` property.

TABLE 7-44: VALID PROPERTY/VALUE PAIRS FOR INTERP

NAME	VALUE	DEFAULT	DESCRIPTION
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array	Model-dependent	The expressions to evaluate.
ext	double between 0 and 1	0.1	Extrapolation distance: How much outside the mesh that the interpolation searches. The scale is in terms of the local element size.
matherr	on | off	off	Error for undefined operation or variable
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
phase	double	0	Evaluate solution at this angle, given in degrees.
refine	auto | integer	auto	Refinement of elements for evaluation points.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
solnum	nonnegative integer array	All solutions	The solutions to use.
t	double array	Empty	The times to use. Available when the underlying solution is transient.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

Eval, Global (Numerical), EvalPoint, EvalGlobal

IntersectionPoint2D, IntersectionPoint3D

Create a data set that enables the evaluation of expressions at the intersection points of particle or ray trajectories and a curve or surface. These data sets can use a Ray or Particle data set as their input.

SYNTAX

```
model.result().dataset().create(<dtag>,"InsterSectionPoint3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"IntersectionPoint2D")` creates an intersection point 2D data set with the name *<dtag>*.

The following properties are available:

TABLE 7-45: VALID PROPERTY/VALUE PAIRS FOR INTERSECTION POINT 2D AND INTERSECTION POINT 3D DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
axis	double array	{0, 1}	Axis direction for a semicircle used as the curve type or a hemisphere used as the plane type.
bounded	on | off	on	Control if a line used as the curve type should be bounded by the points or not.

TABLE 7-45: VALID PROPERTY/VALUE PAIRS FOR INTERSECTION POINT 2D AND INTERSECTION POINT 3D DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
center	double array	{0, 0,}	Center coordinates for a circle, semicircle, sphere, or hemisphere as the curve or plane type.
data	none | data set name	First compatible data set	The data set this feature refers to.
expr	String		Expression for a general curve or plane.
extrasteps	none | specifiedtimes| proportional	specifiedtimes	Controls how the number of extra time steps to find all intersections are added. These extra time steps typically correspond to the exact times of reflections or velocity reinitializations.
genparaactive	on | off	off	Decides if parallel lines or planes should be drawn.
genparadist	double array	{}	Active when genparaactive is on, this property contains the distances from the extra parallel lines or planes to the base plane.
genmethod	threepoint | pointnormal	threepoint	Active when planetype equals general, this property indicates whether the plane should be specified by three points or through one point and a normal.
genpoints	double	0 or 1, depending on index position ([0, 0, 0; 1 0 0; 0 1 0])	Active when method equals threepoint, this property contains the coordinates of the three points in the rows of the matrix. See below for the use of this property and the setIndex method.
genpnpoint	String array of length three	Zero string vector	Active when genmethod equals pointnormal, this property contains the coordinates of the point.
genpnvec	String array of length three	Zero string vector	Active when genmethod equals pointnormal, this property contains the normal vector.
interpolation	linear | cubic	linear	The polynomial order of the method used to interpolate between time steps to evaluate expressions at the intersection points. If cubic is selected, the derivatives at the time steps are also taken into account.
normal	String array of length two or three	Created from the feature tag.	The names of the variables that can be used to evaluate the curve's or plane's normal.
numextrasteps	Nonnegative integer	100	If extrasteps is specifiedtimes, controls the maximum number of extra time steps to use to find all intersections.
planetype	quick | general	quick	Specify plane type for the surface type plane (3D).
propextrasteps	Nonnegative integer	1	If extrasteps is proportional, controls the maximum number of extra time steps to use to find all intersections. The maximum number of extra steps is the product of this proportionality factor with the number of solution times.
radius	double	1	Radius for a circle, semicircle, sphere, or hemisphere as the curve or plane type.

TABLE 7-45: VALID PROPERTY/VALUE PAIRS FOR INTERSECTION POINT 2D AND INTERSECTION POINT 3D DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
quickplane	xy | yz | zx | yx | zy | xz	yz	Specify quick plane type. Active when planetype is quick.
quickx	String	"0"	x-coordinate if planetype is yz or zy.
quicky	String	"0"	y-coordinate if planetype is zx or xz.
quickz	String	"0"	z-coordinate if planetype is xy or yx.
spacevars	String array of length 2	Created from the feature tag.	The names of the variables that evaluate to the plane's parameterization.
type	line | circle | semicircle | general (2D); plane | sphere | hemisphere | general (3D)	line (2D); plane (3D)	The type of curve (2D) or surface (3D).

For specifying the coordinates for a line curve type, for example, use the setIndex method:

```
model.result().dataset("ip2").setIndex("genpoints", "1.3", 0, 1);
```

That line sets the *y* coordinate of point one to the value 1.3.

IntVolume, IntSurface, IntLine

Add a volume, surface, or line integration to evaluate numerical results.

SYNTAX

```
model.result().numerical().create(<ftag>,"IntVolume");
model.result().numerical().create(<ftag>,"IntSurface");
model.result().numerical().create(<ftag>,"IntLine");
model.result().numerical(<ftag>).selection(...);
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace numerical(*<ftag>*) with evaluationGroup(*<ftag>*).

DESCRIPTION

model.result().numerical().create(*<ftag>*,"IntVolume") creates a volume integral feature with the name *<ftag>*.

model.result().numerical().create(*<ftag>*,"IntSurface") creates a surface integral feature with the name *<ftag>*.

model.result().numerical().create(*<ftag>*,"IntLine") creates a line integral feature with the name *<ftag>*.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that one row contains data for all solution numbers. This is identical to `(columnwise)` when `columnwise` is `false`. If `columnwise` is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(allocate, columnwise)` returns the imaginary part of complex result, recomputing the feature if necessary. If `allocate` is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses `allocate true` and `columnwise false.`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-46: VALID PROPERTY/VALUE PAIRS FOR INTEGRATION

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/ value pairs	`Empty`	Parameters to use in the expressions
`data`	`none` | data set name	First compatible data set	The data set this feature refers to
`dataseries`	`average` | `integral` | `maximum` | `minimum` | `none` | `rms` | `stddev` | `variance`	`none`	The operation that is applied to the data series formed by the evaluation
`dataseriesmethod`	`auto` | `integration` | `summation`	`auto`	The method to use for the data series: automatic, integration, or summation.
`descr`	String array	Model-dependent	The descriptions of the expression in `expr`. Is used in the automatic title.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String array	Model-dependent	The expressions to plot.

TABLE 7-46: VALID PROPERTY/VALUE PAIRS FOR INTEGRATION

NAME	VALUE	DEFAULT	DESCRIPTION
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
intorder	positive integer	4	The integration order
intorderactive	on | off	off	Whether to use manually specified integration order
intsurface	on | off	off	Compute surface integral. Available for line integration features of axisymmetric models.
intvolume	on | off	off	Compute volume integral. Available for surface integration features of axisymmetric models.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
maximumobj	abs | real	real	The value being maximized if dataseries is maximum
method	auto | integration | summation	auto	The integration method
minimumobj	abs | real	real	The value being minimized if dataseries is minimum
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.

TABLE 7-46: VALID PROPERTY/VALUE PAIRS FOR INTEGRATION

NAME	VALUE	DEFAULT	DESCRIPTION
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
solnum	nonnegative integer array	All solutions	The solutions to use
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
t	double array	Empty	The times to use. Available when the underlying solution is transient.
table	new | table name	new	The table to use when calling setResult() or appendResult(). new indicates that a new table is created.
tablecols	inner | outer | data | level*1*	data	Whether to use inner or outer solutions as columns in the table when calling setResult() or appendResult(). Applicable only for parametric sweep models. The level values (level1, level2, and so on) are the levels in the parametric sweep.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
unit	String array	Model-dependent	The units to use for the expressions in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

EvalGlobal, EvalPoint, Global (Numerical)

Isosurface

Create an isosurface plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Isosurface");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

model.result(*<pgtag>*).create(*<ftag>*,"Isosurface") creates an isosurface plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

The following properties are available:

TABLE 7-47: VALID PROPERTY/VALUE PAIRS FOR ISOSURFACE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this isosurface.
colorlegend	on | off	on	Whether to show color legend.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
contourlabels	on | off	off	Whether to display labels next to the isosurfaces.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
filledlegend	on | off	on	Whether to show the color legend as a filled legend.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.

TABLE 7-47: VALID PROPERTY/VALUE PAIRS FOR ISOSURFACE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
inheritplot	none | plot name	none	The plot that color and deformation scale are inherited from.
interactive	on | off	off	If true, the isosurfaces can be moved interactively after the plot has been made.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
labelcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black	If contourlabels is on: The label color to use.
labelprec	positive integer	4	If contourlabels is on: The number of significant digits in the isosurface labels.
legendtype	filled | lines	lines	Whether to show the color legend as a filled legend or using lines.
levelmethod	number | levels	number	How to enter isosurface levels.
levels	String array		The levels to plot. Active when levelmethod equals levels.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
number	positive integer	5	Total number of isosurface levels. Active when levelmethod equals number.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.

TABLE 7-47: VALID PROPERTY/VALUE PAIRS FOR ISOSURFACE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
shift	double	0	If interactive is on: The shift that is applied to the level values.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
useder	Boolean	true	Only for isosurface plots: If true, space derivatives of the isosurface expression are used to produce smoother plots.

ATTRIBUTES

Color, Deform, Filter

SEE ALSO

`Isosurface (Data Set)`, `Slice`, `Volume`

Isosurface (Data Set)

Create an isosurface data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Isosurface");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Isosurface")` creates an isosurface data set feature named *<dtag>*.

The following properties are available:

TABLE 7-48: VALID PROPERTY/VALUE PAIRS FOR ISOSURFACE DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`descr`	String		Description of expr.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String	`u`	Expression to find constant level for.
`level`	double array	`{0}`	Levels that defines the data set if levelmethod is levels.
`levelmethod`	`number` | `levels`	`number`	How to specify levels.
`number`	positive integer	5	Total number of contour levels. Active when `levelmethod` is `number`.
`unit`	String		Unit of expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`Isosurface`

Join

Join data sets for joining two data sets to form the difference, for example.

SYNTAX

```
model.result().dataset().create(<dtag>,"Join");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Join")` creates a join data set feature named *<dtag>*.

The following properties are available:

TABLE 7-49: VALID PROPERTY/VALUE PAIRS FOR JOIN DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	None	The first source data set.
`data2`	`none` | data set name	None	The second source data set.
`expr`	String	`data1-data2`	When method is general: The way the evaluations in the first and second data sets is combined. data1 and data2 can be used as symbols for the values from the two data sets, respectively.
`method`	`difference` | `differencenorm` | `explicit` | `general` | `product` | `quotient` | `sum`	`difference`	How to combine the results from evaluating in the two source data sets.
`solutions`	`all` | `one`	`all`	Whether to expose one or all solutions from the first data set.
`solutions2`	`all` | `one`	`all`	Whether to expose one or all solutions from the second data set.

LayeredShell

Create a layered shell data set.

The LayeredShell data set requires a license for the Composite Materials Module, AC/DC Module, or Heat Transfer Module.

SYNTAX

```
model.result().dataset().create(<dtag>,"LayeredShell");
model.result().dataset(<dtag>).set(property, <value>);
model.result().dataset(<dtag>).selection(...);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"LayeredShell")` creates a layered shell data set.

Layered shell data sets refer to another data set and are used to create a volume or domain (3D) data set corresponding to a layered shell physics defined using a surface or boundary (2D) geometry and a built-in extra dimension (1D) geometry. This data set is used to plot or evaluate the quantities on a domain level or its lower dimensions. This data set is called Layered Material in the Model Builder.

The following properties are available:

TABLE 7-50: VALID PROPERTY/VALUE PAIRS FOR LAYEREDSHELL DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	None	The data set that this data set refers to.
`evaluatein`	`meshnodes` | `interfaces` | `layermidplanes`	`meshnodes`	The location of layers to evaluate in: mesh nodes, interfaces, or layer midplanes.
`resolution`	Integer 1–10	1	Refinement level (1–10) when `evaluatein` is set to `meshnodes`.

TABLE 7-50: VALID PROPERTY/VALUE PAIRS FOR LAYEREDSHELL DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
scale	scalar	1	Scale factor for the layers.
seplevels	true | false	false	Separate the levels to create slices on the mesh nodes in the through-thickness direction when evaluatein is set to meshnodes.

LayeredShellSlice

Create a layered shell slice plot.

The LayeredShellSlice plot requires a license for the Composite Materials Module, AC/DC Module, or Heat Transfer Module.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"LayeredShellSlice");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"LayeredShellSlice")` creates a layered shell slice plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

A layered shell slice plot displays a layered shell quantity on a slice created at a specified through thickness location in 3D.

The following properties are available:

TABLE 7-51: VALID PROPERTY/VALUE PAIRS FOR LAYERED SHELL SLICE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this surface.
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.

TABLE 7-51: VALID PROPERTY/VALUE PAIRS FOR LAYERED SHELL SLICE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that color, color range, height scale, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
localzphys	scalar	0	The local z-coordinate, when locdef is set to physical.
localzrel	scalar -1–1	0	The local relative z-coordinate, when locdef is set to relative.
locdef	reference | physical | relative	reference	The location definition: a reference surface, physical z-coordinate, or a relative z-coordinate.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.

TABLE 7-51: VALID PROPERTY/VALUE PAIRS FOR LAYERED SHELL SLICE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
prefixintitle	String	Empty	Added prefix to contribution to title.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.

TABLE 7-51: VALID PROPERTY/VALUE PAIRS FOR LAYERED SHELL SLICE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
wireframe	on | off	off	Whether to plot filled elements or only their edges.

ATTRIBUTES

Deform, Filter, Selection

SEE ALSO

Surface

Line

Create a line plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Line");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Line")` creates a line plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Line plots display a quantity on lines, curves and edges in 2D or 3D.

The following properties are available:

TABLE 7-52: VALID PROPERTY/VALUE PAIRS FOR LINE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this line plot.
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.

TABLE 7-52: VALID PROPERTY/VALUE PAIRS FOR LINE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
inheritplot	none | plot name	none	The plot that color, color range, tube scale, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inherittubescale	Boolean	true	If inheritplot is not none and linetype is tube: Determines if the tube scale is inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
linetype	line | tube	line	Plot lines or tubes.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title
radiusexpr	String	1	The tube radius. Active when linetype is tubes.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).

TABLE 7-52: VALID PROPERTY/VALUE PAIRS FOR LINE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
tuberadiusscale	double	1	The scale factor applied to the tube radii if tuberadiusscaleactive is true.

TABLE 7-52: VALID PROPERTY/VALUE PAIRS FOR LINE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
tuberadiusscaleactive	Boolean	false	If true, tuberadiusscale is used, otherwise the scale factor is computed automatically.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
wireframe	on | off	off	Whether to plot filled elements or only their edges.

ATTRIBUTES

Deform, Filter, Height, AberrationHeight, HistogramHeight, TableHeight

EXAMPLES

Line plot on 2D solution:

Code for Use with Java

```
DatasetFeature ds = model.result().dataset().create("dset1", "Solution");
ds.set("solution", "sol1");

ResultFeature pg = model.result().create("pg1",2);
pg.set("data","dset1");
pg.create("line1","Line");
pg.feature("line1").set("expr", "3*u");
```

Code for Use with MATLAB

```
ds = model.result.dataset.create('dset1', 'Solution');
ds.set('solution', 'sol1');

pg = model.result.create('pg1',2);
pg.set('data','dset1');
pg.create('line1','Line');
pg.feature('line1').set('expr', '3*u');
```

Line plot on cut plane in 3D, using the Thermal color table:

Code for Use with Java

```
DatasetFeature ds2 = model.result().dataset().create("cp1", "CutPlane");
ds2.set("data", "dset2");

ResultFeature pg2 = model.result().create("pg2",3);
pg2.create("line2","Line");
pg2.feature("line2").set("data", "cp1");
pg2.feature("line2").set("expr", "2*u");
pg2.feature("line2").set("colortable", "Thermal");

pg2.run();
```

Code for Use with MATLAB

```
ds2 = model.result.dataset.create('cp1', 'CutPlane');
ds2.set('data', 'dset2');

pg2 = model.result.create('pg2',3);
```

```
pg2.create('line2','Line');
pg2.feature('line2').set('data', 'cp1');
pg2.feature('line2').set('expr', '2*u');
pg2.feature('line2').set('colortable', 'Thermal');

pg2.run;
```

SEE ALSO

LineGraph

LineData

Create a line data plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"LineData");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"LineData")` creates a line data plot feature named *<ftag>* belonging to the 2D or 3D plot group *<pgtag>*.

Line data plots are used to visualize raw point data given as points, elements, and colors as line segments (see the examples below). Line data plots can be added to 2D and 3D plot groups.

The following properties are available:

TABLE 7-53: VALID PROPERTY/VALUE PAIRS FOR LINE DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
colordata	double 1D array		The color data for the line data plot as a real N-vector.
coloring	colortable | uniform	uniform	How to color the lines.
colorlegend	on | off	on	Whether to show color legend when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
description	String		A label showing a short description of the stored data.

TABLE 7-53: VALID PROPERTY/VALUE PAIRS FOR LINE DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`elementdata`	integer 2D array		The element data for the line data plot, providing connections between the points. The data is an (edim+1)-by-M integer matrix with values that are 0-based indices into `pointdata`. The right-hand rule defines the normal direction in 3D. In 2D the order does not matter.
`pointdata`	double 2D array		The point data for the line data plot, as x and y coordinates in 2D and x, y, and z coordinates in 3D in an sdim-by-N real matrix.
`rangecoloractive`	`on` | `off`	`off`	Whether to use the manual color range specified in `rangecolormin` and `rangecolormax`. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
`rangecolormax`	double	Plot-dependent	The maximum color range value. Active when `rangecoloractive` is on.
`rangecolormin`	double	Plot-dependent	The minimum color range value. Active when `rangecoloractive` is on.
`rangedatactive`	`on` | `off`	`off`	Whether to use the manual data range specified in `rangedatamin` and `rangedatamax`. Values outside the data range are not plotted.
`rangedatamax`	double	Plot-dependent	The maximum data value. Active when `rangedataactive` is on.
`rangedatamin`	double	Plot-dependent	The minimum data value. Active when `rangedataactive` is on.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `manual` | `none`	`none`	`auto` if the title contribution should be computed automatically. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.

ATTRIBUTES

None.

EXAMPLES

A method for creating a line data plot in 2D for data representing a sine curve $(x, \sin(x))$:

Code for Use with Java

```
ResultFeature pg = m.result().create("pg1", 2);
ResultFeature plot = pg.create("line1", "LineData");
int N = 100;
double[][] p = new double[2][N];
int[][] t = new int[2][N - 1];
double[] color = new double[N];
for (int i = 0; i < N; i++) {
  double x = 4 * Math.PI * i / N;
  p[0][i] = x;
```

```
  p[1][i] = Math.sin(x);
  if (i > 0) {
    t[0][i - 1] = i - 1;
    t[1][i - 1] = i;
  }
}
plot.set("pointdata", p)
    .set("elementdata", t)
    .set("colordata", color);
plot.run();
```

A method for creating a line data plot in 3D for data representing a curve $(x, x^{1.3}, x^{1.6})$:

Code for Use with Java

```
pg = m.result().create("pg2", 3);
plot = pg.create("line1", "LineData");
p = new double[3][N];
t = new int[2][N - 1];
color = new double[N];
for (int i = 0; i < N; i++) {
  p[0][i] = i;
  p[1][i] = Math.pow(i, 1.3);
  p[2][i] = Math.pow(i, 1.6);
  if (i > 0) {
    t[0][i - 1] = i - 1;
    t[1][i - 1] = i;
  }
}
plot.set("pointdata", p)
    .set("elementdata", t)
    .set("colordata", color);
plot.run();
```

SEE ALSO

AnnotationData, ArrowData, PointData, SurfaceData, TubeData

LineGraph

Create a line graph plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"LineGraph");
model.result(<pgtag>).feature(<ftag>).selection(...);
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"LineGraph")` creates a line graph plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

A line graph plot is used to visualize quantities on lines, either cut lines or boundaries (2D) and edges (3D) in a geometry. Line graph plots can be added to 1D plot groups.

The following properties are available:

TABLE 7-54: VALID PROPERTY/VALUE PAIRS FOR LINE GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
autodescr	on | off	Model dependent	Whether the automatic legends should include the expression descriptions.
autoexpr	on | off	Model dependent	Whether the automatic legends should include the expressions.
autolegends	on | off	on	Whether to use the automatically computed legends or the legends defined in the legends property.
autounit	on | off	off	Whether the automatic legends should include the unit.
const	String array of property/value pairs	Empty	Parameters to use in the expressions
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
legend	on | off	off	Whether to show legends
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legendprefix	String		A prefix added to the automatic legend.

TABLE 7-54: VALID PROPERTY/VALUE PAIRS FOR LINE GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
`legends`	String array	The last computed automatic legends	Manual legends active when `legendmethod` is set to `manual`.
`legendsuffix`	String		A suffix added to the automatic legend.
`linecolor`	`custom` | `cycle` | `black` | `blue` | `cyan` | `gray` | `green` | `magenta` | `red` | `white` | `yellow`	`cycle`	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
`linewidth`	double	`0.5`	The line width.
`linemarker`	`none` | `cycle` | `asterisk` | `circle` | `diamond` | `plus` | `point` | `square` | `star` | `triangle`	`none`	The line markers, if any. Cycle indicates that the marker is different for each line.
`looplevel`	integer row matrix	`All solutions` on all levels	The solutions to use, per level.
`looplevelindices`	integer row matrix	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `looplevelinput` is `manualindices` on a level.
`looplevelinput`	String array with `all` | `first` | `last` | `manual` | `manualindices` | `interp` on each level	`all` on all levels	How to input the solution to use, per level. `manual` on a level indicates that `looplevel` is used on that level. `manualindices` on a level indicates that `looplevelindices` is used on that level. `interp` on a level indicates that `interp` is used on that level.
`markerpos`	`interp` | `datapoints`	`interp`	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in `markers`). Markers are visible when `linemarker` is set.
`markers`	integer	8	The number of markers to show. Markers are visible when `linemarker` is set.
`linestyle`	`none` | `cycle` | `solid` | `dotted` | `dashed` | `dashdot`	`solid`	The line style, if any. Cycle indicates that the line style is different for each line.
`outerinput`	`all` | `first` | `last` | `manual` | `manualindices`	`all`	How to input the outer solutions to use. Applicable only for parametric sweep models. `manual` indicates that `outersolnum` is used. `manualindices` indicates that `outersolnumindices` is used.
`outersolnum`	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the `solnum` property is not used.

TABLE 7-54: VALID PROPERTY/VALUE PAIRS FOR LINE GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
plotonsecyaxis	Boolean	true	Plot on secondary y-axis, if twoyaxes is set to true in the parent plot group.
prefixintitle	String	Empty	Added prefix to contribution to title.
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
solnum	integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

TABLE 7-54: VALID PROPERTY/VALUE PAIRS FOR LINE GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
xdata	arc | reversedarc | expr	solution	x-axis data. expr uses the expression in xdataexpr. arc uses the curve's arc length, and reversedarc uses the arc length measured from the curve's endpoint.
xdataexpr	String	Model-dependent	Expression for x-axis data
xdatadescr	String	Model-dependent	Description of expression in xdataexpr.
xdataunit	String	Model-dependent	The unit to use for the expression in xdataexpr. If the old unit is not valid when the expression changes, the unit property is reset to default.

ATTRIBUTES

Color, Filter

SEE ALSO

Line

MatrixHistogram

Create a matrix histogram plot for 2D plot groups.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"MatrixHistogram");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"MatrixHistogram")` creates a histogram plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Use a matrix histogram if you have a precomputed matrix that you want to visualize as a 2D histogram. For example, in a fatigue analysis, you can use it for rainflow counting to visualize the distribution of stress amplitudes and mean stresses. The matrix then contains data points in the *xy*-plane, where the *x*- and *y*-values are stresses. Matrix histogram plots can be added to 2D plot groups.

The following properties are available:

TABLE 7-55: VALID PROPERTY/VALUE PAIRS FOR MATRIX HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
axisunit	String	Empty	Unit for the histogram axes.
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color the slices.
colorlegend	on | off	on	Whether to show color legend when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.

TABLE 7-55: VALID PROPERTY/VALUE PAIRS FOR MATRIX HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable
const	String array of property/ value pairs	Empty	Parameters to use in the expressions.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal|lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
innerinput	all | first | last | manual|manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	integer row matrix	all on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices|interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.

TABLE 7-55: VALID PROPERTY/VALUE PAIRS FOR MATRIX HISTOGRAM PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
prefixintitle	String	Empty	Added prefix to contribution to title
solnum	integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title.	The title to use when titletype is manual
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
xdata	String	Empty	Data for the histogram's x-axis.
ydata	String	Empty	Data for the histogram's y-axis.

ATTRIBUTES

Height, AberrationHeight, HistogramHeight, TableHeight

SEE ALSO

Histogram

MaxMinVolume, MaxMinSurface, MaxMinLine, MaxMinPoint

Create max/min marker plots.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"MaxMinVolume");
model.result(<pgtag>).create(<ftag>,"MaxMinSurface");
model.result(<pgtag>).create(<ftag>,"MaxMinLine");
model.result(<pgtag>).create(<ftag>,"MaxMinPoint");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"MaxMinVolume")` creates a max/min marker plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

This plot type displays the maximum and minimum of an expression and the points there they are attained.

The following properties are available:

TABLE 7-56: VALID PROPERTY/VALUE PAIRS FOR MAX/MIN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
backgroundcolor	none | custom | black | blue | cyan | gray | green |magenta | red | white | yellow	none	The color to use for a background rectangle, or none for no background.
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	black	The color with which markers are plotted.
const	String array of property/ value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color	The color to use when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
display	minmax | min | max	minmax	The selection determines which markers are shown.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.

TABLE 7-56: VALID PROPERTY/VALUE PAIRS FOR MAX/MIN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
expr	String		The expression to compute the maximum and minimum for.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritbackgroundcolor	Boolean	true	If inheritplot is not none: Determines if the background color is inherited.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that the color and deformation scale are inherited from.
labelprefix	String		Add an optional prefix to the maximum and minimum labels.
labelsuffix	String		Add an optional suffix to the maximum and minimum labels.
precision	integer > 0	6	The number of decimals displayed in the labels in the GUI.
prefixintitle	String	Empty	Added prefix to contribution to title.
refine	integer > 0	2	The number of refinements of each mesh element when computing the maximum and minimum.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
showframe	true | false	false	Show a rectangular frame around the maximum and minimum values.
suffixintitle	String	Empty	Added suffix to contribution to title.
title	String	The auto-title	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

ATTRIBUTES

Deform

Find extremal values (maximum or minimum).

SYNTAX

```
model.result().numerical().create(<ftag>,"MaxVolume");
model.result().numerical().create(<ftag>,"MinVolume");
model.result().numerical().create(<ftag>,"MaxSurface");
model.result().numerical().create(<ftag>,"MinSurface");
model.result().numerical().create(<ftag>,"MaxLine");
model.result().numerical().create(<ftag>,"MinLine");
model.result().numerical(<ftag>).selection(...);
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace `numerical(<ftag>)` with `evaluationGroup(<ftag>)`.

DESCRIPTION

`model.result().numerical().create(<ftag>,"MaxVolume")` creates a volume maximum feature with the name *<ftag>*, and similarly for `"MinVolume"`.

`model.result().numerical().create(<ftag>,"MaxSurface")` creates a surface maximum feature with the name *<ftag>*, and similarly for `"MinSurface"`.

`model.result().numerical().create(<ftag>,"MaxLine")` creates a line maximum feature with the name *<ftag>*, and similarly for `"MinLine"`.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that one row contains data for all solution numbers. This is identical to `(columnwise)` when `columnwise` is `false`. If `columnwise` is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(allocate, columnwise)` returns the imaginary part of complex result, recomputing the feature if necessary. If `allocate` is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses `allocate true` and `columnwise false`.

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-57: VALID PROPERTY/VALUE PAIRS FOR MAXIMUM AND MINIMUM

NAME	VALUE	DEFAULT	DESCRIPTION
`const`	String array of property/value pairs	Empty	Parameters to use in the expressions.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`dataseries`	`average` | `integral` | `maximum` | `minimum` | `none` | `rms` | `stddev` | `variance`	`none`	The operation that is applied to the data series formed by the evaluation.
`dataseriesmethod`	`auto` | `integration` | `summation`	`auto`	The method to use for the data series: automatic, integration, or summation.
`descr`	String array	Model-dependent	The descriptions of the expressions in `expr`. Is used in the automatic title.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String array	Model-dependent	The expressions to plot.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	integer row matrix	`All solutions` on all levels	The solutions to use, per level.
`looplevelindices`	integer row matrix	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `looplevelinput` is `manualindices` on a level.
`looplevelinput`	String array with `all` | `first` | `last` | `manual` | `manualindices` | `interp` on each level	`all` on all levels	How to input the solution to use, per level. `manual` on a level indicates that `looplevel` is used on that level. `manualindices` on a level indicates that `looplevelindices` is used on that level. `interp` on a level indicates that `interp` is used on that level.

TABLE 7-57: VALID PROPERTY/VALUE PAIRS FOR MAXIMUM AND MINIMUM

NAME	VALUE	DEFAULT	DESCRIPTION
obj	abs | real	real	The function of each real or complex number that is maximized/minimized.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
refine	nonnegative integer	1	The element refinement to use. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
solnum	nonnegative integer array	All solutions	The solutions to use.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
t	double array	Empty	The times to use. Available when the underlying solution is transient.
table	new | table name	new	The table to use when calling setResult() or appendResult(). new indicates that a new table is created.
tablecols	inner | outer | data | level*1*	data	Whether to use inner or outer solutions as columns in the table when calling setResult() or appendResult(). Applicable only for parametric sweep models. The level values (level1, level2, and so on) are the levels in the parametric sweep.

TABLE 7-57: VALID PROPERTY/VALUE PAIRS FOR MAXIMUM AND MINIMUM

NAME	VALUE	DEFAULT	DESCRIPTION
`timeinterp`	`on` | `off`	`off`	`on` if `t` is used to determine time steps, `off` if `solnum` is used.
`unit`	String array	Model-dependent	The units to use for the expressions in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

SEE ALSO

`IntVolume, IntSurface, IntLine`

Mesh

Create a mesh plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Mesh");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Mesh")` creates a mesh plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

This plot type provides visualization of meshes.

The following properties are available:

TABLE 7-58: VALID PROPERTY/VALUE PAIRS FOR MESH PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`colorlegend`	`on` | `off`	`on`	Whether to show color legend when `elemcolor` is set to `quality` or `size`.
`colortablerev`	`on` | `off`	`on`	Whether to reverse to color table when `elemcolor` is set to `quality` or `size`.
`colortable`	color table name	`TrafficLight`	The element color table to use when `elemcolor` is set to `quality` or `size`. See Color Tables for a list of color tables. 2D and 3D only.
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to
`elemcolor`	`quality` | `size` | color	`quality`	How to color the elements 2D and 3D only. The default, `quality`, uses a mesh quality measure. `size` colors the elements according to the local mesh element size.
`elemfilter`	`random` | `quality` | `qualityrev` | `size` | `expression` | `logicalexpression`	`random`	If `filteractive` is on: The expression to use for filtering when only a subset of the elements are shown. 2D and 3D only.
`elemscale`	double in [0,1]	1	The factor with which the elements are scaled before display. 2D and 3D only.

TABLE 7-58: VALID PROPERTY/VALUE PAIRS FOR MESH PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
elemtype2	all | tri | quad	all	2D mesh element types to plot
elemtype3	all | tet | pyr | prism | hex	all	3D mesh element types to plot: all, tetrahedron, pyramid, prism, or hex.
filteractive	on | off	off	Whether to use element filtering
filterexpr	String	x	The expression to use for filtering when elemfilter is set to expression. 2D and 3D only.
logfilterexpr	String	'1'	The logical expression to use for filtering when elemfilter is set to 'logicalexpression'. 2D and 3D only.
meshdomain	all | point | edge | surface | volume (if 3D)	all	Mesh domain level(s) to plot. 2D and 3D only.
plotonsecyaxis	Boolean	true	Plot on secondary y-axis, if twoyaxes is set to true in the parent plot group. For 1D graph plots only.
qualexpr	String		A custom expression for a mesh quality measure (used when qualmeasure is set to custom).
qualmeasure	skewness | maxangle | volcircum | vollength | condition | growth | custom	skewness	The mesh quality measure used when plotting the mesh quality: equiangular skewness, maximum angle, volume versus circumradius, volume versus length, condition number, element growth rate, or a custom expression.
tetkeep	Double in [0, 1]	1	The fraction of the elements to display. 2D and 3D only.
title	String	The auto-title	The title to use when titletype is manual. 2D and 3D only.
titletype	auto | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. manual if the manual title should be used (the title property). none if no title should be displayed. 2D and 3D only.
wireframecolor	none | color	black	How to color the wireframe mesh; 'none' means that it is not displayed at all. 2D and 3D only.
1dfilter	size | none	none	Plot the mesh size as the y-axis data. 1D only.

ATTRIBUTES

Deform, Filter

SEE ALSO

Mesh (Data Set)

Mesh (Data Set)

Create a mesh data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Mesh");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Mesh")` creates a mesh data set feature named *<dtag>*.

This data set provides support for evaluation of spatial coordinates and mesh variables on a mesh.

The following properties are available:

TABLE 7-59: VALID PROPERTY/VALUE PAIRS FOR MESH DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
mesh	String	Empty	The mesh that this data set refers to.

SEE ALSO

Mesh

Mesh (Export)

Export a mesh.

SYNTAX

```
model.result().export().create(<ftag>,"Mesh");
model.result().export().create(<ftag>,<dtag>,"Mesh");
model.result().export(<ftag>).set(property, <value>);
model.result().export(<ftag>).run();
```

DESCRIPTION

`model.result().export().create(<ftag>,"Mesh")` creates a mesh export feature with the name *<ftag>*.

`model.result().export().create(<ftag>,<dtag>,"Mesh")` creates a mesh export feature with the name *<ftag>* for the data set *<dtag>*.

The following properties are available:

TABLE 7-60: VALID PROPERTY/VALUE PAIRS FOR MESH EXPORT

PROPERTY	VALUE	DEFAULT	DESCRIPTION
alwaysask	on | off	off	Always ask for filename when saving. This property is ignored when running without a GUI.
data	String		The name of the data set to export.
filename	String		The output file.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
solnum	integer array		Solution number to take values from.
stlformat	binary | text	binary	STL file format.
t	String		Time to evaluate in if timeinterp is on.
timeinterp	on | off	off	Enable/disable explicit time to evaluate in.

SEE ALSO

Data

Create 2D and 3D mirror data sets.

SYNTAX

```
model.result().dataset().create(<dtag>,"Mirror2D");
model.result().dataset().create(<dtag>,"Mirror3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Mirror2D")` creates a 2D mirror data set feature named *<dtag>*.

`model.result().dataset().create(<dtag>,"Mirror3D")` creates a 3D mirror data set feature named *<dtag>*.

This data set takes data from another data set and adds a mirror copy with respect to an axis or plane of reflection (for 2D and 3D, respectively).

The following properties are available for Mirror 2D and Mirror 3D:

TABLE 7-61: VALID PROPERTY/VALUE PAIRS FOR MIRROR DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to
`genpoints`	double matrix	{{0, 0, 0}, {1,0,0}}	Active when `method` equals `twopoint`, this property contains the coordinates of the two points in the two rows of the matrix.
`hasvar`	Boolean	`false`	If true, space and axis indicator variables are defined
`method`	`twopoint` | `pointdir`	`twopoint`	Decides if the line should be specified by two points or through one point and a direction
pddir	String array	`{"0","1"}`	Active when `method` equals `pointdir`, this property contains the direction.
pdpoint	String array	`{"0","0"}`	Active when `method` equals `pointdir`, this property contains the coordinates of the point.
`sidevar`	String		If hasvar is true: The name of the positive side variable, which is 1 on the side where the original data resides and 0 on the other side.
`spacevars`	String array	Depends on the feature's tag	If hasvar is true: The name of space variables, which evaluate to the coordinates after the transformation performed by the mirror data set.
`vectortrans`	`symmetric` | `antisymmetric`	`symmetric`	Use a symmetric or antisymmetric vector transformation for the mirror operation.

The following properties are available for Mirror 3D:

TABLE 7-62: VALID PROPERTY/VALUE PAIRS

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | data set name	First compatible data set	The data set this feature refers to
genmethod	threepoint | pointnormal	threepoint	Active when planetype equals general, this property indicates whether the plane should be specified by three points or through one point and a normal.
genpoints	double matrix	{{0, 0, 0}, {1,0,0}, {0,1,0}}	Active when method equals threepoint, this property contains the coordinates of the three points in the rows of the matrix.
genpnpoint	String array of length three	Zero string vector	Active when genmethod equals pointnormal, this property contains the coordinates of the point.
genpnvec	String array of length three	Zero string vector	Active when genmethod equals pointnormal, this property contains the normal vector.
hasvar	Boolean	false	If true, space and axis indicator variables are defined
planetype	quick | general	yz	Specify plane type
quickplane	xy | yz | zx	yz	Specify quick plane type. Active when planetype is quick.
quickx	String	"0"	x-coordinate if planetype is yz
quicky	String	"0"	y-coordinate if planetype is zx
quickz	String	"0"	z-coordinate if planetype is xy
sidevar	String		If hasvar is true: The name of the positive side variable, which is 1 on the side where the original data resides and 0 on the other side.
spacevars	String array	Depends on the feature's tag	If hasvar is true: The names of space variables, which evaluate to the coordinates after the transformation performed by the mirror data set.

Multislice

Create a slice plot in multiple directions at once.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Multislice");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Multislice")` creates a slice feature in multiple directions named *<ftag>* belonging to the plot group *<pgtag>*.

The following properties are available:

TABLE 7-63: VALID PROPERTY/VALUE PAIRS FOR MULTISLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color the slices.
colorlegend	on | off	on	Whether to show color legend when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that color, color range, and deformation scale are inherited from.

TABLE 7-63: VALID PROPERTY/VALUE PAIRS FOR MULTISLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
multiplanexmethod	number | coord	number	Indicates whether the x-coordinates of the x-planes should be specified by number of planes to distribute evenly across the data or by coordinates.
multiplaneymethod	number | coord	number	Indicates whether the y-coordinates of the y-planes should be specified by number of planes to distribute evenly across the data or by coordinates.
multiplanezmethod	number | coord	number	Indicates whether the z-coordinates of the z-planes should be specified by number of planes to distribute evenly across the data or by coordinates.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.

TABLE 7-63: VALID PROPERTY/VALUE PAIRS FOR MULTISLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
suffixintitle	String	Empty	Added suffix to contribution to title
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual

TABLE 7-63: VALID PROPERTY/VALUE PAIRS FOR MULTISLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom
xnumber	String	1	Number of planes in the x-direction. Active when multiplanexmethod is set to number.
xcoord	String array	Empty	Absolute coordinates in the x-direction, active when multiplanexmethod is set to coord
ynumber	String	1	Number of planes in the y-direction. Active when multiplaneymethod is set to number
ycoord	String array	Empty	Absolute coordinates in the z-direction, active when multiplaneymethod is set to coord
znumber	String	1	Number of planes in the z-direction. Active when multiplanezmethod is set to number
zcoord	String array	Empty	Absolute coordinates in the z-direction, active when multiplanezmethod is set to coord.

ATTRIBUTES

Deform, Filter

SEE ALSO

Slice, Volume

Nyquist

Create a Nyquist plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Nyquist");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Nyquist")` creates a Nyquist plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Nyquist plots are used to visualize complex-valued variables. Nyquist plots can be added to 1D plot groups.

The following properties are available:

TABLE 7-64: VALID PROPERTY/VALUE PAIRS FOR NYQUIST PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`autodescr`	`on` | `off`	`Model dependent`	Whether the automatic legends should include the expression descriptions.
`autoexpr`	`on` | `off`	`Model dependent`	Whether the automatic legends should include the expressions.
`autolegends`	`on` | `off`	`on`	Whether to use the automatically computed legends or the legends defined in the `legends` property. The automatic legends display the description and expression for each line.
`autounit`	`on` | `off`	`off`	Whether the automatic legends should include the unit.
`const`	String array of property/value pairs	`Empty`	Parameters to use in the expressions.
`customlinecolor`	RGB-triplet	`{0,0,1} or last used edgecolor.`	The color to use for the lines. Active when `linecolor` is set to `custom`.
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to.
`descr`	String array	Model-dependent.	The description of the expressions in `expr`. Is used in the automatic legends.
`descriptionintitle`	`on` | `off`	`on`	Whether the title contribution should contain the description when `titletype` is `custom`.
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String array	Model-dependent.	The expressions to plot.
`expressionintitle`	`on` | `off`	`off`	Whether the title contribution should contain the expression when `titletype` is `custom`.
`legend`	`on` | `off`	`off`	Whether to show legends.
`legendmethod`	`automatic` | `manual`	`automatic`	Whether to use the automatic legends or the legends supplied in the `legends` property.
`legendprefix`	String		A prefix added to the automatic legend.

TABLE 7-64: VALID PROPERTY/VALUE PAIRS FOR NYQUIST PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
legendsuffix	String		A suffix added to the automatic legend.
linecolor	custom | cycle | cyclereset | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line. Use cyclereset to restart the cycling of colors from the first color.
linewidth	double	0.5	The line width.
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
prefixintitle	String	Empty	Added prefix to contribution to title
solnum	nonnegative integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
suffixintitle	String	Empty	Added suffix to contribution to title
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title.	The title to use when titletype is manual.

TABLE 7-64: VALID PROPERTY/VALUE PAIRS FOR NYQUIST PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String array	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitcircle	Boolean	false	Whether to plot the unit circle along with the axis.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

OctaveBand

Create an Octave Band Plot.

The Octave Band Plot requires a license for the Acoustics Module.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"OctaveBand");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"OctaveBand")` creates an octave band plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

The octave band plots a weighted frequency response in bands (octave or 1/3 octave) or as a continuous frequency response. The frequency can be weighted.

The following properties are available:

TABLE 7-65: VALID PROPERTY/VALUE PAIRS FOR OCTAVE BAND PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
amplref	double	1	Reference level for the amplitude expression type.
const	String array of property/ value pairs	Empty	Parameters to use in the expressions.
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.

TABLE 7-65: VALID PROPERTY/VALUE PAIRS FOR OCTAVE BAND PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
expr	String	Model-dependent.	The expression used to transform the input to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
exprtype	amplitude | power | transfer	amplitude	Type of expression: amplitude, power, or transfer function.
inband	on | off	on	Whether to use in-band data only.
innerinput	all | first | last | manual|manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
legend	on | off	off	Whether to show legends.
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
levelref	double	0	Reference level for the transfer function expression type.
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
linewidth	double	0.5	The line width.
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.

TABLE 7-65: VALID PROPERTY/VALUE PAIRS FOR OCTAVE BAND PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
powerref	double	1	Reference level for the power expression type.
prefixintitle	String	Empty	Added prefix to contribution to title
sdim	fromdataset | 0 | 1 | 2 | 3	fromdataset	The space dimension to evaluate the underlying data set in
solnum	integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
style	continuous | octave | octave3	octave	Octave band style: continuous, octave bands, or 1/3 octave bands.
suffixintitle	String	Empty	Added suffix to contribution to title

TABLE 7-65: VALID PROPERTY/VALUE PAIRS FOR OCTAVE BAND PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
title	String	The auto-title.	The title to use when titletype is manual
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
type	curve | solid	curve	Use a filled histogram (solid) or a histogram drawn using lines (curve). This property is only available when function is discrete.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
weightexpr	expression		Value or expression to use as weighting.
weighting	a | c | z | expression	z	Weighting function for octave band plot: A-weighting, C-weighting, Z-weighting, or a user-defined expression.

OpticalAberration

Plot various types of monochromatic aberration that arise when electromagnetic rays are focused by a system of lenses and mirrors.

The Optical Aberration plot is available with the Ray Optics Module.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"OpticalAberration");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"OpticalAberration")` creates an optical aberration plot feature named *<ftag>* belonging to the plot group *<pgtag>*. The optical aberration plot is used to visualize various types of monochromatic aberration. Optical aberration plots can be added to 2D plot groups.

The following properties are available:

TABLE 7-66: VALID PROPERTY/VALUE PAIRS FOR OPTICAL ABERRATION PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this surface.
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.

TABLE 7-66: VALID PROPERTY/VALUE PAIRS FOR OPTICAL ABERRATION PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to, which must be an Intersection Point 3D data set. This Intersection Point 3D data set should describe the intersection points of rays with a Gaussian reference hemisphere centered at the focus.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritplot	none | plot name	none	The plot that color and color range are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
lunit	Any length unit	\u00b5m (micron)	Length unit for plotting combinations of Zernike polynomials.
maxorder	2, 3, 4, or 5	5	Maximum polynomial order for the Zernike coefficients calculation,
ngrid	int	1000	The number of grid points to plot on the unit circle when rendering the optical aberration plot. Use an integer value between 100 and 1,000,000.
posexpr	String array	("0","0")	Position of the center of the unit circle in which the Zernike polynomials are plotted. By specifying nonzero components for some instances of the Optical Aberration plot it is possible to display multiple such plots side-by-side in the Graphics window.
terms	all | higherorder | selectindividual	all	Terms in Zernike polynomial to include: all, higher-order terms, or individually selected terms.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
z00	Boolean	false	Include the z(0,0), piston term (if terms is set to selectindividual)

TABLE 7-66: VALID PROPERTY/VALUE PAIRS FOR OPTICAL ABERRATION PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
z1m1	Boolean	false	Include the z(1,-1), vertical tilt term (if terms is set to selectindividual)
z11	Boolean	false	Include the z(1,1), horizontal tilt term (if terms is set to selectindividual)
z2m2	Boolean	false	Include the z(2,-2), oblique astigmatism term (if terms is set to selectindividual)
z20	Boolean	false	Include the z(2,0), defocus term (if terms is set to selectindividual)
z22	Boolean	false	Include the z(2,2), astigmatism term (if terms is set to selectindividual)
z3m3	Boolean	false	Include the z(3,-3), oblique trefoil term (if terms is set to selectindividual)
z3m1	Boolean	false	Include the z(3,-1), vertical coma term (if terms is set to selectindividual)
z31	Boolean	false	Include the z(3,1), horizontal coma term (if terms is set to selectindividual)
z33	Boolean	false	Include the z(3,3), horizontal trefoil term (if terms is set to selectindividual)
z4m4	Boolean	false	Include the z(4,-4), oblique quatrefoil term (if terms is set to selectindividual)
z4m2	Boolean	false	Include the z(4,-2), oblique secondary astigmatism term (if terms is set to selectindividual)
z40	Boolean	false	Include the z(4,0), spherical aberration term (if terms is set to selectindividual)
z42	Boolean	false	Include the z(4,2), secondary astigmatism term (if terms is set to selectindividual)
z44	Boolean	false	Include the z(4,4), horizontal quatrefoil term (if terms is set to selectindividual)
z5m5	Boolean	false	Include the z(5,-5) term (if terms is set to selectindividual)
z5m3	Boolean	false	Include the z(5,-3) term (if terms is set to selectindividual)
z5m1	Boolean	false	Include the z(5,-1) term (if terms is set to selectindividual)
z51	Boolean	false	Include the z(5,1) term (if terms is set to selectindividual)
z53	Boolean	false	Include the z(5,3) term (if terms is set to selectindividual)
z55	Boolean	false	Include the z(5,5) term (if terms is set to selectindividual)

Parametric1D, Parametric2D

Extend a 1D or 2D data set by using a parameter as dimension.

SYNTAX

```
model.result().dataset().create(<dtag>,"Parametric1D");
model.result().dataset().create(<dtag>,"Parametric2D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Parametric2D")` creates a parametric data set feature named *<dtag>*. This data set extends a data set by using a parameter, such as time, as a dimension.

The following properties are available:

TABLE 7-67: VALID PROPERTY/VALUE PAIRS FOR THE PARAMETRIC1D AND PARAMETRIC2D DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`levelscale`	double	1	The scaling factor applied to the levels if levelscaleactive is true.
`levelscaleactive`	Boolean	`false`	If true, levelscale is used to scale the levels; otherwise the scale factor is computed automatically.
`leveltrans`	`none` | expression	`none`	Use an expression in terms of the level variable to define a level transformation.
`solnum`	Integer array	All solutions	The solutions to use for extrapolation.
`solnumindices`	String or integer array	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`t`	double array	Empty	The times to use as intermediate layers in the extrusion.
`transexpr`	String	`level`	Level transformation expression (as a function of `level`; the default value means no transformation).

ParCurve2D, ParCurve3D

Create a 2D or 3D parameterized curve data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"ParCurve2D");
model.result().dataset().create(<dtag>,"ParCurve3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"ParCurve2D")` creates a 2D parameterized curve data set feature named *<dtag>*.

`model.result().dataset().create(<dtag>,"ParCurve3D")` creates a 3D parameterized curve data set feature named *<dtag>*.

Evaluation is made along an arbitrary parameterized curve in 2D or 3D.

The following properties are available:Add option for evaluating outside the mesh:

TABLE 7-68: VALID PROPERTY/VALUE PAIRS FOR PARAMETERIZED CURVE DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
name	String	none	The name of this feature
bndsnap	Boolean	false	If true, each point is snapped to the closest boundary. Available in 3D only.
data	none | data set name	First compatible data set	The data set this feature refers to
global	boolean	false	If set to true, the data set only evaluates globally defined expressions
par1	String	t	The curve parameter
parmin1	double	0	The minimum value for par
parmax1	double	1	The maximum value for par
exprx	String	0	The expression for x(par)
expry	String	0	The expression for y(par)
exprz	String	0	The expression for z(par)
res	integer	1000	Resolution (number of discretization points along the curve)

The global property can be useful for BEM models, for example, to be able to evaluate globally defined expressions outside the mesh.

SEE ALSO

ParSurface

ParSurface

Create a parameterized surface data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"ParSurface");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"ParSurface")` creates a parameterized surface data set feature named *<dtag>*.

Evaluation is made along an arbitrary parameterized surface in 3D.

The following properties are available:

TABLE 7-69: VALID PROPERTY/VALUE PAIRS FOR A PARAMETERIZED CURVE DATA SET

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | data set name	First compatible data set	The data set this feature refers to
exprx	String	0	The expression for x(par1, par2)
expry	String	0	The expression for y(par1, par2)
exprz	String	0	The expression for z(par1, par2)
global	boolean	false	If set to true, the data set only evaluates globally defined expressions
par1	String	s	The first surface parameter
par2	String	t	The second surface parameter

TABLE 7-69: VALID PROPERTY/VALUE PAIRS FOR A PARAMETERIZED CURVE DATA SET

NAME	VALUE	DEFAULT	DESCRIPTION
parmin1	double	0	The minimum value for par1.
parmax1	double	1	The maximum value for par1
parmin2	double	0	The minimum value for par2
parmax2	double	1	The maximum value for par2
res	integer	200	Resolution (the number of discretization points for each parameter)

The `global` property can be useful for BEM models and for far-field postprocessing, for example, to be able to evaluate globally defined expressions outside the mesh.

SEE ALSO

`ParCurve2D, ParCurve3D`

Particle

Create a massless particle tracing plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Particle");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Particle")` creates a massless particle tracing plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

With massless particle tracing, you can visualize path lines, that is, trajectories of particles released in a flow field, which can be time-dependent or static. For time-dependent flows you can also use a snapshot in time of the flow field as a static field. The motion of the particles does not affect the flow field. Particle tracing is available in 2D and 3D plot groups.

The following properties are available:

TABLE 7-70: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
arrowbase	heat|tail|center	head	Whether the head, tail, or center of the arrow is located at the particle position.
arrowexpr	string array		Active when pointtype is set to arrow. Determines the direction in which the arrow points.
arrowlength	logarithmic|normalized|proportional	proportional	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
arrowscale	positive double	1	If arrowscalefactor is true: the length scale factor
arrowscaleactive	boolean	false	If true, arrowscale is used; otherwise the scale factor is computed automatically.
arrowtype	arrow | arrowhead | cone	arrow	The type of arrow to draw.

TABLE 7-70: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
atol	manual | automatic	automatic	Whether to specify a manual absolute tolerance for the position. automatic indicates that the absolute tolerance for the position is the mean of the lengths of the bounding box of the geometry multiplied by the relative tolerance.
atolpos	positive double	0.001	Absolute tolerance for the position. Active when atol is set to manual.
bndcoord	double array	0	Vector of values from 0 to 1 to describe the starting points. Active when bndmethod is set to coord. Available in 2D only.
bndmethod	number | coord	number	Active when posmethod is set to bnd. Available in 2D only.
bndnumber	positive integer	10	The number of equidistant starting points along the selected boundaries. Available in 2D only.
bndselection	Reference to a named selection on boundaries	First available named selection	The boundaries to start from. Available in 2D only.
comettailexpr	String array		Active when pointtype is set to comettail. Determines the direction in which the comet tail points.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customlinecolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use for lines. Active when linecolor is set to custom.
custompointcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use for points. Active when pointcolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expressions in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom
dropfreq	positive double	1	Particles are released at these intervals when dropmethod is set to freq.
dropmethod	once | freq | times	once	Method to use when releasing particles.
droptimes	double array	1	The specific times when to release particles. Used when dropmethod is set to times.
edgetol	positive double	0.001	The absolute tolerance controlling how close to the geometry boundary the path lines are cut when they exit the geometry. A lower value cuts the line closer to the geometry boundary.
expr	String array of length 2 in 2D and 3 in 3D	Model-dependent	Expressions for the components to plot.
hmax	double	0.1	The maximum time step. Active when stepsize is set to manual.

TABLE 7-70: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
hstart	double	0.1	The initial time step. Active when stepsize is set to manual.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if the arrow scale is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that sphere scale, tube scale, and deformation scale are inherited from.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the sphere scale is inherited.
inherittubescale	Boolean	true	If inheritplot is not none and linetype is tube: Determines if the tube scale is inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
linecolor	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	black (2D), red (3D)	The uniform color to use for lines.
linetype	none | line | tube	line	Plot particle traces as lines or tubes, or not at all.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
maxsteps	positive integer	1000	The maximum number of steps to use in the particle simulation. Active when maxstepsactive is set to on.
maxstepsactive	on | off	off	Whether to manually specify the maximum number of steps used in particle simulation. off indicates that the limit varies in this way: for static flow fields, the algorithm uses the value 1000; for time-dependent flows, there is no upper limit of the number of steps, and the particle simulation goes on until it reaches the end time.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.

TABLE 7-70: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
pointcolor	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use for points.
pointdom	disappear | stick	stick	stick plots the points on the boundary at the exit point, and disappear does not render these points at all.
pointlineanim	on | off	off	When animating particle tracing plots with points, this property indicates whether the points at the current time should appear on top of the lines.
pointautoscale	on | off	on	If enabled, the point radii are scaled so that the maximum radius is 0.01 of the plot scale.
pointradiusexpr	String	1	The point radius expression.
pointtype	none | point | comettail	none	Selects between plotting the path lines' endpoints as points, comet tails, or not at all.
posmethod	start | bnd	start	The type of particle tracing positioning. Choose specific starting points or a boundary to start from. Available in 2D only.
prefixintitle	String	Empty	Added prefix to contribution to title.
radiusexpr	String	1	The tube radius.
resolution	coarser | coarse | normal | fine | finer | extrafine		Affects the number of output points by adding points between each time step taken in the ODE solver, using a 4th-order interpolation, to produce a smoother output.
rtol	positive double	0.001	The relative error tolerance that the ODE solver uses.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
static	on | off	off	Only affects time-dependent problems. When set to on, this property freezes the time and considers this a static flow field.
statictend	double	1	The maximum time at which to end the particle-tracing simulation for static flow fields. Active when statictendactive is set to on.
statictendactive	on | off	off	Whether to specify the end time for static flow fields automatically. (For time-dependent flows, the automatic end time is the last time that the time-dependent solver returns.) When set to off, there is no upper limit of the time. In this case, the particle simulation goes on until all particles exit the geometry or the simulation reaches the maximum number of steps.

TABLE 7-70: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
stepsize	automatic | manual	automatic	Whether to specify initial (hstart) and maximum (hmax) time step manually.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
tailscale	positive double	1	Active when pointtype is set to comettail and tailscaleactive is on. Specifies the manual scale factor with which the comet tail expression is multiplied.
tailscaleactive	on | off	off	Active when pointtype is set to comettail. Specifies whether manual tail scaling is enabled.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
tstart	double	0	Manual start time. Active when tstartactive is set to on.
tstartactive	on | off	off	on indicates a manual start time (set in the tstart property). Off indicates that the start time becomes either the first time value that the time-dependent solver returns or 0 for stationary flows. Available when dropmethod is set to once or freq.
tubeautoscale	on | off	on	If enabled, the tube radii are scaled so that the maximum tube radius is 0.02 of the plot scale.
tvar	String	partt	The name of the variable for time. Normally there is no need to change the default name. You can use this names in expressions as well as for the color when coloring the path lines according to an expression.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
xcoord	double array	Empty	Absolute coordinates in the x-direction, active when posmethod is set to start.
ycoord	double array	Empty	Absolute coordinates in the y-direction, active when postmethod is set to start.
zcoord	double array	Empty	Absolute coordinates in the z-direction, active when posmethod is set to coord. Available in 3D only.

ATTRIBUTES

Color (applies to lines), Deform

SEE ALSO

ParticleMass, Streamline

Particle (1D Plot)

Create a particle plot, which plots particle properties over time or compares particle properties against each other at a set of time steps.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Particle1D");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Particle1D")` creates a particle plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

With the particle plot, you can plot properties of all particles in a data set versus time, or plot two particle properties against each other at a set of selected times. When plotting particle properties versus time, it is possible to apply data series operations to the particle data. The particle plot is available in 1D plot groups.

The following properties are available:

TABLE 7-71: VALID PROPERTY/VALUE PAIRS FOR PARTICLE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
autodescr	on | off	Model dependent	Whether the automatic legends should include the expression descriptions.
autoexpr	on | off	Model dependent	Whether the automatic legends should include the expressions.
autolegends	on | off	on	Whether to use the automatically computed legends or the legends defined in the legends property. The automatic legends display the description and expression for each line.
const	String array of property/ value pairs	Empty	Parameters to use in the expressions.
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
dataseries	none | average | sum | maximum | minimum | rms | stddev | variance	sum	The data series operation that is applied to all particles. Effective only when xdata is not expr.
descr	String array	Model-dependent.	The description of the expressions in expr. Is used in the automatic legends.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
expr	String array	Model-dependent.	The expressions to plot.

TABLE 7-71: VALID PROPERTY/VALUE PAIRS FOR PARTICLE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
legend	on | off	off	Whether to show legends.
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
linecolor	custom | cycle | black | blue | cyan | gray | green |magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the color is different for each line.
linewidth	double	0.5	The line width
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.

TABLE 7-71: VALID PROPERTY/VALUE PAIRS FOR PARTICLE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
prefixintitle	String	Empty	Added prefix to contribution to title.
solnum	nonnegative integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

TABLE 7-71: VALID PROPERTY/VALUE PAIRS FOR PARTICLE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
xdata	expr | solution	solution	x-axis data. expr uses the expression in xdataexpr. solution uses the available solutions in the underlying data set, such as time steps.
xdataexpr	String	Model-dependent	Expression for x-axis data
xdatadescr	String	Model-dependent	Description of expression in xdataexpr
xdataphaseunit	String	rad	The unit in which xdataphaserange is described
xdatasolnumtype	all | inner | outer | valid level	outer	Whether the expression should be evaluated for every inner or every outer solution, or for a specific level (level1, level2, and so on). Applicable only for models containing multiple levels.
xdataunit	String	Model-dependent	The unit to use for the expression in xdataexpr. If the old unit is not valid when the expression changes, the unit property is reset to default.

ATTRIBUTES

Color (applies to lines), Filter (Particle Tracing, Point Trajectories, Ray Tracing,).

SEE ALSO

Particle (Evaluation), ParticleTrajectories, ParticleBin

Particle (Data Set)

Create a particle data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Particle");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Particle")` creates a particle data set.

A particle data set is required to plot particle trajectories. The particle data set identifies the geometry in which the particle data is stored and the degrees of freedom which determine the position of each particle.

The following properties are available:

TABLE 7-72: VALID PROPERTY/VALUE PAIRS FOR PARTICLE DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
solution	String	first available solution	The solution this data set refers to.
pgeomspec	manual | fromphysics	manual	The method of specifying the particle geometry and the names of the particle position degrees of freedom.

TABLE 7-72: VALID PROPERTY/VALUE PAIRS FOR PARTICLE DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
physicsinterface	none or the tag of a valid physics interface	none	The physics interface from which the particle geometry and the names of the particle position degrees of freedom are defined.
pgeom	String	pgeom	The geometry in which the particle degrees of freedom are defined. The correct name of this particle geometry is pgeom_*<tag>*, where *<tag>* is the name for the Particle Tracing interface node.
posdof	String array	mod1.qx, mod1.qy	The position degrees of freedom of the particles.

SEE ALSO

Particle (Evaluation)

Particle (Evaluation)

Particle evaluations to evaluate quantities on particle trajectories.

SYNTAX

```
model.result().numerical().create(<ftag>,"Particle");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace `numerical(<ftag>)` with `evaluationGroup(<ftag>)`.

DESCRIPTION

`model.result().numerical().create(<ftag>,"Particle")` creates a particle evaluation feature with the name *<ftag>*. Particle evaluation can be performed on trajectories accessed through a particle data set.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that there is one row per point, with one row containing data for all solution numbers. This is identical to `(<columnwise>)` when *<columnwise>* is `false`. If *<columnwise>* is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>)` returns the imaginary part of complex result, recomputing the feature if necessary. If *<allocate>* is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses *<allocate>* `true` and *<columnwise>* `false`.

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. `<outersolnum>` is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-73: VALID PROPERTY/VALUE PAIRS FOR PARTICLE EVALUATIONS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First particle compatible data set	The particle data set this feature refers to
`descr`	String	Model-dependent	The description of the expression in `expr`. Is used in the automatic title.
`evaluate`	`all` | `fraction` | `number`	`all`	What particles to evaluate.
`expr`	String	Model-dependent	The expression to evaluate.
`fraction`	double	1	If `evaluate` is `fraction`: The fraction of particles to evaluate.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	integer row matrix	`All solutions` on all levels	The solutions to use, per level.
`looplevelindices`	integer row matrix	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `looplevelinput` is `manualindices` on a level.
`looplevelinput`	String array with `all` | `first` | `last` | `manual` | `manualindices` | `interp` on each level	`all` on all levels	How to input the solution to use, per level. `manual` on a level indicates that `looplevel` is used on that level. `manualindices` on a level indicates that `looplevelindices` is used on that level. `interp` on a level indicates that `interp` is used on that level.
`number`	`double`	100	If `evaluate` is `number`: The number of particles to evaluate.

TABLE 7-73: VALID PROPERTY/VALUE PAIRS FOR PARTICLE EVALUATIONS

NAME	VALUE	DEFAULT	DESCRIPTION
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
solnum	nonnegative integer array	All solutions	The solutions to use
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active
t	double array	Empty	The times to use. Available when the underlying solution is transient.
table	new | table name	new	The table to use when calling setResult() or appendResult(). new indicates that a new table is created.
tablecols	inner | outer | data | level*1*	data	Whether to use inner or outer solutions as columns in the table when calling setResult() or appendResult(). Applicable only for parametric sweep models. The level values (level1, level2, and so on) are the levels in the parametric sweep.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

ParticleBin

Create a particle bin data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"ParticleBin");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"ParticleBin")` creates a particle bin set. This data set evaluates an expression over all particles and then groups them into subintervals, or bins, based on which particles return similar values. If this data set is then used in any other particle tracing plot or evaluation, each bin produces a single particle having position and other properties equal to the average over particles in the bin.

The following properties are available:

TABLE 7-74: VALID PROPERTY/VALUE PAIRS FOR PARTICLE BIN DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First particle data set	The particle data set this feature refers to
`distribution`	`equalnumber` | `equalwidth`	`equalnumber`	Distribution of particle bins. Active when `method` is set to `number`.
`limits`	String		String listing the limits of all bins. Active when `method` is set to `limits`.
`method`	`limits` | `number` | `tolerance`	`limits`	The method used to define the limits of the particle bins
`number`	`positive integer`	10	Number of particle bins. Active when `method` is set to `number`.
`tolerance`	String		Maximum difference between expression values such that particles are placed in the same bin. Active when `method` is set to `tolerance`.

ParticleMass

Create a particle tracing plot with mass.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ParticleMass");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"ParticleMass")` creates a particle tracing plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

With particle tracing, you can visualize path lines (that is, trajectories of particles released in a flow field), which can be time dependent or static. For time-dependent flows you can also use a snapshot in time of the flow field as a static field. The motion of the particles does not affect the flow field. Particle tracing is available in 2D and 3D plot groups.

The following properties are available:

TABLE 7-75: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS WITH MASS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`arrowbase`	`heat` | `tail` | `center`	`head`	Whether the head, tail, or center of the arrow is located at the particle position.
`arrowexpr`	string array		Active when `pointtype` is set to `arrow`. Determines the direction in which the arrow points.

TABLE 7-75: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS WITH MASS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
arrowlength	logarithmic | normalized | proportional	proportional	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
arrowscale	positive double	1	If arrowscalefactor is true: the length scale factor.
arrowscaleactive	boolean	false	If true, arrowscale is used; otherwise the scale factor is computed automatically.
arrowtype	arrow | arrowhead | cone	arrow	The type of arrow to draw
atol	manual | automatic	automatic	Whether to specify a manual absolute tolerance for the position and velocity. automatic indicates that the absolute tolerance for the position is the mean of the lengths of the bounding box of the geometry multiplied by the relative tolerance.
atolpos	positive double	0.001	Absolute tolerance for the position. Active when atol is set to manual.
atolvel	positive double	0.001	Absolute tolerance for the velocity. Active when atol is set to manual.
bndcoord	double array	0	Vector of values from 0 to 1 to describe the starting points. Active when bndmethod is set to coord. Available in 2D only.
bndmethod	number | coord	number	Active when posmethod is set to bnd. Available in 2D only.
bndnumber	positive integer	10	The number of equidistant starting points along the selected boundaries. Available in 2D only.
bndselection	Reference to a named selection on boundaries	First available named selection	The boundaries to start from. Available in 2D only.
comettailexpr	String array		Active when pointtype is set to comettail. Determines the direction in which the comet tail points.
const	String array of property/ value pairs	Empty	Parameters to use in the expressions
customlinecolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use for lines. Active when linecolor is set to custom.
custompointcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use for points. Active when pointcolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to
descr	String	Model-dependent	Description of forces to plot
dropfreq	positive double	1	Particles are released at these intervals when dropmethod is set to freq.
dropmethod	once | freq | times	once	Method to use when releasing particles.

TABLE 7-75: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS WITH MASS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
droptimes	double array	1	The specific times when to release particles. Used when dropmethod is set to times.
edgetol	positive double	0.001	The absolute tolerance controlling how close to the geometry boundary the path lines are cut when they exit the geometry. A lower value cuts the line closer to the geometry boundary.
fx	String	Mode-dependent	x-component for the force expression
fy	String	Mode-dependent	y-component for the force expression
fz	String	Model-dependent	z-component for the force expression. In 2D, this property is only used if the underlying geometry is axisymmetric.
hmax	double	0.1	The maximum time step. Active when stepsize is set to manual.
hstart	double	0.1	The initial time step. Active when stepsize is set to manual.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if the arrow scale is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that sphere scale, tube scale, and deformation scale are inherited from.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the sphere scale is inherited.
inherittubescale	Boolean	true	If inheritplot is not none and linetype is tube: Determines if the tube scale is inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
linecolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black (2D), red (3D)	The uniform color to use for lines.
linetype	none | line | tube	line	Plot particle tracing lines as lines or tubes, or not at all.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.

TABLE 7-75: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS WITH MASS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
mass	String	1	The particle mass.
maxsteps	positive integer	1000	The maximum number of steps to use in the particle simulation. Active when maxstepsactive is set to on.
maxstepsactive	on | off	off	Whether to manually specify the maximum number of steps used in particle simulation. off indicates that the limit varies in this way: for static flow fields, the algorithm uses the value 1000; for time-dependent flows, there is no upper limit of the number of steps, and the particle simulation goes on until it reaches the end time.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
pointcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use for points.
pointdom	disappear | stick	stick	stick plots the points on the boundary at the exit point, and disappear does not render these points at all.
pointlineanim	on | off	off	When animating particle tracing plots with points, this property indicates whether the points at the current time should appear on top of the lines.
pointtype	none | point | comettail	none	Selects between plotting the path lines' endpoints as points, comet tails, or not at all.
posmethod	start | bnd (in 2D)	start	The type of particle tracing positioning. Choose specific starting points or a boundary to start from. Available in 2D only.
radiusexpr	String	1	The tube radius.
pointautoscale	on | off	on	If enabled, the point radii are scaled so that the maximum radius is 0.01 of the plot scale.
pointradiusexpr	String	1	The point radius expression.
resolution	coarser | coarse | normal | fine | finer | extrafine		Affects the number of output points by adding points between each time step taken in the ODE solver, using a 4th-order interpolation, to produce a smoother output
rtol	positive double	0.001	The relative error tolerance that the ODE solver uses

TABLE 7-75: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS WITH MASS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
static	on | off	off	Only affects time-dependent problems. When set to on, this property freezes the time and considers this a static flow field.
statictend	double	1	The maximum time at which to end the particle-tracing simulation for static flow fields. Active when statictendactive is set to on.
statictendactive	on | off	off	Whether to specify the end time for static flow fields automatically. (For time-dependent flows, the automatic end time is the last time that the time-dependent solver returns.) When set to off, there is no upper limit of the time. In this case, the particle simulation goes on until all particles exit the geometry or the simulation reaches the maximum number of steps.
stepsize	automatic | manual	automatic	Whether to specify initial (hstart) and maximum (hmax) time step manually.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
tailscale	positive double	1	Active when pointtype is set to comettail and tailscaleactive is on. Specifies the manual scale factor with which the comet tail expression is multiplied.
tailscaleactive	on | off	off	Active when pointtype is set to comettail. Specifies whether manual tail scaling is enabled.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual
titletype	auto | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. manual if the manual title should be used (the title property). none if no title should be displayed.
tstart	double	0	Manual start time. Active when tstartactive is set to on.
tubeautoscale	on | off	on	If enabled, the tube radii are scaled so that the maximum tube radius is 0.02 of the plot scale.

TABLE 7-75: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRACING PLOTS WITH MASS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
tstartactive	on | off	off	On indicates a manual start time (set in the tstart property). Off indicates that the start time becomes either the first time value that the time-dependent solver returns or 0 for stationary flows. Available when dropmethod is set to once or freq.
tvar	String	partt	The name of the variable for time. Normally there is no need to change the default name. You can use this names in expressions as well as for the color when coloring the path lines according to an expression.
velvarx	String	partu	The name of the variable for the x-component of the velocity
velvary	String	partv	The name of the variable for the y-component of the velocity
velvarz	String	partw	The name of the variable for the z-component of the velocity. In 2D, this property is only used if the underlying geometry is axisymmetric.
velstartx	String	0	x-component for initial velocity
velstarty	String	0	y-component for initial velocity
velstartz	String	0	z-component for initial velocity. In 2D, this property is only used if the underlying geometry is axisymmetric.
xcoord	double array	Empty	Absolute coordinates in the x-direction, active when posmethod is set to start.
ycoord	double array	Empty	Absolute coordinates in the y-direction, active when postmethod is set to start.
zcoord	double array	Empty	Absolute coordinates in the z-direction, active when posmethod is set to coord. Available in 3D only.

ATTRIBUTES

Color (applies to lines), Deform

SEE ALSO

Particle, PointTrajectories, Streamline

ParticleTrajectories

Create a particle trajectories plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ParticleTrajectories");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

model.result(*<pgtag>*).create(*<ftag>*,"ParticleTrajectories") creates a particle trajectories plot feature named *<ftag>* belonging to plot group *<pgtag>*.

A particle data set is required to plot particle trajectories. The particle data set identifies the geometry in which the particle data is stored and the degrees of freedom which determine the position of each particle.

The following properties are available:

TABLE 7-76: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
arrowbase	heat|tail|center	head	Whether the head, tail, or center of the arrow is located at the particle position.
arrowexpr	string array		Active when pointtype is set to arrow. Determines the direction in which the arrow points.
arrowlength	logarithmic|normalized|proportional	proportional	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
arrowscale	positive double	1	If arrowscaleactive is true: the length scale factor.
arrowscaleactive	boolean	false	If true, arrowscale is used, otherwise the scale factor is computed automatically.
arrowtype	arrow | arrowhead | cone	arrow	The type of arrow to draw.
comettailexpr	String array	inverse of velocity vector of the first available particle tracing interface	Active when pointtype is set to comettail. Determines the direction in which the comet tail points and the relative sizes of the tails of different particles.
data	none | parent | data set name	parent	The data set this feature refers to.
ellipsearrowbase	head | tail	head	The base for the arrow to draw for ellipses.
ellipsearrowtype	arrow | cone	arrow	The type of arrow to draw for ellipses.
ellipsecount	positive integer	10	Maximum number of ellipses.
ellipsetimes	String array		Collection of times for polarization ellipses.
extrasteps	none | specifiedtimes| proportional	proportional	Controls how the number of extra time steps rendered in the trajectory plot is calculated. These extra time steps typically correspond to the exact times of reflections or velocity reinitializations.
fixedpointsize	Boolean	false	Use constant radii for the plotted spheres.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if the arrow scale is inherited.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.

TABLE 7-76: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritellipsecale	Boolean	true	If inheritplot is not none: Determines if the ellipse scale factor is inherited.
inheritplot	none | plot name	none	The plot that color, color range, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the radius scale factor is inherited.
inherittailscale	Boolean	true	If inheritplot is not none: Determines if the tail scale factor is inherited.
inherittubescale	Boolean	true	If inheritplot is not none: Determines if the tube radius scale factor is inherited.
interpolation	none | uniform	none	The type of interpolation used to plot lines when linetype is line, ribbon, or tube.
linecolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black (2D), red (3D)	The uniform color to use for lines.
linetype	none | line | ribbon | tube	line	Plot particle traces as lines, ribbons, or tubes, or not at all.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
numextrasteps	Nonnegative integer	100	If extrasteps is specifiedtimes, controls the maximum number of extra time steps to render in the plot.
pointautoscale	on | off	on	If enabled, the point radii are scaled based on the size of the geometry.
pointcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use for points.
pointlineanim	on | off	off	When animating particle tracing plots with points, this property indicates whether the points at the current time should appear on top of the lines.
pointradiusexpr	String	0.001	The point radius expression.

TABLE 7-76: VALID PROPERTY/VALUE PAIRS FOR PARTICLE TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
pointtype	none | point | comettail | arrow | ellipse	none	Plot particles as points, with comet tails, with arrows, with polarization ellipses, or not at all.
propextrasteps	Nonnegative integer	1	If extrasteps is proportional, controls the maximum number of extra time steps to render in the plot. The maximum number of extra steps is the product of this proportionality factor with the number of solution times.
radiusexpr	String	1	The tube radius expression
ribbondirexpr	String array		Expressions for the components of the ribbon direction.
semimajorexpr	String array		Expressions for the polarization ellipses' semi-major axis,
semiminorexpr	String array		Expressions for the polarization ellipses' semi-minor axis,
sphereradiusscale	positive double		The scale factor applied to the point radii if sphereradiusscaleactive is on.
sphereradiusscaleactive	on | off	off	If on, sphereradiusscale is used; otherwise the scale factor is computed automatically.
tailscale	positive double	1	Active when pointtype is set to comettail and tailscaleactive is on. Specifies the manual scale factor with which the comet tail expression is multiplied.
tailscaleactive	on | off	off	Active when pointtype is set to comettail. Specifies whether manual tail scaling is enabled.
title	String		Active when title is set to manual. Specifies the plot title.
titletype	automatic | manual | none	automatic	Determines how the plot title is specified.
tuberadiusscale	String	1	The scale factor applied to the tube radii if tuberadiusscaleactive is on.
tuberadiusscaleactive	on | off	off	If on, tuberadiusscale is used; otherwise, the scale factor is computed automatically
widthscale	double	1	The scale factor applied to the ribbon widths if widthscaleactive is true.
widthscaleactive	Boolean	false	If true, widthscale is used; otherwise, the scale factor is computed automatically

SEE ALSO

Particle (Evaluation)

ATTRIBUTES

Color, Deform, Export, Filter (Particle Tracing, Point Trajectories, Ray Tracing,).

PhasePortrait

Create a phase portrait plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"PhasePortrait");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"PhasePortrait")` creates a plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

You can use phase portraits in 2D and 2D axisymmetric models to visualize large data sets of particle trajectories.

The following properties are available:

TABLE 7-77: VALID PROPERTY/VALUE PAIRS FOR PHASE PORTRAIT

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | parent | data set name	parent	The data set this feature refers to.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
fixedpointsize	Boolean	false	Use constant radii for the plotted spheres.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited. Available in 2D and 3D.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the radius scale factor is inherited.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	integer row matrix	all on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.

TABLE 7-77: VALID PROPERTY/VALUE PAIRS FOR PHASE PORTRAIT

NAME	VALUE	DEFAULT	DESCRIPTION
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
prefixintitle	String	Empty	Added prefix to contribution to title.
pointcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use for points.
pointradiusexpr	String	1	The point radius expression.
solnum	nonnegative integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
sphereradiusscale	positive double		The scale factor applied to the point radii if sphereradiusscaleactive is on.
sphereradiusscaleactive	Boolean	false	If true, sphereradiusscale is used; otherwise the scale factor is computed automatically.
suffixintitle	String	Empty	Added suffix to contribution to title
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title.	The title to use when titletype is manual

TABLE 7-77: VALID PROPERTY/VALUE PAIRS FOR PHASE PORTRAIT

NAME	VALUE	DEFAULT	DESCRIPTION
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom
xdata	position | manual	position	Whether to use the particle position or user-defined x-axis data.
xmanual	String	Empty	User-defined x-axis data used if xdata is set to manual.
ydata	position | manual	position	Whether to use the particle position or user-defined y-axis data.
ymanual	String	Empty	User-defined y-axis data used if ydata is set to manual.

ATTRIBUTES

Color

Plot

Export plots to files.

SYNTAX

```
model.result().export().create(<ftag>,"Plot");
model.result().export().create(<ftag>,<pgtag>,<plottag>, "Plot");
model.result().export(<ftag>).set(property, <value>);
model.result().export(<ftag>).run();
```

DESCRIPTION

`model.result().export().create(<ftag>,"Plot")` creates a plot export feature with the name *<ftag>*.

`model.result().export().create(<ftag>,<pgtag>,<plottag>, "Plot")` creates a plot export feature with the name *<ftag>* for the plot *<plottag>* in the plot group *<pgtag>*.

To export a 3D surface from a plot to an STL file, use `stl` as filename extension.

The following properties are available:

TABLE 7-78: VALID PROPERTY/VALUE PAIRS FOR PLOT EXPORTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
alwaysask	on | off	off	Always ask for filename when saving. This property is ignored when running without a GUI.
exporttype	text | vtu | stlascii | stlbin	text	File type for the export: a text file. VTU file, or STL file.
ifexists	append | overwrite	overwrite	If the file exists, append to or overwrite the file contents. Not available for VTU files.

TABLE 7-78: VALID PROPERTY/VALUE PAIRS FOR PLOT EXPORTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`plotgroup`	String		The name of the plot group containing the plot to export
`plot`	String		The name of the plot (in `plotgroup`) to export
`compact`	Boolean	`false`	Only applicable for streamline and particle tracing plots. If true, the exported data contains one line per streamline or particle rather than one line per point on a streamline or particle trajectory.
`filename`	String		The output file.
`fullprec`	`on` | `off`	`on`	If on, floating-point numbers are written in full precision, otherwise they are written with six significant digits. Not for STL files.
`header`	`on` | `off`	`off`	Enable/disable a data header in the output file (for text files only).
repeat	`on` | `off`	`off`	Enable/disable repeated playing of the animation.
`sort`	`on` | `off`	`off`	Enable/disable sorting of the points with respect to the coordinates.
`struct`	`sectionwise` | `spreadsheet`	`spreadsheet`	Format of the exported data.

SEE ALSO

`Height, AberrationHeight, HistogramHeight, TableHeight`

PlotGroup1D, PlotGroup2D, PlotGroup3D

Create a 1D, 2D, or 3D plot group.

SYNTAX

```
model.result().create(<pgtag>, dim);
model.result(<pgtag>).set(property, <value>);
model.result(<pgtag>).run();
```

DESCRIPTION

`model.result().create(`*`<pgtag>`*`,`*`dim`*`)` creates a plot group named *`<pgtag>`* of view dimension *`dim`*. A plot group is a group of plots that are shown together in a graphics or plot window.

1D plot groups contain graph plots.

The following properties are available for 1D plot groups:

TABLE 7-79: VALID PROPERTY/VALUE PAIRS FOR 1D PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
`axisactive`	`on` | `off`	`off`	Use manual axis formatting settings.
`axiscommonexp`	`on` | `off`	`on`	Use a common exponent for all axis values.
`axisnotation`	`automatic` | `engineering` | `scientific`	`automatic`	Use an automatic notation (decimal or scientific) for axis values or always use engineering or scientific notation.
`axisprecision`	positive integer	4	Precision for number format (number of digits).
`axistrailingzeros`	`on` | `off`	`off`	Show trailing zeros for axis values.

TABLE 7-79: VALID PROPERTY/VALUE PAIRS FOR 1D PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | data set name	First compatible data set	The data set this feature refers to. This is the default data set for all plots in the group.
datasetintitle	on | off	off	Whether the title should contain the data set when titletype is custom.
dateintitle	on | off	off	Whether the title contribution of plots in this group should contain the current date when titletype is custom.
descriptionintitle	on | off	on	Whether the title contribution of plots in this group should contain the description when titletype is custom.
expressionintitle	on | off	off	Whether the title contribution of plots in this group should contain the expression when titletype is custom.
filenameintitle	on | off	off	Whether the title contribution of plots in this group should contain the name of the MPH-file when titletype is custom.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels	The times to use, for transient levels. Available when data is not none and the underlying data is transient.
legendpos	upperright | middleright | lowerright | upperleft | middleleft | lowerleft | middleright | center | middleleft	upperright	The position of the legends for all plots in this group.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
manualgrid	on | off	off	Whether to use the automatic grid spacing or the grid settings specified in xspacing and yspacing.

TABLE 7-79: VALID PROPERTY/VALUE PAIRS FOR 1D PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
paramindicator	String		The parameter indicator to use when titletype is manual.
phaseintitle	on | off	off	Whether the title should contain the phase when titletype is custom.
prefixintitle	String	Empty	Added prefix to group contribution to title.
preserveaspect	on | off	off	Whether the x- and y-axis should have equal scale.
showgrid	on | off	on	Display the grid in the plot.
showlegendsmaxmin	on | off	off	Show maximum and minimum values for color legends (when a Color Expression has been added).
solnum	Integer array	All solutions	The solutions to plot. Available when the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
savedatainmodel	true | false	false	Save plot data in the model.
suffixintitle	String	Empty	Added suffix to group contribution to title.
switchxy	on | off	off	Switch the data on the x- and y-axes in 1D plot groups.
t	double array	Empty	The times to plot. Available when the underlying solution is transient.
timeintitle	on | off	off	Whether the title contribution of plots in this group should contain the current time when titletype is custom.
title	String	The auto-title.	The title to use when titletype is manual.
titlecolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black	The color of the title.

TABLE 7-79: VALID PROPERTY/VALUE PAIRS FOR 1D PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
titleparamindicator	true | false	true	Add a parameter indicator to the plot title, when titletype is custom.
titletype	auto | custom | manual | none	auto	auto if the title should be computed automatically. custom if the title should be computed automatically, but customized. manual if the manual title should be used (the title property). none if no title should be displayed.
twoyaxes	true | false	false	Use two y-axes.
typeintitle	on | off	on	Whether the title contribution of plots in this group should contain the type when titletype is custom.
unitintitle	on | off	on	Whether the title contribution of plots in this group should contain the unit when titletype is custom.
xextra	double array	Empty	Extra grid points to include along the x-axis
xlabel	String	Empty	The label on the x-axis.
xlabelactive	on | off	off	on if a manual x-axis label should be used, off if it should be computed automatically.
xlog	on | off	off	Whether to use a logarithmic scale along the x-axis.
xmax	double	Computed automatically	The maximum value of the x-axis.
xmin	double	Computed automatically	The minimum value of the x-axis.
xspacing	double	Computed automatically	The grid spacing on the x-axis. Used if manualgrid is set to on.
yextra	double array	Empty	Extra grid points to include along the y-axis
ylabel	String	Empty	The label on the y-axis.
ylabelactive	on | off	off	on if a manual y-axis label should be used, off if it should be computed automatically.
ylog	on | off	off	Whether to use a logarithmic scale along the y-axis.
ylogsec	on | off	off	Whether to use a logarithmic scale along the secondary y-axis.
ymax	double	Computed automatically	The maximum value of the y-axis.
ymaxsec	double	Computed automatically	The maximum value of the secondary y-axis.
ymin	double	Computed automatically	The minimum value of the y-axis.
yminsec	double	Computed automatically	The minimum value of the secondary y-axis.
ysecextra	double array	Empty	Extra grid points to include along the secondary y-axis
yseclabel	String	Empty	The label on the secondary y-axis.

TABLE 7-79: VALID PROPERTY/VALUE PAIRS FOR 1D PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
yseclabelactive	on | off	off	on if a manual secondary y-axis label should be used, off if it should be computed automatically.
ysecspacing	double	Computed automatically	The grid spacing on the secondary y-axis. Used of manualgrid is set to on.
yspacing	double	Computed automatically	The grid spacing on the y-axis. Used of manualgrid is set to on.
window	graphics | new | window*X*, where X is an integer	graphics	The window where the plot group is displayed. When plotting on a graphics server, graphics is equivalent to new.
windowtitle	String	Computed automatically	The title to use for the window where the plot group is displayed. It is not possible to change the title of the graphics window.
windowtitleactive	on | off	off	Set windowtitleactive to on to enter a manual window title in windowtitle.

The following properties are available for 2D and 3D plot groups:

TABLE 7-80: VALID PROPERTY/VALUE PAIRS FOR 2D AND 3DPLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
axisactive	on | off	off	Use manual axis formatting settings.
axiscommonexp	on | off	on	Use a common exponent for all axis values.
axisnotation	automatic | engineering | scientific	automatic	Use an automatic notation (decimal or scientific) for axis values or always use engineering or scientific notation.
axisprecision	positive integer	4	Precision for number format (number of digits).
axistrailingzeros	on | off	off	Show trailing zeros for axis values.
customedgecolor	RGB-triplet	{1,1,1} or last used edgecolor	The color to use when plotting data set edges. Active when edgecolor is set to custom.
data	none | data set name	parent	The data set this feature refers to. This is the default data set for all plots in the group.
datasetintitle	on | off	off	Whether the title should contain the data set when titletype is custom.
edgecolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black	The color to use when plotting data set edges.
edges	on | off	on	Whether to plot data set edges.
expressionintitle	on | off	off	Whether the title contribution of plots in this group should contain the expression when titletype is custom.
frametype	mesh | material | spatial| geometry	spatial	The frame used when data set edges are plotted.
inherithide	on | off	off	Whether to propagate hiding of objects to lower dimensions in plots.

TABLE 7-80: VALID PROPERTY/VALUE PAIRS FOR 2D AND 3DPLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
interp	double array	Time corresponding to last selected solnum for transient levels	The time to use, for transient levels. Available when data is not none and the underlying data is transient.
legendactive	on | off	off	Use manual color legend formatting settings.
legendcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black	How to color the values in the color legend.
legendcommonexp	on | off	on	Use a common exponent for all color legend values.
legendnotation	automatic | engineering | scientific	automatic	Use an automatic notation (decimal or scientific) for color legend values or always use engineering or scientific notation.
legendprecision	positive integer	3	Precision for number format (number of digits).
legendpos	alternating | bottom | left | leftdouble | right | rightdouble	right	The position of the legends for all plots in this group.
legendtrailingzeros	on | off	off	Show trailing zeros for axis values.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not none and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use Applicable only for parametric sweep models.
paramindicator	String		The parameter indicator to use when titletype is manual.
phaseintitle	on | off	off	Whether the title should contain the phase when titletype is custom.
prefixintitle	String	Empty	Added prefix to group contribution to title.
showhiddenobjects	on | off	off	Whether hidden objects should be visible in plots.
showlegends	on | off	on	Show color legends.
showlegendsmaxmin	on | off	off	Show maximum and minimum values in color legends.
showlegendsunit	on | off	off	Show the unit above the color legend.

TABLE 7-80: VALID PROPERTY/VALUE PAIRS FOR 2D AND 3DPLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
`solnum`	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when the underlying data has multiple solutions.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active.
`solutionintitle`	`on` | `off`	`on`	Whether the title should contain the solution when `titletype` is `custom`.
`suffixintitle`	String	Empty	Added suffix to group contribution to title.
`t`	double	Time corresponding to last selected `solnum`.	The time to use, for transient problems. If it is not available in any solnum, the time is interpolated in the solution.
`timeinterp`	`on` | `off`	`off`	`on` if `t` is used to determine time steps, `off` if `solnum` is used.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titleparamindicator`	`true` | `false`	`true`	Add a parameter indicator to the plot title, when `titletype` is `custom`.
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title should be computed automatically. `custom` if the title should be computed automatically, but customized. `manual` if the manual title should be used (the `title` property). `none` if no title should be displayed.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution of plots in this group should contain the type when `titletype` is `custom`.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution of plots in this group should contain the unit when `titletype` is `custom`.
`view`	`auto` | view name	`auto`	The view settings to use when displaying this plot group. `auto` indicates that the view is selected automatically, or be created if there is none. Typically geometry-based data sets such as solution or mesh data sets use the current geometry view. Surface plots with height attributes do not use the view setting.
`window`	`graphics` | `new` | `windowX`, where `X` is an integer	`graphics`	The window where the plot group is displayed. When plotting on a graphics server, `graphics` is equivalent to `new`.
`windowtitle`	String	Computed automatically	The title to use for the window where the plot group is displayed. It is not possible to change the title of the graphics window.

TABLE 7-80: VALID PROPERTY/VALUE PAIRS FOR 2D AND 3DPLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
windowtitleactive	on | off	off	Set windowtitleactive to on to enter a manual window title in windowtitle.
xlabel	String	Empty	The label on the x-axis. Available for 2D plot groups.
xlabelactive	on | off	off	on if a manual x-axis label should be used, off if it should be computed automatically. Available for 2D plot groups.
ylabel	String	Empty	The label on the y-axis. Available for 2D plot groups.
ylabelactive	on | off	off	on if a manual y-axis label should be used, off if it should be computed automatically. Available for 2D plot groups.

SEE ALSO

EvaluationGroup, PolarGroup, Solution, SmithGroup

PoincareMap

Create a plot of a Poincaré map.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"PoincareMap");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"PoincareMap")` creates a plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Plots of a Poincaré map are used to visualize where particle trajectories intersect a given plane, for example, to illustrate where a ray passes or where particles are deposited. They can be added to 2D and 3D plot groups.

The following properties are available:

TABLE 7-81: VALID PROPERTY/VALUE PAIRS FOR POINCARÉ MAP

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | parent | data set name	parent	The data set this feature refers to.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
fixedpointsize	Boolean	false	Use constant radii for the plotted spheres.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited. Available in 2D and 3D.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the radius scale factor is inherited.

TABLE 7-81: VALID PROPERTY/VALUE PAIRS FOR POINCARÉ MAP

NAME	VALUE	DEFAULT	DESCRIPTION
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	integer row matrix	all on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
prefixintitle	String	Empty	Added prefix to contribution to title.
pointradiusexpr	String	1	The point radius expression.
solnum	nonnegative integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
sphereradiusscale	positive double		The scale factor applied to the point radii if sphereradiusscaleactive is on.

TABLE 7-81: VALID PROPERTY/VALUE PAIRS FOR POINCARÉ MAP

NAME	VALUE	DEFAULT	DESCRIPTION
sphereradiusscaleactive	Boolean	false	If true, sphereradiusscale is used; otherwise the scale factor is computed automatically.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.

ATTRIBUTES

Color

PointData

Create a point data plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"PointData");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"PointData")` creates a point data plot feature named *<ftag>* belonging to the 2D or 3D plot group *<pgtag>*.

Point data plots are used to visualize raw point data given as points and colors (see the example below). Point data plots can be added to 2D and 3D plot groups.

The following properties are available:

TABLE 7-82: VALID PROPERTY/VALUE PAIRS FOR POINT DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
colordata	double 1D array		The color data for the point data plot as a real N-vector.

TABLE 7-82: VALID PROPERTY/VALUE PAIRS FOR POINT DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
coloring	colortable | uniform	uniform	How to color the points.
colorlegend	on | off	on	Whether to show color legend when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
description	String		A label showing a short description of the stored data.
pointdata	double 2D array		The point data for the point data plot, as x and y coordinates in 2D and x, y, and z coordinates in 3D in an sdim-by-N real matrix.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range are not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
sphereradiusscale	positive double	1	The scale factor applied to the point radii.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | manual | none	none	auto if the title contribution should be computed automatically. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.

ATTRIBUTES

None.

EXAMPLE

A method for creating a circle of points in 2D.

Code for Use with Java

```
pg = m.result().create("pg5", 2);
plot = pg.create("pt1", "PointData");
N = 17;
p = new double[2][N];
color = new double[N];
double R = 1000;
for (int i = 0; i < N; i++) {
  double angle = i * 2 * Math.PI / N;
  p[0][i] = R * Math.cos(angle);
  p[1][i] = R * Math.sin(angle);
  color[i] = p[1][i];
}
plot.set("pointdata", p)
    .set("colordata", color)
    .set("coloring", "colortable");
plot.run();
```

SEE ALSO

AnnotationData, ArrowData, LineData, SurfaceData, TubeData

PointGraph

Create a point graph plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"PointGraph");
model.result(<pgtag>).feature(<ftag>).selection(...);
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"PointGraph")` creates a graph point plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Point plot is used to visualize quantities on points, either cut points or points in a geometry. Point plots can be added to 1D plot groups.

The following properties are available:

TABLE 7-83: VALID PROPERTY/VALUE PAIRS FOR POINT GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
autodescr	on | off	Model dependent	Whether the automatic legends should include the expression descriptions.
autoexpr	on | off	Model dependent	Whether the automatic legends should include the expressions.
autolegends	on | off	on	Whether to use the automatically computed legends or the legends defined in the legends property. The automatic legends display the point numbers of the plotted points for geometry-based point plots. For cut point plots, the legend displays the point coordinates.
autounit	on | off	off	Whether the automatic legends should include the unit.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.

TABLE 7-83: VALID PROPERTY/VALUE PAIRS FOR POINT GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor	The color to use for the lines. Active when linecolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
freqmax	integer		If xaxisdata is spectrum and freqrangeactive is true: The upper frequency bound.
freqmin	integer		If xaxisdata is spectrum and freqrangeactive is true: The lower frequency bound.
freqrangeactive	on | off	false	If xaxisdata is spectrum: Controls whether a manual frequency range is used.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
legend	on | off	off	Whether to show legends.
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legendprefix	String		A prefix added to the automatic legend.
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
legendsuffix	String		A suffix added to the automatic legend.
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
linewidth	double	0.5	The line width.

TABLE 7-83: VALID PROPERTY/VALUE PAIRS FOR POINT GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
nfreqs	integer	1	If xaxisdata is spectrum and nfreqsactive is true: The number of frequencies to plot.
nfreqsactive	Boolean	false	If xaxisdata is spectrum: Controls whether the number of frequencies is set manually.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
plotonsecyaxis	Boolean	true	Plot on secondary y-axis, if twoyaxes is set to true in the parent plot group.
prefixintitle	String	Empty	Added prefix to contribution to title

TABLE 7-83: VALID PROPERTY/VALUE PAIRS FOR POINT GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
`scale`	Boolean	`false`	If xdata is spectrum: The frequency spectrum is transformed so that it has the same scale as the original data.
`solnum`	integer array	All solutions	The solutions to plot. Available when `data` is not `parent` and the underlying data has multiple solutions.
`solnumindices`	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active
`suffixintitle`	String	Empty	Added suffix to contribution to title
`t`	double array	Empty	The times to plot. Available when `data` is not `parent` and the underlying solution is transient.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title contribution should be computed automatically, possibly using the group's customization. `custom` if the title contribution should be computed automatically, but customized. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution should contain the type when `titletype` is `custom`
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution should contain the unit when `titletype` is `custom`
`xdata`	`expr` | `solution` | `spectrum` | `phase`	`solution`	x-axis data. `expr` uses the expression in `xdataexpr`. `solution` uses the available solutions in the underlying data set, for example, time steps. `phase` uses a phase range, and rearranged phase plots.
`xdataexpr`	String	Model-dependent	Expression for x-axis data
`xdatadescr`	String	Model-dependent	Description of expression in `xdataexpr`
`xdataphaserange`	double array	`range(0, 0.5, 2π)`	The phases for which the expression should be evaluated when `xdata` is `phase`.
`xdataphaseunit`	String	rad	The unit in which `xdataphaserange` is described

TABLE 7-83: VALID PROPERTY/VALUE PAIRS FOR POINT GRAPHS

NAME	VALUE	DEFAULT	DESCRIPTION
`xdatasolnumtype`	`all` | `inner` | `outer` | `valid level`	outer	Whether the expression should be evaluated for every inner or every outer solution, or for a specific level (`level1`, `level2`, and so on). Applicable only for models containing multiple levels.
`xdataunit`	String	Model-dependent	The unit to use for the expression in `xdataexpr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

ATTRIBUTES

None.

SEE ALSO

LineGraph

PointTrajectories

Create a point trajectories plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"PointTrajectories");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).selection(...);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"PointTrajectories")` creates a point trajectories plot feature named *<ftag>* belonging to plot group *<pgtag>*.

`model.result(<pgtag>).feature(<ftag>).selection()` returns the selection of points for which to plot trajectories. Selections are only available when you use points as the plot data. See Selections for more information about the available selection methods.

A solution or cut point data set is required to plot point trajectories.

The following properties are available:

TABLE 7-84: VALID PROPERTY/VALUE PAIRS FOR POINT TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`arrowbase`	`heat`|`tail`| `center`	`head`	Whether the head, tail, or center of the arrow is located at the arrow position.
`arrowexpr`	string array		Active when `pointtype` is set to `arrow`. Determines the direction in which the arrow points.
`arrowlength`	`logarithmic`| `normalized`| `proportional`	`proportional`	The arrow scaling: `Proportional` uses the actual arrow length, `normalized` a unit length, and `logarithmic` a length proportional to the logarithm of the arrow length.
`arrowscale`	positive double	1	If `arrowscalefactor` is true: the length scale factor.

TABLE 7-84: VALID PROPERTY/VALUE PAIRS FOR POINT TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
arrowscaleactive	boolean	false	If true, arrowscale is used, otherwise the scale factor is computed automatically.
arrowtype	arrow | arrowhead | cone	arrow	The type of arrow to draw.
comettailexpr	String array	inverse of velocity vector of the first available particle tracing interface	Active when pointtype is set to comettail. Determines the direction in which the comet tail points and the relative sizes of the tails of different point trajectories.
coordinatesexpr			
data	none | parent | data set name	parent	The data set this feature refers to.
ellipsecount	positive integer	10	Maximum number of ellipses.
ellipsetimes	String array		Collection of times for polarization ellipses.
extrasteps	none | specifiedtimes| proportional	proportional	Controls how the number of extra time steps rendered in the trajectory plot is calculated. These extra time steps typically correspond to the exact times of reflections or velocity reinitializations.
expr	String array		The x-, y-, and z-expressions for the trajectory data (mapped from globalexpr or pointsexpr depending on the plotdata property's setting).
fixedpointsize	Boolean	false	Use constant radii for the plotted spheres.
globalexpr	String array		The x-, y-, and z-expressions for global plot data.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if the arrow scale is inherited.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritellipsecale	Boolean	true	If inheritplot is not none: Determines if the ellipse scale factor is inherited.
inheritplot	none | plot name	none	The plot that color, color range, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the radius scale factor is inherited.

TABLE 7-84: VALID PROPERTY/VALUE PAIRS FOR POINT TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
inherittailscale	Boolean	true	If inheritplot is not none: Determines if the tail scale factor is inherited.
inherittubescale	Boolean	true	If inheritplot is not none: Determines if the tube radius scale factor is inherited.
interpolation	none | uniform	none	The type of interpolation used to plot lines when linetype is line or tube.
linecolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black (2D), red (3D)	The uniform color to use for lines.
linetype	none | line | ribbon | tube	line	Plot particle traces as lines, ribbons, or tubes, or not at all.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
plotdata	global | points	points	The plot data used for the point trajectories: points in the geometry (points) or a user-defined global expression (global).
pointautoscale	on | off	on	If enabled, the point radii are scaled based on the size of the geometry.
pointcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use for points.
pointlineanim	on | off	off	When animating particle tracing plots with points, this property indicates whether the points at the current time should appear on top of the lines.
pointradiusexpr	String	0.001	The point radius expression.
pointsexpr	String array		The x-, y-, and z-expressions for points as the plot data.
pointtype	none | point | comettail | arrow | ellipse	none	Plot particles as points, with comet tails, with arrows, with polarization ellipses, or not at all.
radiusexpr	String	1	The tube radius expression
semimajorexpr	String array		Expressions for the polarization ellipses' semi-major axis,
semiminorexpr	String array		Expressions for the polarization ellipses' semi-minor axis,
sphereradiusscale	positive double		The scale factor applied to the point radii if sphereradiusscaleactive is on.
sphereradiusscaleactive	on | off	off	If on, sphereradiusscale is used; otherwise the scale factor is computed automatically.

TABLE 7-84: VALID PROPERTY/VALUE PAIRS FOR POINT TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`tailscale`	positive double	1	Active when `pointtype` is set to `comettail` and `tailscaleactive` is `on`. Specifies the manual scale factor with which the comet tail expression is multiplied.
`tailscaleactive`	`on` | `off`	`off`	Active when `pointtype` is set to `comettail`. Specifies whether manual tail scaling is enabled.
`title`	String		Active when `title` is set to `manual`. Specifies the plot title.
`titletype`	`automatic` | `manual` | `none`	`automatic`	Determines how the plot title is specified.
`tuberadiusscale`	String	1	The scale factor applied to the tube radii if tuberadiusscaleactive is `on`.
`tuberadiusscaleactive`	`on` | `off`	`off`	If `on`, `tuberadiusscale` is used, otherwise the scale factor is computed automatically

ATTRIBUTES

Color, Deform, Export, Filter (Particle Tracing, Point Trajectories, Ray Tracing,)

SEE ALSO

`ParticleTrajectories`

PolarGroup

Create a polar plot group.

SYNTAX

```
model.result().create(<pgtag>, "PolarGroup");
model.result(<pgtag>).set(property, <value>);
model.result(<pgtag>).run();
```

DESCRIPTION

`model.result().create(`*`<pgtag>`*`,"PolarGroup")` creates a polar plot group named *<pgtag>*. A polar plot group displays the containing graph plots in a polar coordinate system.

The following properties are available for polar plot groups:

TABLE 7-85: VALID PROPERTY/VALUE PAIRS FOR POLAR PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
`angularunit`	`degrees` | `radians`	`degrees`	The angular unit: degrees or radians.
`data`	`none` | data set name	First compatible data set	The data set this feature refers to. This is the default data set for all plots in the group.
`datasetintitle`	`on` | `off`	`off`	Whether the title should contain the data set when `titletype` is `custom`
`expressionintitle`	`on` | `off`	`off`	Whether the title contribution of plots in this group should contain the expression when `titletype` is `custom`

TABLE 7-85: VALID PROPERTY/VALUE PAIRS FOR POLAR PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not none and the underlying data is transient.
legendpos	upperright | lowerright | upperleft | lowerleft	upperright	The position of the legends for all plots in this group
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
manualgrid	on | off	off	Whether to use the automatic grid spacing or the grid settings specified in rspacing and tspacing.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
phaseintitle	on | off	off	Whether the title should contain the phase when titletype is custom.
prefixintitle	String	Empty	Added prefix to group contribution to title
rextra	double array	Empty	Extra grid points to include along the r-axis
rmax	double	Computed automatically	The maximum value of the r-axis

TABLE 7-85: VALID PROPERTY/VALUE PAIRS FOR POLAR PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
`rmin`	double	Computed automatically	The minimum value of the r-axis
`rotdir`	`ccw` | `cw`	ccw	Rotation direction: counterclockwise or clockwise.
`rspacing`	double	Computed automatically	The grid spacing on the r-axis. Used if `manualgrid` is set to `on`.
`showlegendsmaxmin`	`on` | `off`	`off`	Show maximum and minimum values for color legends (when a Color Expression has been added).
`solnum`	Integer array	`All solutions`	The solutions to plot. Available when the underlying data has multiple solutions.
`solnumindices`	String or integer array	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active
`suffixintitle`	String	Empty	Added suffix to group contribution to title
`symmetricangle`	`on` | `off`	`off`	Display angles as +-180 degrees around zero instead as a full 360 degree revolution.
`t`	double array	Empty	The times to plot. Available when the underlying solution is transient.
`textra`	double array	Empty	Extra grid points to include along the θ-axis, in degrees
`title`	String	The auto-title.	The title to use when `titletype` is `manual`
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title should be computed automatically. `custom` if the title should be computed automatically, but customized. `manual` if the manual title should be used (the `title` property). `none` if no title should be displayed.
`tspacing`	double	Computed automatically	The grid spacing on the θ-axis. Used of `manualgrid` is set to `on`.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution of plots in this group should contain the type when `titletype` is `custom`
`unitintitle`	`on` | `off`	`on`	Whether the title contribution of plots in this group should contain the unit when `titletype` is `custom`
`window`	`graphics` | `new` | `windowX`, where X is an integer	`graphics`	The window where the plot group is displayed. When plotting on a graphics server, `graphics` is equivalent to `new`.
`windowtitle`	String	Computed automatically	The title to use for the window where the plot group is displayed. It is not possible to change the title of the graphics window.

TABLE 7-85: VALID PROPERTY/VALUE PAIRS FOR POLAR PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
windowtitleactive	on | off	off	Set windowtitleactive to on to enter a manual window title in windowtitle
zeroangle	right | up | left | down	right	Direction of the zero angle.

SEE ALSO

PlotGroup1D, PlotGroup2D, PlotGroup3D, SmithGroup

PrincipalLine, PrincipalSurface, PrincipalVolume

Create a principal stress or principal strain plot in volumes, on surfaces, or on lines (edges).

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"PrincipalVolume");
model.result(<pgtag>).create(<ftag>,"PrincipalSurface");
model.result(<pgtag>).create(<ftag>,"PrincipalLine");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"PrincipalVolume")` create a volume principal stress or principal strain plot named *<ftag>* belonging to the plot group *<pgtag>*.

The following properties are available:

TABLE 7-86: VALID PROPERTY/VALUE PAIRS FOR PRINCIPAL STRESS/STRAIN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
arrowcount	positive integer	200	The number of arrows. Available for PrincipalSurface in 3D.
arrowlength	normalized | proportional | logarithmic	proportional	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
arrowtype	arrow | cone	arrow	The type of arrow to draw.
arrowxmethod	number | coord	number	Indicates whether the x-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for PrincipalSurface in 2D and PrincipalVolume in 3D.
arrowymethod	number | coord	number	Indicates whether the y-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for PrincipalSurface in 2D and PrincipalVolume in 3D.
arrowzmethod	number | coord	number	Indicates whether the z-coordinates of the arrows should be specified by number of points to distribute evenly across the data or by coordinates. Available for PrincipalVolume in 3D.

TABLE 7-86: VALID PROPERTY/VALUE PAIRS FOR PRINCIPAL STRESS/STRAIN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The color to use.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
gporder	poitive integer	1	If pattern is gauss: The Gauss point order.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if arrow scale is inherited.
inherit color	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritplot	none | plot name	none	The plot that arrow scale and color are inherited from.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
placement|	elements | uniform | uniformani | gausspoints	uniform	If uniform, then the arrows are distributed uniformly. If uniformanisotropic, then the arrows are distributed uniformly with weights taken from the weight property. If elements, then arrows are drawn in mesh element centroids. If gausspoints, the arrows are drawn in the Gauss points (with order set by gporder). Available for PrincipalSurface in 3D.
princdirstrainexpr	3-by-3 string matrix	Physics-dependent	If type is strain: The expressions for the principal directions.
princdirstressexpr	3-by-3 string matrix	Physics-dependent	If type is stress: The expressions for the principal directions.

TABLE 7-86: VALID PROPERTY/VALUE PAIRS FOR PRINCIPAL STRESS/STRAIN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
princstraindata	manual | any available principal strain data	First available principal strain data	The data used for the principal strain plot. If set to manual, specify principal values and directions. The data is referred to using the physics interface and an integer: solid_1, for example, is the first available principal strain data from a Solid Mechanics interface.
princstressdata	manual | any available principal stress data	First available principal stress data	The data used for the principal stress plot. If set to manual, specify principal values and directions. The data is referred to using the physics interface and an integer: solid_1, for example, is the first available principal stress data from a Solid Mechanics interface.
princvalstrainexpr	1-by-3 string matrix	Physics-dependent	If type is strain: The expressions for the principal values.
princvalstressexpr	1-by-3 string matrix	Physics-dependent	If type is stress: The expressions for the principal values.
revcoordsys	cylindrical | cartesian	cartesian	Coordinate system for principal stress/strain vectors. Only available for plots that use a 1D or 2D revolution data set that has default axis settings and points to a solution or mesh data set for an axisymmetric geometry.
scale	positive double	1	If scaleactive is true: The length scale factor.
scaleactive	Boolean	false	Whether to use manual scaling.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise, first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
t	double	Time corresponding to last selected solnum	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. manual if the manual title should be used (the title property). none if no title should be displayed.
type	stress | strain	stress	Selection between principal stress and principal strain plot.
weight	double array	1	If placement is uniformani: The weights given to the different axis directions.

TABLE 7-86: VALID PROPERTY/VALUE PAIRS FOR PRINCIPAL STRESS/STRAIN PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
xnumber	nonnegative integer	15 (3D), 7 (2D)	Number of points in the x-direction. Active when arrowxmethod is set to number. Available for PrincipalSurface in 2D and PrincipalVolume in 3D.
xcoord	double array	Empty	Absolute coordinates in the x-direction, active when arrowxmethod is set to coord. Available for PrincipalSurface in 2D and PrincipalVolume in 3D.
ynumber	integer	15 (3D), 7 (2D)	Number of points in the y-direction. Active when arrowymethod is set to number. Available for PrincipalSurface in 2D and PrincipalVolume in 3D.
ycoord	double array	Empty	Absolute coordinates in the z-direction, active when arrowymethod is set to coord. Available for PrincipalSurface in 2D and PrincipalVolume in 3D.
znumber	integer	15 (3D), 7 (2D)	Number of points in the z-direction. Active when arrowzmethod is set to number. Available for PrincipalVolume in 3D.
zcoord	double array	Empty	Absolute coordinates in the z-direction, active when arrowzmethod is set to coord. Available for PrincipalVolume in 3D.

ATTRIBUTES

Color, Deform, Filter, Selection

RadiationPattern

Create a radiation pattern plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"RadiationPattern");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"RadiationPattern")` creates a radiation pattern plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Radiation pattern plots are used to visualize radiation patterns in the far-field for antennas, for example. They can be added to all types of plot groups.

The following properties are available:

TABLE 7-87: VALID PROPERTY/VALUE PAIRS FOR RADIATION PATTERN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
anglerestr	manual | none	none	Whether there is a restriction on the angle range that is evaluated.
autodescr	on | off	Model dependent	Whether the automatic legends should include the expression descriptions. Available in 1D.

TABLE 7-87: VALID PROPERTY/VALUE PAIRS FOR RADIATION PATTERN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
autoexpr	on | off	Model dependent	Whether the automatic legends should include the expressions. Available in 1D.
autolegends	on | off	on	Whether to use the automatically computed legends or the legends defined in the legends property. The automatic legends display the description and expression for each line. Available in 1D.
beamwidth	Boolean	false	Compute the beam width (when set to true). Available in 1D.
center	double array of length 3	{0, 0, 0}	If circle is manual: The center of the circle to evaluate on. Available in 2D and 3D.
center2	double array of length 2	{0, 0}	If circle is manual and the data set is 2D: The center of the circle to evaluate on. Available in 1D.
center3	double array of length 3	{0, 0, 0}	If circle is manual and the data set is 3D: The center of the circle to evaluate on. Available in 1D.
circle	manual | unit	unit	The circle to evaluate on. Available in 1D.
colorexpr	String	Model-dependent.	The color of the far-field surface. Available in 3D.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customgridcolor	RGB-triplet	{0,0,1}	f grid is fine, normal, or coarse and gridcolor is custom: The grid's color. Available in 3D.
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom. Available in 1D.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String array	Model-dependent.	The description of the expressions in expr. Is used in the automatic legends.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
directivity	on | off	off	Whether to compute the maximum directivity and the direction where it is attained. Available in 2D and 3D when anglerestr is none.
directivityexpr	String array	Model-dependent.	The expressions to use for the directivity computation.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.

TABLE 7-87: VALID PROPERTY/VALUE PAIRS FOR RADIATION PATTERN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`expr`	String array	Model-dependent.	The expressions to plot.
`expressionintitle`	`on` | `off`	`off`	Whether the title contribution should contain the expression when `titletype` is `custom`.
`grid`	`fine` | `normal` | `coarse` | `none`	`none`	The type of grid to display on the far-field surface. Available in 3D.
`gridcolor`	`custom` | `black` | `blue` | `cyan` | `gray` | `green` | `magenta` | `red` | `white` | `yellow`	`black`	If `grid` is `fine`, `normal`, or `coarse`: The grid's color. Available in 3D.
`inheritcolor`	Boolean	`true`	If inheritplot is not none: Determines if the color is inherited. Available in 2D and 3D.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`legend`	`on` | `off`	`off`	Whether to show legends. Available in 1D.
`legendmethod`	`automatic` | `manual`	`automatic`	Whether to use the automatic legends or the legends supplied in the `legends` property. Available in 1D.
`legendprefix`	String		A prefix added to the automatic legend.
`legends`	String array	The last computed automatic legends.	Manual legends active when `legendmethod` is set to `manual`. Available in 1D.
`legendsuffix`	String		A suffix added to the automatic legend.
`leveldown`	double (nonnegative)	`0`	The level down from the reference direction to compute the beam width for (when `beamwidth` is `true`). Available in 1D.
`linecolor`	`custom` | `cycle` | `black` | `blue` | `cyan` | `gray` | `green` | `magenta` | `red` | `white` | `yellow`	`cycle`	How to color the lines in the graph. Cycle indicates that the colors is different for each line. Available in 1D.
`linewidth`	double	`0.5`	The line width. Available in 1D.
`linemarker`	`none` | `cycle` | `asterisk` | `circle` | `diamond` | `plus` | `point` | `square` | `star` | `triangle`	`none`	The line markers, if any. Cycle indicates that the marker is different for each line. Available in 1D.
`linestyle`	`none` | `cycle` | `solid` | `dotted` | `dashed` | `dashdot`	`solid`	The line style, if any. Cycle indicates that the line style is different for each line. Available in 1D.
`looplevel`	integer row matrix	`all` on all levels	The solutions to use, per level.

TABLE 7-87: VALID PROPERTY/VALUE PAIRS FOR RADIATION PATTERN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set. Available in 1D.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set. Available in 1D.
normal	double array of length 3	{0, 0, 1} for 3D, {0, 1, 0} for 2D axisymmetry.	If the data set is 3D or 2D axially symmetric: The normal of the circle to evaluate on. Available in 1D.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
phidisc	integer >= 2	50 (1D); 20 (2D and 3D)	The angular discretization (number of angles) in the phi direction.
phimin	double	0	If anglerestr is manual: The minimum phi angle in degrees.
phirange	double	360	If anglerestr is manual: The phi angle's range in degrees.
phivar	String	Empty	For 2D axisymmetric radiation pattern plots only, evaluate the azimuthal angle once for each angle using the variable name in phivar. If empty, an evaluate-once-and-revolve approach is used instead.
prefixintitle	String	Empty	Added prefix to contribution to title.
radius	String	1	If circle is manual: The radius of the circle to evaluate on.

TABLE 7-87: VALID PROPERTY/VALUE PAIRS FOR RADIATION PATTERN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. The default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range are not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
refdir	double array of length 3	{1, 0, 0} for 3D, {0, 0, 1} for 2D axisymmetry.	If the data set is 3D or 2D axially symmetric: The reference direction of the circle to evaluate on. Available in 1D.
solnum	nonnegative integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
sphere	manual | unit	unit	The sphere to evaluate on. Available in 2D and 3D.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
thetadisc	integer >= 2	10	The angular discretization (number of elevation angles) in the theta direction. Available in 2D and 3D.
thetamin	double	0	If anglerestr is manual: The minimum theta angle in degrees. Available in 2D and 3D.
thetarange	double	360	If anglerestr is manual: The phi angle's range in degrees. Available in 2D and 3D.
threshold	double		Threshold value for the evaluated radius maps to the plotted radius 0 if thresholdactive is on (3D only).
thresholdactive	on | off	off	Use a manual threshold value (3D only).
title	String	The auto-title.	The title to use when titletype is manual.

TABLE 7-87: VALID PROPERTY/VALUE PAIRS FOR RADIATION PATTERN PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
useradiusascolor	on | off	off	Use the expression in expr as the colorexpr. Available in 3D only.

ATTRIBUTES

Export

Ray (1D Plot)

Create a ray plot, which plots ray properties over time or compares ray properties against each other at a set of time steps.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Ray1D");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Ray1D")` creates a ray plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

With the ray plot, you can plot properties of all rays in a data set versus time, or plot two ray properties against each other at a set of selected times. When plotting ray properties versus time, it is possible to apply data series operations to the ray data. The ray plot is available in 1D plot groups.

The following properties are available:

TABLE 7-88: VALID PROPERTY/VALUE PAIRS FOR RAY PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
autodescr	on | off	Model dependent	Whether the automatic legends should include the expression descriptions.
autoexpr	on | off	Model dependent	Whether the automatic legends should include the expressions.

TABLE 7-88: VALID PROPERTY/VALUE PAIRS FOR RAY PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
autolegends	on | off	on	Whether to use the automatically computed legends or the legends defined in the legends property. The automatic legends display the description and expression for each line.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
dataseries	none | average | sum | maximum | minimum | rms | stddev | variance	sum	The data series operation that is applied to all rays. Effective only when xdata is not expr.
descr	String array	Model-dependent.	The description of the expressions in expr. Is used in the automatic legends.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
expr	String array	Model-dependent.	The expressions to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
legend	on | off	off	Whether to show legends.
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the color is different for each line.
linewidth	double	0.5	The line width
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.

TABLE 7-88: VALID PROPERTY/VALUE PAIRS FOR RAY PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
prefixintitle	String	Empty	Added prefix to contribution to title.
solnum	nonnegative integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.

TABLE 7-88: VALID PROPERTY/VALUE PAIRS FOR RAY PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
xdata	expr | solution	solution	x-axis data. expr uses the expression in xdataexpr. solution uses the available solutions in the underlying data set, such as time steps.
xdataexpr	String	Model-dependent	Expression for x-axis data
xdatadescr	String	Model-dependent	Description of expression in xdataexpr
xdataphaseunit	String	rad	The unit in which xdataphaserange is described
xdatasolnumtype	all | inner | outer | valid level	outer	Whether the expression should be evaluated for every inner or every outer solution, or for a specific level (level1, level2, and so on). Applicable only for models containing multiple levels.
xdataunit	String	Model-dependent	The unit to use for the expression in xdataexpr. If the old unit is not valid when the expression changes, the unit property is reset to default.

ATTRIBUTES

Color (applies to lines), Global (Numerical)

SEE ALSO

Ray (Evaluation), RayTrajectories, RayBin

Ray (Data Set)

Create a ray data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Ray");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Ray")` creates a ray data set.

A ray data set is required to plot ray trajectories. The ray data set identifies the geometry in which the ray data is stored and the degrees of freedom which determine the position of each ray.

The following properties are available:

TABLE 7-89: VALID PROPERTY/VALUE PAIRS FOR RAY DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`solution`	String	first available solution	The solution this data set refers to.
`pgeomspec`	`manual` | `fromphysics`	`manual`	The method of specifying the ray geometry and the names of the ray position degrees of freedom.
`physicsinterface`	`none` or the tag of a valid physics interface	`none`	The physics interface from which the ray geometry and the names of the ray position degrees of freedom are defined.
`rgeom`	String	`rgeom`	The geometry in which the ray degrees of freedom are defined. The correct name of this ray geometry is `pgeom_<name>`, where `<name>` is the name for the Geometrical Optics or Ray Acoustics interface node.
`posdof`	String array	`mod1.qx, mod1.qy`	The position degrees of freedom of the rays.

Ray (Evaluation)

Ray evaluations to evaluate quantities on ray trajectories.

SYNTAX

```
model.result().numerical().create(<ftag>,"Ray");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getReal();
model.result().numerical(<ftag>).getReal(<columnwise>);
model.result().numerical(<ftag>).getReal(<outersolnum>);
model.result().numerical(<ftag>).getReal(<columnwise>,<outersolnum>);
model.result().numerical(<ftag>).getImag();
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>);
model.result().numerical(<ftag>).getImag(<outersolnum>);
model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>,<outersolnum>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).computeResult();
model.result().numerical(<ftag>).setResult();
model.result().numerical(<ftag>).appendResult();
```

When added to an evaluation group, replace `numerical(<ftag>)` with `evaluationGroup(<ftag>)`.

DESCRIPTION

`model.result().numerical().create(<ftag>,"Ray")` creates a ray evaluation feature with the name *<ftag>*. Ray evaluations can be performed on trajectories accessed through a ray data set.

`model.result().numerical(<ftag>).getReal()` returns the real result, recomputing the feature if necessary. Data is ordered such that there is one row per point, with one row containing data for all solution numbers. This is identical to `(<columnwise>)` when *<columnwise>* is `false`. If *<columnwise>* is `true`, the ordering is the opposite: each *column* contains the values for all solution numbers.

`model.result().numerical(<ftag>).getImag(<allocate>, <columnwise>)` returns the imaginary part of complex result, recomputing the feature if necessary. If *<allocate>* is `true`, a zero-valued matrix is allocated even when the result is real. `getImag()` uses *<allocate>* `true` and *<columnwise>* `false.`

`model.result().numerical(<ftag>).isComplex()` returns true if the result is complex. The resulting value is a scalar, which true if any of the expressions in an array is complex-valued.

`model.result().numerical(<ftag>).isComplex(<outersolnum>)` returns true if the result is complex for the given outer solution. *<outersolnum>* is applicable only for parametric sweep solutions and is the index of each outer parametric solution.

`model.result().numerical(<ftag>).computeResult()` returns the matrix of data that the `setResult` method adds to a table. The matrix includes data only, not the parameter columns, and it does not use any table-specific settings.

`model.result().numerical(<ftag>).setResult()` and `model.result().numerical(<ftag>).appendResult()` evaluates the feature and set or append the result in the table indicated by the `table` property.

The following properties are available:

TABLE 7-90: VALID PROPERTY/VALUE PAIRS FOR RAY EVALUATIONS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First ray compatible data set	The ray data set this feature refers to.
`descr`	String	Model-dependent	The description of the expression in `expr`. Is used in the automatic title.
`evaluate`	`all` | `fraction` | `number`	all	What ray to evaluate.
`expr`	String	Model-dependent	The expression to evaluate.
`fraction`	double	1	If `evaluate` is `fraction`: The fraction of rays to evaluate.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`interp`	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	integer row matrix	`All solutions` on all levels	The solutions to use, per level.

TABLE 7-90: VALID PROPERTY/VALUE PAIRS FOR RAY EVALUATIONS

NAME	VALUE	DEFAULT	DESCRIPTION
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
number	double	100	If evaluate is number: The number of particles to evaluate.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
solnum	nonnegative integer array	All solutions	The solutions to use.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
t	double array	Empty	The times to use. Available when the underlying solution is transient.
table	new | table name	new	The table to use when calling setResult() or appendResult(). new indicates that a new table is created.

TABLE 7-90: VALID PROPERTY/VALUE PAIRS FOR RAY EVALUATIONS

NAME	VALUE	DEFAULT	DESCRIPTION
tablecols	inner | outer | data | level*1*	data	Whether to use inner or outer solutions as columns in the table when calling setResult() or appendResult(). Applicable only for parametric sweep models. The level values (level1, level2, and so on) are the levels in the parametric sweep.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

RayBin

Create a ray bin data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"RayBin");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

model.result().dataset().create(*<dtag>*,"RayBin") creates a ray bin data set. This data set evaluates an expression over all rays and then groups them into subintervals, or bins, based on which rays return similar values. If this data set is then used in any other ray plot or evaluation, each bin produces a single ray having position and other properties equal to the average over rays in the bin.

The following properties are available:

TABLE 7-91: VALID PROPERTY/VALUE PAIRS FOR RAY BIN DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | data set name	First ray data set	The ray data set this feature refers to.
distribution	equalnumber | equalwidth	equalnumber	Distribution of ray bins. Active when method is set to number.
limits	String		String listing the limits of all bins. Active when method is set to limits.
method	limits | number | tolerance	limits	The method used to define the limits of the ray bins.
number	positive integer	10	Number of ray bins. Active when method is set to number.
tolerance	String		Maximum difference between expression values such that rays are placed in the same bin. Active when method is set to tolerance.

RayTrajectories

Create a ray trajectories plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"RayTrajectories");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"RayTrajectories")` creates a ray trajectories plot feature named `<ftag>` belonging to plot group `<pgtag>`.

A ray data set is required to plot ray trajectories. The ray data set identifies the geometry in which the ray data is stored and the degrees of freedom which determine the position of each ray.

The following properties are available:

TABLE 7-92: VALID PROPERTY/VALUE PAIRS FOR RAY TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`arrowbase`	`heat`|`tail`|`center`	`head`	Whether the head, tail, or center of the arrow is located at the ray position.
`arrowexpr`	string array		Active when `pointtype` is set to `arrow`. Determines the direction in which the arrow points.
`arrowlength`	`logarithmic`|`normalized`|`proportional`	`proportional`	The arrow scaling: `Proportional` uses the actual arrow length, `normalized` a unit length, and `logarithmic` a length proportional to the logarithm of the arrow length.
`arrowscale`	positive double	1	If `arrowscaleactive` is true: the length scale factor.
`arrowscaleactive`	boolean	`false`	If true, `arrowscale` is used, otherwise the scale factor is computed automatically.
`arrowtype`	`arrow` | `arrowhead` | `cone`	`arrow`	The type of arrow to draw.
`comettailexpr`	String array	inverse of velocity vector of the first available ray tracing interface	Active when `pointtype` is set to `comettail`. Determines the direction in which the comet tail points and the relative sizes of the tails of different rays.
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to.
`extrasteps`	`none` | `specifiedtimes`| `proportional`	`proportional`	Controls how the number of extra time steps rendered in the trajectory plot is calculated. These extra time steps typically correspond to the exact times of reflections and refractions.
`fixedpointsize`	Boolean	`false`	Use constant radii for the plotted spheres.
`inheritarrowscale`	Boolean	`true`	If `inheritplot` is not none: Determines if the arrow scale is inherited.
`inheritcolor`	Boolean	`true`	If `inheritplot` is not `none`: Determines if the color is inherited.
`inheritdeformscale`	Boolean	`true`	If `inheritplot` is not `none`: Determines if the deformation scale is inherited.
`inheritellipsecale`	Boolean	`true`	If `inheritplot` is not `none`: Determines if the ellipse scale factor is inherited.
`inheritplot`	`none` | plot name	`none`	The plot that color, color range, and plot scales are inherited from.

TABLE 7-92: VALID PROPERTY/VALUE PAIRS FOR RAY TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the radius scale factor is inherited.
inherittailscale	Boolean	true	If inheritplot is not none: Determines if the tail scale factor is inherited.
inherittubescale	Boolean	true	If inheritplot is not none: Determines if the tube radius scale factor is inherited.
interpolation	none | uniform	none	The type of interpolation used to plot lines when linetype is line or tube.
linecolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black (2D), red (3D)	The uniform color to use for lines.
linetype	none | line | ribbon | tube	line	Plot ray traces as lines, ribbons, or tubes, or not at all.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
numextrasteps	Nonnegative integer	100	If extrasteps is specifiedtimes, controls the maximum number of extra time steps to render in the plot.
pointautoscale	on | off	on	If enabled, the point radii are scaled based on the size of the geometry.
pointcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use for points.
pointlineanim	on | off	off	When animating ray trajectories plots with points, this property indicates whether the points at the current time should appear on top of the lines.
pointradiusexpr	String	0.001	The point radius expression.
pointtype	none | point | comettail | arrow | ellipse	none	Plot particles as points, with comet tails, with arrows, with polarization ellipses, or not at all.
propextrasteps	Nonnegative integer	1	If extrasteps is proportional, controls the maximum number of extra time steps to render in the plot. The maximum number of extra steps is the product of this proportionality factor with the number of solution times.
radiusexpr	String	1	The tube radius expression.
sphereradiusscale	positive double		The scale factor applied to the point radii if sphereradiusscaleactive is on.
sphereradiusscaleactive	on | off	off	If on, sphereradiusscale is used; otherwise the scale factor is computed automatically.

TABLE 7-92: VALID PROPERTY/VALUE PAIRS FOR RAY TRAJECTORIES PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`tailscale`	positive double	1	Active when `pointtype` is set to `comettail` and `tailscaleactive` is `on`. Specifies the manual scale factor with which the comet tail expression is multiplied.
`tailscaleactive`	`on` | `off`	`off`	Active when `pointtype` is set to `comettail`. Specifies whether manual tail scaling is enabled.
`title`	String		Active when `title` is set to `manual`. Specifies the plot title.
`titletype`	`automatic` | `manual` | `none`	`automatic`	Determines how the plot title is specified.
`tuberadiusscale`	String	1	The scale factor applied to the tube radii if tuberadiusscaleactive is `on`.
`tuberadiusscaleactive`	`on` | `off`	`off`	If `on`, `tuberadiusscale` is used; otherwise, the scale factor is computed automatically.

ATTRIBUTES

Color, Deform, Export, Filter (Particle Tracing, Point Trajectories, Ray Tracing,)

SEE ALSO

Ray (1D Plot), Ray (Evaluation)

Receiver2D, Receiver3D

SYNTAX

```
model.result().dataset().create(<dtag>,"Receiver2D");
model.result().dataset().create(<dtag>,"Receiver3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Receiver2D")` and `model.result().dataset().create(<dtag>,"Receiver3D")` create 2D and 3D receiver data sets, respectively. Use these data sets to collect the data necessary to visualize the impulse response for a Ray Acoustics simulation (of room acoustics, for example), using an Impulse Response plot. The Impulse Response plot uses the data from a Receiver data set as input.

The following properties are available:

TABLE 7-93: VALID PROPERTY/VALUE PAIRS FOR RECEIVER2D AND RECEIVER3D DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`center`	double array	{0, 0,} (2D); {0, 0, 0} (3D)	Center coordinates.
`data`	`none` | data set name	First ray data set	The ray data set this feature refers to.
`directivity`	`omnidirectional` | `user`	`omnidirectional`	The directivity type: omnidirectional, or a user-defined expression (in dB),
`directivityexpr`	double	0	An expression for the directivity. Active when `directivity` is set to `user`.

TABLE 7-93: VALID PROPERTY/VALUE PAIRS FOR RECEIVER2D AND RECEIVER3D DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
dirvar	String	<dtag>dir	Variable for the directivity.
distance	double	0	Source-receiver distance. Active when radiusinput is set to expr.
distvar	String	<dtag>dist	Variable for the distance traveled.
extrasteps	specifiedtimes | proportional | none	omnidirectional	Specification of the maximum number of extra time steps rendered: as a specified number of times, as proportional to the number of solution times, or none.
firstvar	String	<dtag>first	Variable for the first ray arrival time.
interpolation	linear | cubic	linear	Interpolation between time steps: linear or cubic.
nrays	integer	0	Number of rays. Active when radiusinput is set to expr.
numextrasteps	nonnegative integer	100	Maximum number of extra time steps. Active when extrasteps is set to specifiedtimes.
propextrasteps	nonnegative integer	1	Proportionality factor for extra time steps. Active when extrasteps is set to propotional.
radius	double	0	Radius. Active when radiusinput is set to user.
radiusinput	expr | user	expr	Define the input for the radius using an expression or a user-defined radius.
volume	double	0	Room volume. Active when radiusinput is set to expr.
volvar	String	<dtag>vol	Variable for the volume.

ReflectionGraph, ImpedanceGraph, AdmittanceGraph

Create a reflection graph, impedance graph, or admittance graph in a Smith plot. You can add a Reflection Graph, Impedance Graph, and Admittance Graph to a SmithGroup.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ReflectionGraph");
model.result(<pgtag>).create(<ftag>,"ImpedanceGraph");
model.result(<pgtag>).create(<ftag>,"AdmittanceGraph");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

The reflection graph, impedance graph, and admittance graph are all graphs that appear in a Smith plot. The expressions to use can be S-parameters from an RF simulation, for example. For an impedance plot you can also provide a reference impedance; for an admittance plot you can also provide a reference admittance.

The following properties are available:

The following properties are available:

TABLE 7-94: VALID PROPERTY/VALUE PAIRS FOR REFLECTION GRAPH, IMPEDANCE GRAPH, AND ADMITTANCE GRAPH.

NAME	VALUE	DEFAULT	DESCRIPTION
autodescr	on | off	Model dependent	Whether the automatic legends should include the expression descriptions.
autoexpr	on | off	Model dependent	Whether the automatic legends should include the expressions.
autolegends	on | off	on	Whether to use the automatically computed legends or the legends defined in the legends property. The automatic legends display the description and expression for each line.
autounit	on | off	off	Whether the automatic legends should include the unit.
const	String array of property/ value pairs	Empty	Parameters to use in the expressions.
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String array	Model-dependent.	The description of the expressions in expr. Is used in the automatic legends.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array	Model-dependent.	The expressions to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
legend	on | off	off	Whether to show legends.

TABLE 7-94: VALID PROPERTY/VALUE PAIRS FOR REFLECTION GRAPH, IMPEDANCE GRAPH, AND ADMITTANCE GRAPH.

NAME	VALUE	DEFAULT	DESCRIPTION
`legendmethod`	`automatic` | `manual`	`automatic`	Whether to use the automatic legends or the legends supplied in the `legends` property.
`legendprefix`	String		A prefix added to the automatic legend.
`legends`	String array	The last computed automatic legends.	Manual legends active when `legendmethod` is set to `manual`.
`legendsuffix`	String		A suffix added to the automatic legend.
`linecolor`	`custom` | `cycle` | `black` | `blue` | `cyan` | `gray` | `green` | `magenta` | `red` | `white` | `yellow`	`cycle`	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
`linewidth`	double	`0.5`	The line width.
`linemarker`	`none` | `cycle` | `asterisk` | `circle` | `diamond` | `plus` | `point` | `square` | `star` | `triangle`	`none`	The line markers, if any. Cycle indicates that the marker is different for each line.
`linestyle`	`none` | `cycle` | `solid` | `dotted` | `dashed` | `dashdot`	`solid`	The line style, if any. Cycle indicates that the line style is different for each line.
`looplevel`	integer row matrix	`All solutions` on all levels	The solutions to use, per level.
`looplevelindices`	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `looplevelinput` is `manualindices` on a level.
`looplevelinput`	String array with `all` | `first` | `last` | `manual` | `manualindices` | `interp` on each level	`all` on all levels	How to input the solution to use, per level. `manual` on a level indicates that `looplevel` is used on that level. `manualindices` on a level indicates that `looplevelindices` is used on that level. `interp` on a level indicates that `interp` is used on that level.
`markerpos`	`interp` | `datapoints`	`interp`	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in `markers`). Markers are visible when `linemarker` is set.
`markers`	integer	8	The number of markers to show. Markers are visible when `linemarker` is set.
`outerinput`	`all` | `first` | `last` | `manual` | `manualindices`	`all`	How to input the outer solutions to use. Applicable only for parametric sweep models. `manual` indicates that `outersolnum` is used. `manualindices` indicates that `outersolnumindices` is used.

TABLE 7-94: VALID PROPERTY/VALUE PAIRS FOR REFLECTION GRAPH, IMPEDANCE GRAPH, AND ADMITTANCE GRAPH.

NAME	VALUE	DEFAULT	DESCRIPTION
`outersolnum`	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the `solnum` property is not used.
`outersolnumindices`	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `outerinput` is `manualindices`.
`prefixintitle`	String	Empty	Added prefix to contribution to title.
`solnum`	nonnegative integer array	All solutions	The solutions to plot. Available when `data` is not `parent` and the underlying data has multiple solutions.
`solnumindices`	String or integer array	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`solrepresentation`	`solnum` | `solutioninfo`	`solutioninfo`	Indicates which method of selecting solutions is active.
`suffixintitle`	String	Empty	Added suffix to contribution to title.
`t`	double array	Empty	The times to plot. Available when `data` is not `parent` and the underlying solution is transient.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title contribution should be computed automatically, possibly using the group's customization. `custom` if the title contribution should be computed automatically, but customized. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution should contain the type when `titletype` is `custom`.
`unit`	String	Model-dependent	The unit to use for the expression in `expr`. If the old unit is not valid when the expression changes, the unit property is reset to default.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution should contain the unit when `titletype` is `custom`.
`y0`	double	50	Reference impedance (Impedance Graph only).
`z0`	double	0.02	Reference admittance (Admittance Graph only).

ATTRIBUTE

Color

SEE ALSO

SmithGroup

ResponseSpectrum2D, ResponseSpectrum3D

Create a response spectrum 2D or 3D data set. A response spectrum analysis is a modal-based method for estimating the structural response to a transient, nondeterministic event. Typical applications are dimensioning against earthquakes and shocks.

The ResponseSpectrum2D and ResponseSpectrum3D data sets require a license for the Structural Mechanics Module.

SYNTAX

```
model.result().dataset().create(<dtag>,"ResponseSpectrum2D");
model.result().dataset().create(<dtag>,"ResponseSpectrum3D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(`*`<dtag>`*`,"ResponseSpectrum2D")` creates a 2D response spectrum data set feature named *<dtag>*.

`model.result().dataset().create(`*`<dtag>`*`,"ResponseSpectrum3D")` creates a 3D response spectrum data set feature named *<dtag>*.

The input to a response spectrum is the results from an eigenfrequency computation.

The following properties are available for ResponseSpectrum2D and ResponseSpectrum3D:

TABLE 7-95: VALID PROPERTY/VALUE PAIRS FOR RESPONSE SPECTRUM2D AND RESPONSE SPECTRUM3D DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`abscouplingterms`	Boolean	`false`	Use absolute value for coupling terms, when `modecomb` is `cqc`, `grouping`, or `tenpercent`.
`abscouplingtermsdoublesum`	Boolean	`false`	Use absolute value for coupling terms (NRC RG 1.92 Rev. 1), when `modecomb` is `doublesum`.
`augmentwithrigidresponse`	Boolean	`false`	Augment with rigid response, when `spatialcomb` is `cqc3` or `srss3` (3D only).
`data`	`none` | data set name	First compatible data set	The eigenvalue data set this feature refers to.
`durationtime`	nonnegative scalar	0	The time of duration (in seconds) when `modecomb` is `doublesum`.
`freqlimitperiodic`	nonnegative scalar	0	Frequency limit for purely periodic modes (when `rigidmodes` is not `none`).

TABLE 7-95: VALID PROPERTY/VALUE PAIRS FOR RESPONSE SPECTRUM2D AND RESPONSE SPECTRUM3D DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
freqlimitrigid	nonnegative scalar	0	Frequency limit for purely rigid modes (when rigidmodes is gupta).
masscorrectiongupta	missingmass | none	none	Mass correction when rigidmodes is gupta: none or missing mass method.
masscorrectionlindleyyow	staticzpa | missingmass | none	none	Mass correction when rigidmodes is lindleyyow: none, missing mass method, or static ZPA method.
modecomb	cqc | abssum | srss | doublesum | grouping | tenpercent	cqc	Mode combination: CQC (Der Kiureghian), absolute value sun, SRSS, double sum (Rosenblueth), grouping method, or ten percent method. Available when spatialcomb is srss or percent.
primaxisrotation	angle	0[deg]	Primary axis rotation (3D only).
primhorizspectrum	none | function name	none	Horizontal spectrum function in 2D; primary horizontal spectrum function in 3D.
reldamp	0–1	0.05	Relative damping when modecomb is cqc or doublesum.
rigidmodes	lindleyyow | gupta | none	none	Rigid modes.
sechorizscale	nonnegative scalar	0.5	Secondary horizontal spectrum scale factor, when spatialcomb is cqc3 or srss3 (3D only).
sechorizspectrum	none | function name	none	Secondary horizontal spectrum function (3D only).
spatialcomb	srss | percent | cqc3 | srss3	srss	Spatial combination: SRSS, percent method, CQC3 (3D only), or SRSS3 (3D only).
spectrumfunof	frequency | periodtime	frequency	If the spectrum depends on frequency or period time.
spectrumtype	pseudoacc | displacement | pseudovel	pseudoacc	Spectrum type: pseudo-acceleration, displacement, or pseudo-velocity spectrum.
vertspectrum	none | function name	none	Vertical spectrum function.

TABLE 7-95: VALID PROPERTY/VALUE PAIRS FOR RESPONSE SPECTRUM2D AND RESPONSE SPECTRUM3D DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
wgtsmallresponse	0–1 (0-100%)	40[%]	Weight factor for smaller response (when spatialcomb is percent).
zeroperiodaccfreq	nonnegative scalar	0	Zero period acceleration frequency (when rigidmodes is not none). Available when spatialcomb is srss or percent.

SEE ALSO

Solution

Revolve1D, Revolve2D

Create a 1D or 2D revolve data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Revolve1D");
model.result().dataset().create(<dtag>,"Revolve2D");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Revolve1D")` creates a 1D revolved data set feature named *<dtag>*.

`model.result().dataset().create(<dtag>,"Revolve2D")` creates a 2D revolved data set feature named *<dtag>*.

The revolved data set needs to supply variables that cannot be expressed in terms of the coordinates of the underlying data set: The spatial coordinates and the rotation angle. Therefore the xmesh interpolation/evaluation has to be extended with support for supplying the values of these variables in a given set of points. The names of the spatial coordinates need not be exposed to the user, but the revolution angle should be available as `revphi`.

The source data sets for the revolutions can be any 1D and 2D data sets although the feature is primarily intended for axisymmetric coordinate systems.

The following properties are available for Revolve1D:

TABLE 7-96: VALID PROPERTY/VALUE PAIRS FOR REVOLVE DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
anglevar	String	Derived from feature name	The name of the angle variable in the revolved coordinate system.
data	none | data set name	First compatible data set	The data set this feature refers to.
hasspacevars	Boolean	false	If true, spacevars and anglevars are made available for evaluation.
planemap	xy | xz	xz	The 3D plane that the 2D xy plane is mapped to.
point	double	0	The point that is the axis of revolution.
revangle	double	360	The revolution angle (degrees).
revlayers	integer >= 3	50	The number of revolution layers.

TABLE 7-96: VALID PROPERTY/VALUE PAIRS FOR REVOLVE DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
spacevars	String array	Derived from feature name	The names of the space variables in the revolved coordinate system.
startangle	double	0	The angle where the revolved sector begins (degrees).

The following properties are available for Revolve2D:

TABLE 7-97: VALID PROPERTY/VALUE PAIRS FOR 2D REVOLVE DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | data set name	First compatible data set	The data set this feature refers to.
method	twopoint | pointdir	twopoint	Decides if the line should be specified by two points or through one point and a direction.
genpoints	double matrix	{{0, 0, 0}, {1,0,0}}	Active when method equals twopoint, this property contains the coordinates of the two points in the two rows of the matrix.
layermethod	coarse | custom | fine | normal	normal	The method used for choosing how many layers to use.
modenumber	integer	0	The azimuthal mode number.
pddir	String array	{"0","1"}	Active when method equals pointdir, this property contains the direction.
pdpoint	String array	{"0","0"}	Active when method equals pointdir, this property contains the coordinates of the point.
revlayers	integer >= 3	50	The number of revolution layers if layermethod is custom.

SEE ALSO

Solution

ScatterVolume, ScatterSurface

Create a scatter plot on surfaces or in volumes.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ScatterVolume");
model.result(<pgtag>).create(<ftag>,"ScatterSurface");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Scatter...")` creates a scatter plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Scatter plots are available in 2D and 3D.

The following properties are available:

TABLE 7-98: VALID PROPERTY/VALUE PAIRS FOR SCATTER PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
arrowxmethod	number | coord	number	Indicates whether the x-coordinates of the spheres should be specified by number of points to distribute evenly across the data or by coordinates.
arrowymethod	number | coord	number	Indicates whether the y-coordinates of the spheres should be specified by number of points to distribute evenly across the data or by coordinates.
arrowzmethod	number | coord	number	Indicates whether the z-coordinates of the spheres should be specified by number of points to distribute evenly across the data or by coordinates. Available for ScatterVolume.
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The color to use.
colorexpr	String		The expression for the colors of the spheres.
colordescr	String		A description of colorexpr.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expressions in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array of length 2 in 2D and 3 in 3D	Mode-dependent	The components to plot.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritplot	none | plot name	none	The plot that color and sphere scale are inherited from.

TABLE 7-98: VALID PROPERTY/VALUE PAIRS FOR SCATTER PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritspherescale	Boolean	true	If inheritplot is not none: Determines if the sphere scale is inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
planecoordsys	cutplane | cartesian	cartesian	Coordinate system for scatter plot vectors. Only available for plots that use a cut plane data set that points to a 3D solution or mesh data set.
prefixintitle	String	Empty	Added prefix to contribution to title.
radiusexpr	String		The expression for the radii of the spheres.
radiusdescr	String		A description of radiusexpr.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.

TABLE 7-98: VALID PROPERTY/VALUE PAIRS FOR SCATTER PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
revcoordsys	cylindrical | cartesian	cartesian	Coordinate system for scatter plot vectors. Only available for plots that use a 1D or 2D revolution data set that has default axis settings and points to a solution or mesh data set for an axisymmetric geometry.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
sphereradiusscale	double	1	The scale factor applied to the sphere radii if sphereradiusscaleactive is true.
sphereradiusscaleactive	Boolean	false	If true, sphereradiusscale is used; otherwise the scale factor is computed automatically.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
xnumber	nonnegative integer	15 (3D), 7 (2D)	Number of points in the x-direction. Active when arrowxmethod is set to number.
xcoord	double array	Empty	Absolute coordinates in the x-direction, active when arrowxmethod is set to coord.
ynumber	integer	15 (3D), 7 (2D)	Number of points in the y-direction. Active when arrowymethod is set to number.

TABLE 7-98: VALID PROPERTY/VALUE PAIRS FOR SCATTER PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
ycoord	double array	Empty	Absolute coordinates in the z-direction, active when arrowymethod is set to coord.
znumber	integer	15 (3D), 7 (2D)	Number of points in the z-direction. Active when arrowzmethod is set to number. Available for ScatterVolume.
zcoord	double array	Empty	Absolute coordinates in the z-direction, active when arrowzmethod is set to coord. Available for ScatterVolume.

SEE ALSO

Surface, Volume

Sector2D, Sector3D

Create a 2D or 3D sector symmetry data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Sector2D");
model.result().dataset().create(<dtag>,"Sector3D");
model.result().dataset(<dtag>).set(property, <value>);
model.result().dataset(<dtag>).run();
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Sector2D")` creates a 2D sector symmetry data set feature named *<dtag>*.

`model.result().dataset().create(<dtag>,"Sector3D")` creates a 3D sector symmetry feature named *<dtag>*.

This data set takes data from another data sets and expands it using sector symmetry around an axis.

The following properties are available for Sector 2D and Sector 3D:

TABLE 7-99: VALID PROPERTY/VALUE PAIRS FOR SECTOR SYMMETRY DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
data	none | data set name	First compatible data set	The data set this feature refers to.
genpoints	double matrix	{{0, 0, 0}, {1,0,0}}	When method is twopoint: The coordinates of two points on the symmetry axis. Available for Sector3D.
hasspacevars	Boolean	false	If true, spacevars are made available for evaluation.
hasvar	Boolean	false	If true, an axis indicator variable is defined.
include	all | manual	all	Use all sectors or specify manually which ones to include.
method	twopoint | pointdir	twopoint	Decides if the line should be specified by two points or through one point and a direction. Available for Sector3D.

TABLE 7-99: VALID PROPERTY/VALUE PAIRS FOR SECTOR SYMMETRY DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
mode	integer	0	If sectors is odd or trans is rot: The azimuthal mode number use to transform the solution's phase between sectors.
pddir	String array	{"0","1"}	When method is pointdir: The direction in which the symmetry axis points. Available for Sector3D.
pdpoint	String array	{"0","0"}	When method is pointdir: The coordinates of a point on the symmetry axis. Available for Sector3D.
point	double array of length 2	{0, 0}	The coordinates of the symmetry axis. Available for Sector2D.
reflaxis	String array of length 2 in 2D and length 3 in3D	{"1","0"} in 2D, {"1","0", "0"} in 3D	If trans is rotrefl: The direction in which the reflection axis/plane (for 2D and 3D respectively) points.
sectors	integer >= 2	2	The number of sectors.
sectorsinclude	integer >= 2	sectors	The number of sectors to include (when include = manual).
sectorvar	String	created from feature's tag	Name of variable that evaluates to the sector number, which starts at 0 for the first sector.
spacevarst	String array of length 2 in 2D and length 3 in 3D	created from feature's tag	Names of variables that evaluate to the space coordinates in the coordinate system after sector symmetry expansion.
startsector	integer >= 0	0	Starting sector for manual selection of sectors to include (when include = manual).
trans	rot | rotrefl	rot	If sectors is even: Controls whether the transformation performed between consecutive sectors is rotation or rotation and reflection.

Selection

Add a selection attribute to a plot.

SYNTAX

```
model.result(<pgtag>).feature(<ftag>).create(<atag>,"Selection");
model.result(<pgtag>).feature(<ftag>).feature(<atag>).selection().set(...);
```

DESCRIPTION

`model.result(<pgtag>).feature(<ftag>).create(<atag>,"Selection")` creates a selection attribute named *<atag>* belonging to the plot feature *<ftag>*.

Use selections to limit plots to a certain selection of geometric entities such as domains or boundaries.

See model.selection() for more information about selection.

Selection can be added to arrow plots, contour plots, coordinate system plots, isosurface plots, line plots, max/min plots, mesh plots, multislice plots, principal stress plots, slice plots, streamline plots, and volume plots.

Shell

Create a shell data set.

The Shell data set requires a license for the Structural Mechanics Module.

SYNTAX

```
model.result().dataset().create(<dtag>,"Shell");
model.result().dataset(<dtag>).set(property, <value>);
model.result().dataset(<dtag>).run();
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Shell")` creates a shell data set. A shell data set makes it possible to visualize the top and bottom surfaces of a shell in 3D.

The following properties are available:

TABLE 7-100: VALID PROPERTY/VALUE PAIRS FOR SHELL DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`bottomconst`	4-by-1 real array		Array of bottom shell surface parameters: Local z-coordinate for thickness-dependent results and the x, y, and z coordinates of the reference point for moment computations.
`distanceexpr`	String		String with an expression for the displacement magnitude.
`orientationexpr`	3-by-1 string array		String array of expressions for the components of the displacement direction vector.
`topconst`	4-by-1 real array		Array of top shell surface parameters: Local z-coordinate for thickness-dependent results and the x, y, and z coordinates of the reference point for moment computations.

SEE ALSO

`Solution`

Slice

Create a slice plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Slice");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Slice")` creates a slice feature named *<ftag>* belonging to the plot group *<pgtag>*.

Only one direction of slices is possible in one plot. Use different slice plots together to accomplish several slices in different directions.

The following properties are available:

TABLE 7-101: VALID PROPERTY/VALUE PAIRS FOR SLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`color`	`custom` | `black` | `blue` | `cyan` | `gray` | `green` | `magenta` | `red` | `white` | `yellow`	`red`	The uniform color to use. Active when `coloring` is `uniform`.
`coloring`	`colortable` | `uniform`	`colortable`	How to color the slices.
`colorlegend`	`on` | `off`	`on`	Whether to show color legend, when `coloring` is set to `colortable`.
`colortable`	color table name	`Rainbow`	The color table to use when `coloring` is set to `colortable`. See Color Tables for a list of color tables.
`colortablerev`	`on` | `off`	`off`	Whether to reverse to color table when `coloring` is set to `colortable`.
`colortablesym`	`on` | `off`	`off`	Whether to symmetrize the color range around 0 when `coloring` is set to `colortable`.
`customcolor`	RGB-triplet	`{1,0,0}` or last used color.	The uniform color to use. Active when `color` is set to `custom`.
`const`	String array of property/ value pairs	`Empty`	Parameters to use in the expressions.
`data`	`none` | `parent` | data set name	`parent`	The data set this feature refers to.
`descr`	String	Model-dependent.	The description of the expression in `expr`. Is used in the automatic title.
`descriptionintitle`	`on` | `off`	`on`	Whether the title contribution should contain the description when `titletype` is `custom`
`differential`	`on` | `off`	`on`	Whether the expression should be linearized at the linearization point. Applicable only if `evalmethod` is `harmonic`.
`evalmethod`	`linpoint` | `harmonic` | `lintotal` | `lintotalavg` | `lintotalrms` | `lintotalpeak`	`harmonic`	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
`expr`	String	Model-dependent.	The expression to plot.

TABLE 7-101: VALID PROPERTY/VALUE PAIRS FOR SLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom
gendistance	double array	Empty	Vector of distances from base plane, indicating position of additional parallel planes. Active when genparaactive equals on and genpara equals number.
genmethod	threepoint | pointnormal	threepoint	Active when planetype equals general, this property indicates whether the plane should be specified by three points or through one point and a normal
gennumber	positive integer	4	Number of additional parallel planes. Active when genparaactive equals on and genpara equals number.
genpara	gennumber | gendistances	number	Active when planetype equals general, and genparaactive equals on, this property indicates whether the additional parallel planes should be specify by a number or by a vector of relative distances.
genparaactive	on | off	off	Active when planetype equals general, this property indicates whether there should be additional parallel planes created.
genpnpoint	String array of length three	{"0","0","0"}	Active when genmethod equals pointnormal, this property contains the coordinates of the point.
genpnvec	String array of length three	{"0","0","0"}	Active when genmethod equals pointnormal, this property contains the normal vector.
genpoints	double matrix of size 3x3	{{0,0,0}, {1,0,0}, {0,1,0}}	Active when genmethod equals threepoint, this property contains the coordinates of the three points, with one row per point.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that color, color range, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
interactive	on | off	off	If true, the isosurfaces can be moved interactively after the plot has been made.

TABLE 7-101: VALID PROPERTY/VALUE PAIRS FOR SLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`interp`	double array	Time corresponding to last selected `solnum` for transient levels.	The time to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or `interp`, but only for transient solutions. Available when `data` is not `parent` and the underlying data has multiple solutions.
`outersolnum`	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
`planetype`	`quick` | `general`	`yz`	Specify plane type
`prefixintitle`	String	Empty	Added prefix to contribution to title
`quickplane`	`xy` | `yz` | `zx`	`yz`	Specify quick plane type. Active when `planetype` is `quick`.
`quickx`	String array	0	Absolute x-coordinates for planes, active when `quickxmethod` is set to `coord`
`quickxmethod`	`number` | `coord`	`number`	Active when `planetype` equals `quick` and `quickplane` equals `yz`, this property indicates whether the planes should be specified by one or more absolute coordinates along the x-axis, or a number indicating the number of planes to distribute evenly.
`quickxnumber`	String	5	The number of planes when `quickxmethod` is set to `number`. It can contain a global expression for the number of slices.
`quicky`	String array	0	Absolute y-coordinates for planes, active when `quickymethod` is set to `coord`.
`quickymethod`	`number` | `coord`	`number`	Active when `planetype` equals `quick` and `quickplane` equals `zx`, this property indicates whether the planes should be specified by one or more absolute coordinates along the y-axis, or a number indicating the number of planes to distribute evenly.
`quickynumber`	String	5	The number of planes when `quickymethod` is set to `number`. It can contain a global expression for the number of slices.
`quickz`	String array	0	Absolute z-coordinates for planes, active when `quickzmethod` is set to `coord`.

TABLE 7-101: VALID PROPERTY/VALUE PAIRS FOR SLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
quickzmethod	number | coord	number	Active when planetype equals quick and quickplane equals xy, this property indicates whether the planes should be specified by one or more absolute coordinates along the z-axis, or a number indicating the number of planes to distribute evenly.
quickznumber	String	5	The number of planes when quickzmethod is set to number. It can contain a global expression for the number of slices.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
shift	double	0	If interactive is on: The shift that is applied to the level values.

TABLE 7-101: VALID PROPERTY/VALUE PAIRS FOR SLICE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active
suffixintitle	String	Empty	Added suffix to contribution to title
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom

ATTRIBUTES

Deform, Filter

SEE ALSO

Volume

SmithGroup

Create a Smith plot group.

The Smith Plot Group requires a license for the AC/DC Module, RF Module, MEMS Module, or Plasma Module.

SYNTAX

```
model.result().create(<pgtag>, "SmithGroup");
model.result(<pgtag>).set(property, <value>);
model.result(<pgtag>).run();
```

DESCRIPTION

`model.result().create(<pgtag>,"SmithGroup")` creates a Smith plot group named *<pgtag>*. A Smith plot group displays the containing graph plots as Smith plots.

The following properties are available for Smith plot groups:

TABLE 7-102: VALID PROPERTY/VALUE PAIRS FOR SMITH PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
admittance	on | off	off	Add grid for an admittance Smith plot.
data	none | data set name	First compatible data set	The data set this feature refers to. This is the default data set for all plots in the group.
datasetintitle	on | off	off	Whether the title should contain the data set when titletype is custom
expressionintitle	on | off	off	Whether the title contribution of plots in this group should contain the expression when titletype is custom
impedance	on | off	on	Add grid for an impedance Smith plot.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not none and the underlying data is transient.
legendpos	upperright | lowerright | upperleft | lowerleft	upperright	The position of the legends for all plots in this group
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when looplevelinput is manualindices on a level.

TABLE 7-102: VALID PROPERTY/VALUE PAIRS FOR SMITH PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
phaseintitle	on | off	off	Whether the title should contain the phase when titletype is custom.
prefixintitle	String	Empty	Added prefix to group contribution to title
resolution	fine | normal | coarse	normal	Grid resolution for Smith plot coordinate grid.
showlegendsmaxmin	on | off	off	Show maximum and minimum values for color legends (when a Color Expression has been added).
solnum	Integer array	All solutions	The solutions to plot. Available when the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active
suffixintitle	String	Empty	Added suffix to group contribution to title
t	double array	Empty	The times to plot. Available when the underlying solution is transient.
title	String	The auto-title.	The title to use when titletype is manual
titletype	auto | custom | manual | none	auto	auto if the title should be computed automatically. custom if the title should be computed automatically, but customized. manual if the manual title should be used (the title property). none if no title should be displayed.

TABLE 7-102: VALID PROPERTY/VALUE PAIRS FOR SMITH PLOT GROUPS

NAME	VALUE	DEFAULT	DESCRIPTION
typeintitle	on | off	on	Whether the title contribution of plots in this group should contain the type when titletype is custom
unitintitle	on | off	on	Whether the title contribution of plots in this group should contain the unit when titletype is custom
window	graphics | new | windowX, where X is an integer	graphics	The window where the plot group is displayed. When plotting on a graphics server, graphics is equivalent to new.
windowtitle	String	Computed automatically	The title to use for the window where the plot group is displayed. It is not possible to change the title of the graphics window.
windowtitleactive	on | off	off	Set windowtitleactive to on to enter a manual window title in windowtitle

SEE ALSO

PlotGroup1D, PlotGroup2D, PlotGroup3D, PolarGroup

Solution

Create a solution data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Solution");
model.result().dataset(<dtag>).set(property, <value>);
model.result().dataset(<dtag>).selection(...);
model.result().dataset(<dtag>).createDeformedConfig(<gtag>,<mtag>);
```

DESCRIPTION

model.result().dataset().create(*<dtag>*,"Solution") creates a solution data set.

Solution data sets refer to a solution in a solver sequence. All result features that perform evaluations on a solution refer to these data sets rather than directly to the solution itself. The solution data sets specify which geometry and frame to use for evaluation and whether to evaluate only on a specific selection, among other things. It is possible to have multiple data set solutions referring to the same solution.

The following properties are available:

TABLE 7-103: VALID PROPERTY/VALUE PAIRS FOR SOLUTION DATA SETS

NAME	VALUE	DEFAULT	DESCRIPTION
frametype	mesh | material | spatial| geometry	material or spatial	The frame type that this data set uses for evaluation of spatial coordinates.
geom	String	First available geometry, if any.	The geometry this data set refers to. Only applicable for solutions that refer to a geometry.
phase	double	0	Evaluate solution at this angle, given in degrees
scalefactor	double	1	Multiply solution by this scaling factor
solution	String	First compatible solution	The solution this data set refers to

model.result().dataset(*<dtag>*).createDeformedConfig(*<gtag>*,

<mtag>) creates a new geometry sequence (deformed configuration) tagged *<gtag>* together with a meshing sequence tagged *<mtag>* to use for remeshing of a deformed mesh. The created geometry sequence only contains a `FromMesh` feature.

EXAMPLE

Create a solution data set and set it to point to the second geometry in the solver sequence `sol1`:

Code for Use with Java

```
DatasetFeature ds = model.result().dataset().create("dset1", "Solution");
ds.set("solution", "sol1");
ds.set("geom", "geom2");
```

Code for Use with MATLAB

```
ds = model.result.dataset.create('dset1', 'Solution');
ds.set('solution', 'sol1');
ds.set('geom', 'geom2');
```

SEE ALSO

`PlotGroup1D, PlotGroup2D, PlotGroup3D`

Streamline

Create a streamline plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Streamline");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(`*<pgtag>*`).create(`*<ftag>*`,"Streamline")` creates a streamline plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Streamlines visualize a vector quantity on domains. A streamline is a curve everywhere tangent to an instantaneous vector field. Streamlines are available in 2D and 3D plot groups.

The following properties are available:

TABLE 7-104: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`arrowcount`	positive integer		The number of arrows.
`arrowdistr`	`equalarc` | `equaltime` | `equalinvtime`	`equalarc`	Arrow distribution: equal in arc length, time, or inverse time.
`arrowlength`	`normalized` | `proportional` | `logarithmic`	`normalized`	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
`arrowscale`	positive double	1	The arrow length scale factor.
`arrowtype`	`arrow` | `arrowhead` | `cone`	`arrow`	The type of arrow to draw.
`back`	`on` | `off`	`on`	Allow backward time integration. Only available for time-dependent data sets.

TABLE 7-104: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	black (2D), red (3D)	The uniform color to use for the streamlines and arrows.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array of length 2 in 2D and 3 in 3D	Model-dependent	The components to plot.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if arrow scale is inherited.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that color, tube scale, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritribbonscale	Boolean	true	If inheritplot is not none: Determines if the ribbon scale is inherited.
inherittubescale	Boolean	true	If inheritplot is not none and linetype is tube or ribbon: Determines if the tube or ribbon scale is inherited.

TABLE 7-104: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`interp`	double array	Time corresponding to last selected `solnum` for transient levels.	The time to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`inttol`	positive double	0.001 (2D), 0.01 (3D)	Integration tolerance.
`linearrowtype`	`none` | `tangent`	`none`	Use no arrows or arrows that are tangential to the streamlines.
`linetype`	`line` | `tube` | `ribbon` | `none`	`line`	Plot streamlines as lines, tubes, or ribbons (3D). Use `none` to plot arrows only.
`logrange`	double > 1	100	If `arrowlength` is `logarithmic`: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.
`looplevel`	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or `interp`, but only for transient solutions. Available when `data` is not `parent` and the underlying data has multiple solutions.
`looptol`	positive double	0.01	Loop tolerance.
`madv`	`manual` | `automatic`	`automatic`	Whether to specify advanced parameters when positioning method is `magnitude`.
`maxlen`	positive double	Inf	The length of the streamlines as a fraction of the mean bounding box's size.
`maxsteps`	positive integer	5000	The maximum number of integration steps.
`maxtime`	positive double	Inf	Maximum integration time.
`mdensity`	nonnegative integer	20	The density of the streamlines. Active when `posmethod` is set to `magnitude`. Only available in 2D.
`mdist`	double array of length two containing positive doubles	`{0.05, 0.15}`	Minimum and maximum distance relative to the size of the geometry. Active when `posmethod` is set to `magnitude`. Only available in 3D.
`minitref`	positive integer	1	Boundary element refinement. Active when `madv` is set to `manual`.
`msatfactor`	nonnegative double	1.3	Starting distance factor. Active when `madv` is set to manual. Only available in 3D.
`mseed`	double array of length 2 or 3, depending on space dimension.	`{0,0}` (2D), `{0,0,0}` (3D)	The first starting point. Active when `mseedactive` is set to `on`.

TABLE 7-104: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
mseedactive	on | off	off	Whether to manually specify first starting point. Active when madv is set to manual.
normal	on | off	off	on when vector field should be normalized.
number	integer	20	Approximate number of streamlines. Active when startmethod is set to number.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
planecoordsys	cutplane | cartesian	cartesian	Coordinate system for streamline vectors. Only available for plots that use a cut plane data set that points to a 3D solution or mesh data set.
posmethod	magnitude | start | uniform | selection	selection	The type of streamline positioning. Either starting point controlled, uniform density, magnitude controlled, or starting from selected lines (2D) or surfaces (3D).
prefixintitle	String	Empty	Added prefix to contribution to title
radiusexpr	String	1	The tube radius.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
revcoordsys	cylindrical | cartesian	cartesian	Coordinate system for streamline vectors. Only available for plots that use a 1D or 2D revolution data set that has default axis settings and points to a solution or mesh data set for an axisymmetric geometry.
selnumber	nonnegative integer	20	If posmethod is selection: The approximate number of streamlines placed on the selected edges (2D) or surfaces (3D).

TABLE 7-104: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
startdata	none | cut line or cut plane name	none	Active when posmethod is start: The line or plane where the starting points are distributed evenly.
startmethod	number | coord	number	Active when posmethod is start. Indicates whether the starting points should be specified by number of points to distribute evenly or by coordinates.
stattol	positive double	0.01	Stationary point stop tolerance.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
tuberadiusscale	double	1	The scale factor applied to the tube radii if tuberadiusscaleactive is true.

TABLE 7-104: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
tuberadiusscaleactive	Boolean	false	If true, tuberadiusscale is used, otherwise the scale factor is computed automatically
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
uadv	manual | automatic	automatic	Whether to specify advanced parameters when positioning method is uniform.
udist	positive double	0.15 (3D), 0.05 (2D)	Separating distance relative to the size of the geometry. Active when posmethod is set to uniform.
udistend	nonnegative double	0.5	Terminating distance factor. Active when uadv is set to manual.
uignoredist	nonnegative double	0.5	Fraction of streamline length to ignore. Active when uadv is set to manual.
uinitref	positive integer	1	Boundary element refinement. Active when uadv is set to manual.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
usatfactor	nonnegative double	1.3	Starting distance factor. Active when uadv is set to manual.
useed	double array of length 2 or 3, depending on space dimension.	{0,0} (2D) or {0,0,0} (3D)	The first starting point. Active when useedactive is set to on.
useedactive	on | off	off	Whether to manually specify first starting point. Active when uadv is set to manual.
widthexpr	String	1	The ribbon width.
widthscale	double	1	The scale factor applied to the ribbon widths if widthscaleactive is true.
widthscaleactive	Boolean	false	If true, widthscale is used; otherwise, the scale factor is computed automatically
xcoord	double array	Empty	Absolute coordinates in the x-direction, active when startmethod is set to coord.
ycoord	double array	Empty	Absolute coordinates in the y-direction, active when startmethod is set to coord.
zcoord	double array	Empty	Absolute coordinates in the z-direction, active when startmethod is set to coord. Available in 3D only.

ATTRIBUTES

Color, Deform, Export, Filter

SEE ALSO

Particle, ParticleMass, StreamlineSurface

StreamlineSurface

Create a streamline surface plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"StreamlineSurface");
model.result(<pgtag>).feature(<ftag>).selection(...);
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"StreamlineSurface")` creates a streamline surface plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

This streamline plot visualize a vector quantity as streamlines on plane surfaces. A streamline is a curve everywhere tangent to an instantaneous vector field. Streamline surface plots are available in 3D plot groups.

The following properties are available:

TABLE 7-105: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
arrowcount	positive integer		The number of arrows.
arrowdistr	equalarc | equaltime | equalinvtime	equalarc	Arrow distribution: equal in arc length, time, or inverse time.
arrowlength	normalized | proportional | logarithmic	normalized	The arrow scaling: Proportional uses the actual arrow length, normalized a unit length, and logarithmic a length proportional to the logarithm of the arrow length.
arrowscale	positive double	1	The arrow length scale factor.
arrowtype	arrow | arrowhead | cone	arrow	The type of arrow to draw.
back	on | off	on	Allow backward time integration. Only available for time-dependent data sets.
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expression in expr. Is used in the automatic title.

TABLE 7-105: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array of length 2 in 2D and 3 in 3D	Model-dependent	The components to plot.
inheritarrowscale	Boolean	true	If inheritplot is not none: Determines if arrow scale is inherited.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
inheritplot	none | plot name	none	The plot that color, tube scale, and deformation scale are inherited from.
inherittubescale	Boolean	true	If inheritplot is not none and linetype is tube or ribbon: Determines if the tube or ribbon scale is inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
inttol	positive double	0.001 (2D), 0.01 (3D)	Integration tolerance.
linetype	line | tube | none	line	Plot streamlines as lines or tubes, or use no streamlines to plot arrows only.
logrange	double > 1	100	If arrowlength is logarithmic: The ratio between the maximum arrow length and the arrow length below which no arrow is drawn.

TABLE 7-105: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise, first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
looptol	positive double	0.01	Loop tolerance.
madv	manual | automatic	automatic	Whether to specify advanced parameters when positioning method is magnitude.
maxlen	positive double	Inf	The length of the streamlines as a fraction of the mean bounding box's size.
maxsteps	positive integer	5000	The maximum number of integration steps.
maxtime	positive double	Inf	Maximum integration time.
mdensity	nonnegative integer	20	The density of the streamlines. Active when posmethod is set to magnitude.
minitref	positive integer	1	Boundary element refinement. Active when madv is set to manual.
normal	on | off	off	on when vector field should be normalized.
number	integer	20	Approximate number of streamlines. Active when startmethod is set to number.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
planecoordsys	cutplane | cartesian	cartesian	Coordinate system for streamline vectors. Only available for plots that use a cut plane data set that points to a 3D solution or mesh data set.
posmethod	magnitude | start | uniform	selection	The type of streamline positioning. Either starting point controlled, uniform density, or magnitude controlled.
prefixintitle	String	Empty	Added prefix to contribution to title
radiusexpr	String	1	The tube radius.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.

TABLE 7-105: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
stattol	positive double	0.01	Stationary point stop tolerance.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
tuberadiusscale	double	1	The scale factor applied to the tube radii if tuberadiusscaleactive is true.

TABLE 7-105: VALID PROPERTY/VALUE PAIRS FOR STREAMLINE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
tuberadiusscaleactive	Boolean	false	If true, tuberadiusscale is used, otherwise the scale factor is computed automatically
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
uadv	manual | automatic	automatic	Whether to specify advanced parameters when positioning method is uniform.
udistend	nonnegative double	0.5	Terminating distance factor. Active when uadv is set to manual.
uignoredist	nonnegative double	0.5	Fraction of streamline length to ignore. Active when uadv is set to manual.
uinitref	positive integer	1	Boundary element refinement. Active when uadv is set to manual.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
usatfactor	nonnegative double	1.3	Starting distance factor. Active when uadv is set to manual.

ATTRIBUTES

Color, Deform, Export, Filter

SEE ALSO

Particle, ParticleMass, Streamline

Surface

Create a surface plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Surface");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Surface")` creates a surface plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Surface plots display a quantity as a colored 2D or 3D surface.

The following properties are available:

TABLE 7-106: VALID PROPERTY/VALUE PAIRS FOR SURFACE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this surface.
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritheightscale	Boolean	true	If inheritplot is not none: Determines if height scale is inherited.

TABLE 7-106: VALID PROPERTY/VALUE PAIRS FOR SURFACE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`inheritplot`	`none` | plot name	`none`	The plot that color, color range, height scale, and deformation scale are inherited from.
`inheritrange`	Boolean	`true`	If `inheritplot` is not `none`: Determines if the color and data ranges are inherited.
`interp`	double array	Time corresponding to last selected `solnum` for transient levels.	The time to use, for transient levels. Available when `data` is not `parent` and the underlying data is transient.
`looplevel`	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or `interp`, but only for transient solutions. Available when `data` is not `parent` and the underlying data has multiple solutions.
`outersolnum`	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
`prefixintitle`	String	Empty	Added prefix to contribution to title.
`rangecoloractive`	`on` | `off`	`off`	Whether to use the manual color range specified in `rangecolormin` and `rangecolormax`. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
`rangecolormax`	double	Plot-dependent	The maximum color range value. Active when `rangecoloractive` is `on`.
`rangecolormin`	double	Plot-dependent	The minimum color range value. Active when `rangecoloractive` is `on`.
`rangedatactive`	`on` | `off`	`off`	Whether to use the manual data range specified in `rangedatamin` and `rangedatamax`. Values outside the data range is not plotted.
`rangedatamax`	double	Plot-dependent	The maximum data value. Active when `rangedataactive` is `on`.
`rangedatamin`	double	Plot-dependent	The minimum data value. Active when `rangedataactive` is `on`.
`recover`	`off` | `pprint` | `ppr`	`off`	The derivative recovery method (off, within domains, or everywhere).
`refine`	nonnegative integer	1	The element refinement to use, if `resolution` is set to `manual`. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.

TABLE 7-106: VALID PROPERTY/VALUE PAIRS FOR SURFACE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.

TABLE 7-106: VALID PROPERTY/VALUE PAIRS FOR SURFACE PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
wireframe	on | off	off	Whether to plot filled elements or only their edges.

ATTRIBUTES

Deform, Filter, Height, AberrationHeight, HistogramHeight, TableHeight, Selection

EXAMPLES

Surface plot on 2D solution:

Code for Use with Java

```
DatasetFeature ds = model.result().dataset().create("dset1", "Solution");
ds.set("Solution", "sol1");

ResultFeature pg = result().create("pg1",2);
pg.set("data","dset1");
pg.create("surf1","Surface");
pg.feature("surf1").set("expr", "3*u");
```

Code for Use with MATLAB

```
ds = model.result.dataset.create('dset1', 'Solution');
ds.set('Solution', 'sol1');

ResultFeature pg = result().create('pg1',2);
pg.set('data','dset1');
pg.create('surf1','Surface');
pg.feature('surf1').set('expr', '3*u');
```

Surface plot on cut plane in 3D using a Thermal color table:

Code for Use with Java

```
result().dataset().create("cp1", "CutPlane");

ResultFeature pg2 = result().create("pg2",3);
pg2.create("surf2","Surface");
pg2.feature("surf2").set("data", "cp1");
pg2.feature("surf1").set("expr", "2*u");
pg2.feature("surf1").set("colortable", "Thermal");

pg2.run();
```

Code for Use with MATLAB

```
result.dataset.create('cp1', 'CutPlane');

pg2 = result.create('pg2',3);
pg2.create('surf2','Surface');
pg2.feature('surf2').set('data', 'cp1');
pg2.feature('surf1').set('expr', '2*u');
pg2.feature('surf1').set('colortable', 'Thermal');

pg2.run;
```

SEE ALSO

SurfaceSlit, Volume

Surface (Data Set)

Create a surface data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"Surface");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"Surface")` creates a surface data set with the name *<dtag>*.

The surface data set makes it possible to evaluate surfaces of a 3D model in 2D or 3D. For evaluation in 2D, different parameterizations of the 2D projection are available.

The following properties are available:

TABLE 7-107: VALID PROPERTY/VALUE PAIRS FOR SURFACE DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The solution data set this feature refers to.
param	`face` | `xy` | `yz` | `zx` | `yx` | `zy` | `xz` | `expr`	`face`	The projection used when evaluating in 2D.
exprx	String		When param is expr: The x-axis expression when evaluating in 2D.
expry	String		When param is expr: The y-axis expression when evaluating in 2D.
`hasvars`	Boolean	`false`	If space variables are defined.
`spacevars`	String array	Depends on the feature's tag	If `hasvar` is true: The name of space variables, which evaluate to the coordinates in the data set's coordinate system.

SurfaceData

Create a surface data plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"SurfaceData");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"SurfaceData")` creates a surface data plot feature named *<ftag>* belonging to the 2D or 3D plot group *<pgtag>*.

Surface data plots are used to visualize raw point data given as points, elements, normals (3D only), and colors as surfaces (see the examples below). Surface data plots can be added to 2D and 3D plot groups.

The following properties are available:

TABLE 7-108: VALID PROPERTY/VALUE PAIRS FOR SURFACE DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green |magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
colordata	double 1D array		The color data for the surface data plot as a real N-vector.
coloring	colortable | uniform	uniform	How to color the surfaces.
colorlegend	on | off	on	Whether to show color legend when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
description	String		A label showing a short description of the stored data.
elementdata	integer 2D array		The element data for the surface data plot, providing connections between the points. The data is an (edim+1)-by-M integer matrix with values that are 0-based indices into pointdata. The right-hand rule defines the normal direction in 3D. In 2D the order does not matter.
normaldata	double 2D array		A 3-by-N real matrix for the normals in 3D surface data plots only. This property is optional and can either be empty or have the same length as the number of columns in pointdata. If it is empty, the normals are computed by the standard algorithm used throughout postprocessing.
pointdata	double 2D array		The point data for the surface data plot, as x and y coordinates in 2D and x, y, and z coordinates in 3D in an sdim-by-N real matrix.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.

TABLE 7-108: VALID PROPERTY/VALUE PAIRS FOR SURFACE DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range are not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | manual | none	none	auto if the title contribution should be computed automatically. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.

ATTRIBUTES

None.

EXAMPLES

A method for creating a pentagon as a 2D surface data plot:

Code for Use with Java

```
pg = m.result().create("pg3", 2);
plot = pg.create("surf1", "SurfaceData");
N = 5;
p = new double[2][N + 1];
t = new int[3][N];
color = new double[N + 1];
p[0][0] = 0;
p[1][0] = 0;
for (int i = 0; i < N; i++) {
  double angle = i * 2 * Math.PI / N;
  p[0][i + 1] = Math.cos(angle);
  p[1][i + 1] = Math.sin(angle);
  t[0][i] = 0;
  t[1][i] = i + 1;
  t[2][i] = 1 + (i + 1) % N;
}
plot.set("pointdata", p)
    .set("elementdata", t)
    .set("colordata", color);
plot.run();
```

A method for creating a surface data plot in 3D for data representing the sinc function (sampling function) as function of the radius *r*:

Code for Use with Java

```
pg = m.result().create("pg4", 3);
plot = pg.create("surf1", "SurfaceData");
int Nx = 51;
int Ny = 51;
p = new double[3][Nx * Ny];
t = new int[3][2 * (Nx -1) * (Ny - 1)];
color = new double[Nx * Ny];
int pos = 0;
for (int i = 0; i < Ny; i++) {
  for (int j = 0; j < Nx; j++) {
```

```
      double x = 20 * (j - Nx / 2) / Nx;
      double y = 20 * (i - Ny / 2) / Ny;
      double r = Math.sqrt(x * x + y * y);
      double z = 4 * ((r == 0) ? 1 : (Math.sin(r) / r));
      p[0][pos] = x;
      p[1][pos] = y;
      p[2][pos] = z;
      color[pos] = z;
      pos++;
    }
  }
  pos = 0;
  for (int i = 0; i < Ny - 1; i++) {
    for (int j = 0; j < Nx - 1; j++) {
      int p00 = Nx * i + j;
      int p01 = Nx * i + j + 1;
      int p10 = Nx * (i + 1) + j;
      int p11 = Nx * (i + 1) + j + 1;
      t[0][pos] = p00;
      t[1][pos] = p01;
      t[2][pos] = p11;
      pos++;
      t[0][pos] = p00;
      t[1][pos] = p11;
      t[2][pos] = p10;
      pos++;
    }
  }
  plot.set("pointdata", p)
      .set("elementdata", t)
      .set("colordata", color);
  plot.run();
```

SEE ALSO

AnnotationData, ArrowData, LineData, PointData, TubeData

SurfaceSlit

Create a surface slit plot, for evaluating one expression on the upside and another expression on the downside of a boundary in 3D.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"SurfaceSlit");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"SurfaceSlit")` creates a surface slit plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

Surface slit plots display quantities as colored surfaces on the upside and downside of selected boundaries in a 3D model.

The following properties are available:

TABLE 7-109: VALID PROPERTY/VALUE PAIRS FOR SURFACE SLIT PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this surface.
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to. Only Solution, Surface, and Mesh data sets can be used.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
downdescr	String	Model-dependent.	The description of the expression in downexpr. Is used in the automatic title.
downexpr	String	Model-dependent.	The expression to plot on the downside.
downunit	String	Model-dependent	The unit to use for the expression in downexpr. If the old unit is not valid when the expression changes, the unit property is reset to default.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.

TABLE 7-109: VALID PROPERTY/VALUE PAIRS FOR SURFACE SLIT PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritheightscale	Boolean	true	If inheritplot is not none: Determines if height scale is inherited.
inheritplot	none | plot name	none	The plot that color, color range, height scale, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).

TABLE 7-109: VALID PROPERTY/VALUE PAIRS FOR SURFACE SLIT PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.

TABLE 7-109: VALID PROPERTY/VALUE PAIRS FOR SURFACE SLIT PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`typeintitle`	`on` | `off`	on	Whether the title contribution should contain the type when `titletype` is `custom`.
`unitintitle`	`on` | `off`	on	Whether the title contribution should contain the unit when `titletype` is `custom`.
`updescr`	String	Model-dependent.	The description of the expression in `upexpr`. Is used in the automatic title.
`upexpr`	String	Model-dependent.	The expression to plot on the upside.
`upunit`	String	Model-dependent	The unit to use for the expression in `upexpr`. If the old unit is not valid when the expression changes, the unit property is reset to default.

ATTRIBUTES

`Deform`, `Filter`, `Selection`

SEE ALSO

`Surface`, `Volume`

SystemMatrix

Create a numerical evaluation of system matrix.

SYNTAX

```
model.result().numerical().create(<ftag>,"SystemMatrix");
model.result().numerical(<ftag>).set(property, <value>);
model.result().numerical(<ftag>).getData();
model.result().numerical(<ftag>).getData(<expressionIndex>);
model.result().numerical(<ftag>).getImagData();
model.result().numerical(<ftag>).getImagData(<expressionIndex>);
model.result().numerical(<ftag>).isComplex();
model.result().numerical(<ftag>).isComplex(<outersolnum>);
model.result().numerical(<ftag>).getNData();
model.result().numerical(<ftag>).run();
```

DESCRIPTION

`model.result().numerical().create(<ftag>,"SystemMatrix")` create a system matrix evaluation feature with the name *<ftag>*.

The system matrix evaluation makes it possible to retrieve matrices directly from Assemble and Modal features in a solver sequence. You can also use this methods to retrieve matrices and vectors directly from reduced model data sets.

The following properties are available:

TABLE 7-110: VALID PROPERTY/VALUE PAIRS FOR SYSTEM MATRIX EVALUATIONS.

PROPERTY	VALUE	DEFAULT	DESCRIPTION
feature	String	The first Assemble or Modal feature in the chosen solution.	The solver feature from which the matrix is retrieved.
matrixassem	constraint | constraintforcejac | constraintforcenullbasis | constraintjac | constraintnullbasis | damping | elimdamping | elimload | elimmass | elimstiffness | load | lowerboundconstraint | mass | optconstraint | optconstraintjac | partsol | stiffness | upperboundconstraint | uscale	stiffness	The matrix to retrieve if the solver feature is an Assemble feature. See also the documentation for Assemble in the *COMSOL Multiphysics Reference Manual*.
matrixmodal	allloads | damping | dampingratio | ddinctrl | dinctrl | dinctrl0 | dpartsol | epartsol | inctrl | inctrl0 | inoutput | kud | load | mass | projection | stiffness | output | outputbias | u0 | udot0 | ul	stiffness	The matrix to retrieve if the solver feature is a frequency-dependent Modal Solver feature.
matrixmodalstate	allloads | damping | dampingratio | ddinctrl | dinctrl | dinctrl0 | dpartsol | epartsol | inctrl | inctrl0 | inoutput | kud | load | mass | projection | ssc | ssd | ssma | ssmb | ssmc | ssnull | ssud | ssx0 | stiffness | output | outputbias | u0 | udot0 | ul	stiffness	The matrix to retrieve if the solver feature is a time-dependent Modal Solver feature.
matrixstatespace	ssc | ssd | ssma | ssmb | ssmc | ssnull | ssud | ssx0	ssma	The matrix to retrieve if the solver feature is a State Space feature.
reducedmodelmatrix	allloads | damping | dampingratio | ddinctrl | dinctrl | dinctrl0 | dpartsol | epartsol | inctrl | inctrl0 | inoutput | kud | load | mass | projection | ssc | ssd | ssma | ssmb | ssmc | ssnull | ssud | ssx0 | stiffness | output | outputbias | u0 | udot0 | ul	stiffness	The matrix to retrieve if the solution is from a Reduced Model data set.
solution	String	First compatible solution	The solution this data set refers to.

Table

Create a feature containing a table of data.

SYNTAX

```
model.result().table().create(<ftag>,"Table");
model.result().table(<ftag>).setColumnHeaders(<headers>);
model.result().table(<ftag>).setTableData(<realData>);
model.result().table(<ftag>).setTableData(<realData>, <imagData>);
model.result().table(<ftag>).addColumns(<headers>, <realData>);
model.result().table(<ftag>).addColumns(<headers>, <realData>, <imagData>);
model.result().table(<ftag>).addRow(<realData>);
model.result().table(<ftag>).addRow(<realData>,<imagData>);
model.result().table(<ftag>).removeRow(<index>);
model.result().table(<ftag>).getColumnHeaders();
model.result().table(<ftag>).getReal();
model.result().table(<ftag>).getImag();
model.result().table(<ftag>).Row(<index>);
model.result().table(<ftag>).getImagRow(<index>);
model.result().table(<ftag>).getTableData(<fullPrecision>);
model.result().table(<ftag>).getTableRow(<index>, <fullPrecision>);
model.result().table(<ftag>).getNRows();
model.result().table(<ftag>).isComplex();
model.result().table(<ftag>).clearTableData();
model.result().table(<ftag>).set(property, <value>);
model.result().table(<ftag>).save(<filename>);
model.result().table(<ftag>).save(<filename>, <fullPrecision>);
model.result().table(<ftag>).loadFile(tempFile, ...);
model.result().table(<ftag>).saveFile(tempFile, ...);
```

DESCRIPTION

`model.result().table().create(<ftag>,"Table")` creates a table feature named *<ftag>*. Tables support two data formats, *all* or *filled*. Filled data is typically produced from parametric sweeps and makes it possible to retrieve data for a pair of parameters on a matrix format. Filled tables can be used to make response surface plots. (See `TableSurface`.)

`model.result().table(<ftag>).setColumnHeaders(<headers>)` sets the table's column headers from the string array *<headers>*.

`model.result().table(<ftag>).setTableData(<realData>)` sets the table content from a double matrix containing real data. Any previous real or imaginary data is removed.

`model.result().table(<ftag>).setTableData(<realData>, <imagData>)` sets both real and imaginary data from the double matrices *<realData>* and *<imagData>*, which must be of the same size. *<imagData>* can be `null` to indicate that there is no imaginary data.

`model.result().table(<ftag>).getColumnHeaders()` retrieves the column headers.

`model.result().table(<ftag>).addColumns(<headers>, <realData>)` adds one or more columns and associated real data to the table.

`model.result().table(<ftag>).addColumns(<headers>, <realData>, <imagData>)` adds one or more columns and associated real data and imaginary data to the table.

`model.result().table(<ftag>).addRow(<realData>)` adds one row of real data to the table.

`model.result().table(<ftag>).addRow(<realData>,<imagData>)` adds one row of real and imaginary data to the table.

`model.result().table(<ftag>).removeRow(<index>)` removes the row with a given index from the table. If the row index is out of bounds, nothing happens.

`model.result().table(<ftag>).getColumnHeaders()` returns the column headers in the table.

`model.result().table(<ftag>).getReal()` returns the real part of the table content.

`model.result().table(<ftag>).getImag()` returns the imaginary part of the table content. Note: this method allocates imaginary data if there was none. Check for imaginary content with the `isComplex` method before calling this method if you want to avoid this.

`model.result().table(<ftag>).getRealRow(<index>)` returns the real data in one row.

`model.result().table(<ftag>).getImagRow(<index>)` returns the imaginary data in one row.

`model.result().table(<ftag>).getFilledReal()` returns the real part of the table content on a filled format, when available.

`model.result().table(<ftag>).getFilledImag()` returns the imaginary part of the table content on a filled format, when available.

`model.result().table(<ftag>).getTableData(<fullPrecision>)` returns the table data as a string matrix, with limited or full precision as specified by the Boolean `<fullPrecision>`.

`model.result().table(<ftag>).getTableRow(<index>, <fullPrecision>)` returns the table data for one row as a string array, with limited or full precision.

`model.result().table(<ftag>).getNRows()` returns the number of rows in the table.

`model.result().table(<ftag>).isComplex()` returns true if the table contains imaginary data. This method checks whether imaginary data has been allocated, not if it is different from `0`.

`model.result().table(<ftag>).clearTableData()` removes all table data and column headers.

`model.result().table(<ftag>).save(<filename>)` saves the table `<ftag>` content to the text file `<filename>` in full precision.

For `model.result().table(<ftag>).loadFile()` and `model.result().table(<ftag>).saveFile()`, see The loadFile and saveFile Methods.

The following properties are available:

TABLE 7-111: VALID PROPERTY/VALUE PAIRS FOR TABLES

NAME	VALUE	DEFAULT	DESCRIPTION
`cols`	Parameters in table | `none`	`none`	For tables with filled data, `cols` controls which parameter is used on the columns. Cannot be the same parameter as in `rows`.
`datacol`	Positive integer	1	For tables with filled data, `datacol` controls which data column should be used to populate the filled table.
`descr`	`none` | `data` | `manual`	`data`	For tables with filled data, `descr` controls which description to use for the columns, in addition to the parameter values. `none` gives no description, `manual` uses the description in `descrmanual`, and data uses the description in the table data.
`descrmanual`	String	Empty	Manual column header for tables with filled data, used when `descr` is set to `manual`.
`filename`	String	Empty	The name of the file on which the table is stored, used when `storetable` is set to `inmodelandonfile` or `onfile`.

TABLE 7-111: VALID PROPERTY/VALUE PAIRS FOR TABLES

NAME	VALUE	DEFAULT	DESCRIPTION
`filterstringdata`	`on` | `off`	`off`	For tables with filled data, `filterstringdata` controls whether to filter the input column using `showrowstep`.
`format`	`all` | `filled`	`all`	Controls whether you retrieve `all` or `filled` table data when calling the `getTableData` method.
`param`	Positive integer	1	For tables with filled data containing more than two parameters, `param` is the index indicating which values to use for fixing additional parameters. Additional parameters are ordered from left to right in the original table data.
`rows`	Parameters in table | `none`	`none`	For tables with filled data, `rows` controls which parameter is used on the rows.
`showrowstep`	Positive integer	1	When retrieving filled data using the `getTableData` method, `showrowstep` controls whether to leave all but every `showrowstep` input cells empty, for example, every third cell in the first column. This refers to the input column only. Only applied when `filterstringdata` is on.
`storetable`	`inmodel` | `inmodelandonfile` | `onfile`	`inmodel`	Controls whether table is stored in model(`inmodel`) or on file(`onfile`), or both(`inmodelandonfile`).
`tablebuffersize`	Positive integer	Taken from buffer size preference. The default of which is 10000.	The size of the in-memory buffer size where the table is stored, used when `storetable` is set to `inmodel` or `inmodelandonfile`. In the second case only the last `tablebuffersize` rows are kept in the model; the rest is read from file when necessary.

SEE ALSO

`Table (Plot)`, `TableSurface`

Table (Export)

Export data from tables to files.

SYNTAX

```
model.result().export().create(<ftag>,"Table");
model.result().export(<ftag>).set(property, <value>);
model.result().export(<ftag>).run();
```

DESCRIPTION

`model.result().export().create(<ftag>,"Table")` creates a table export feature with the name *<ftag>*.

The following properties are available:

TABLE 7-112: VALID PROPERTY/VALUE PAIRS FOR TABLE EXPORTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
alwaysask	on | off	off	Always ask for filename when saving. This property is ignored when running without a GUI.
evaluationgroup	none | evaluation group feature name	First available evaluation group	The evaluation group feature this feature refers to, if source is evaluationgroup.
ifexists	append | overwrite	overwrite	If the file exists, append to or overwrite the file contents.
filename	String		The output file.
fullprec	on | off	on	If on, floating-point numbers are written in full precision, otherwise they are written with six significant digits.
header	on | off	off	Enable/disable a data header in the output file.
sort	on | off	off	Enable/disable sorting of the points with respect to the coordinates.
source	table | evaluationgroup	table	Use table data from a table or an evaluation group..
table	none | table feature name	First available table	The table feature this feature refers to, if source is table.

SEE ALSO

Data, Table

Table (Plot)

Plot data from a table in a graph plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Table");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Table")` creates a table graph plot feature named *<ftag>*.

Table graphs can be added to 1D and polar plot groups and displays data from a table.

The following properties are available:

TABLE 7-113: VALID PROPERTY/VALUE PAIRS FOR TABLE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
autolegends	on | off	on	Whether to use the automatically generated legends or the legends defined in the legends property.
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom.
evaluationgroup	none | evaluation group feature name	First available evaluation group	The evaluation group feature this plot refers to, if source is evaluationgroup.
freqmax	integer		If transform is spectrum and freqrangeactive is true: The upper frequency bound.

TABLE 7-113: VALID PROPERTY/VALUE PAIRS FOR TABLE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
freqmin	integer		If transform is spectrum and freqrangeactive is true: The lower frequency bound.
freqrangeactive	on | off	false	If transform is spectrum: Controls whether a manual frequency range is used.
imagplot	on | off	off	If transform is none: When on, the imaginary part of the data in the table is plotted.
legend	on | off	off	Whether to show legends.
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legendprefix	String		A prefix added to the automatic legend.
legends	String array	The last computed automatic legends.	Manual legends active when legendmethod is set to manual.
legendsuffix	String		A suffix added to the automatic legend.
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
linewidth	double	0.5	The line width.
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
nfreqs	integer	1	If transform is spectrum and nfreqsactive is true: The number of frequencies to plot.
nfreqsactive	Boolean	false	If transform is spectrum: Controls whether the number of frequencies is set manually.
plotcolumninput	all | manual	all	The columns to plot. all indicates all columns excluding those used in xaxisdata, manual indicates the columns specified in plotcolumns.
plotcolumns	positive integer array	Empty	The columns to plot when plotcolumninput is manual.
plotonsecyaxis	Boolean	true	Plot on secondary y-axis, if twoyaxes is set to true in the parent plot group.

TABLE 7-113: VALID PROPERTY/VALUE PAIRS FOR TABLE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`preproc{x|y}`	`none` | `linear`	`none`	Use a linear preprocessing of the table data values, which you specify using the scaling and shift properties.
`scale`	Boolean	`false`	If transform ffis spectrum: The frequency spectrum is transformed so that it has the same scale as the original data.
`scaling{x|y}`	double	1.0	Real scaling value for data preprocessing
`shift{x|y}`	double	0.0	Real shift value for data preprocessing
`source`	`table` | `evaluationgroup`	`table`	Use table data from a table or an evaluation group..
`table`	`none` | table feature name	First available table	The table feature this plot refers to, if `source` is `table`.
`transform`	`none` | `spectrum`	`none`	The transformation to apply to the data before plotting.
`xaxisdata`	`auto` | `rowindex` | positive integer	`auto`	The column supplying x-axis data. `auto` determines input based on evaluated result, for example, using an index if the table contains output from a parametric sweep with multiple parameters. `rowindex` means that all columns are used as data and are plotted against the row number in the table.

SEE ALSO

`Table`

TableSurface

Plot data from a table in a surface plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"TableSurface");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(`*`<pgtag>`*`).create(`*`<ftag>`*`,"Table")` creates a table surface plot feature named *`<ftag>`*.

Table surface plots can only be used with tables containing filled data, produced from a parametric sweep. They can be added to 2D plot groups.

The following properties are available:

TABLE 7-114: VALID PROPERTY/VALUE PAIRS FOR TABLE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`color`	`custom` | `black` | `blue` | `cyan` | `gray` | `green` | `magenta` | `red` | `white` | `yellow`	`red`	The uniform color to use. Active when `coloring` is `uniform`.
`coloring`	`colortable` | `uniform`	`colortable`	How to color this surface.

TABLE 7-114: VALID PROPERTY/VALUE PAIRS FOR TABLE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
datacol	Positive integer	1	For tables with filled data, datacol controls which data column should be used to populate the filled table.
dataformat	filledtable | columns | cells	Model dependent	The format of the table data. The default value depends on the table data: Filled table if the data in the table is structurally filled; otherwise, columns if the table contains at least three columns; otherwise, cells. For evaluation groups, filledtable is not available.
descr	none | data | manual	data	For tables with filled data, descr controls which description to use for the columns, in addition to the parameter values. none gives no description, manual uses the description in descrmanual, and data uses the description in the table data.
descrmanual	String	Empty	Manual column header for tables with filled data, used when descr is set to manual.
evaluationgroup	none | evaluation group feature name	First available evaluation group	The evaluation group feature this plot refers to, if source is evaluationgroup.
filterstringdata	on | off	off	For tables with filled data, filterstringdata controls whether to filter the input column using showrowstep.
format	all | filled	all	Controls whether you retrieve all or filled table data when calling the getTableData method.
function	continuous | discrete	continuous	Considering the table data as samples of a continuous function or treating the samples as discrete and draw them as large pixels.
imagplot	on | off	off	If transform is none: When on, the imaginary part of the data in the table is plotted.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritheightscale	Boolean	true	If inheritplot is not none: Determines if height scale is inherited.
inheritplot	none | plot name	none	The plot that color, color range, and height scale is inherited from.

TABLE 7-114: VALID PROPERTY/VALUE PAIRS FOR TABLE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
param	Positive integer	1	For tables with filled data containing more than two parameters, param is the index indicating which values to use for fixing additional parameters. Additional parameters are ordered from left to right in the original table data.
plotdata	table | manual	table	For tables with filled data containing more than two parameters, plotdata controls whether to use manual settings in the plot (table row, column, and so forth), or the filled settings in the table feature. In the latter case, the table's properties are automatically synchronized with the plot's properties.
preproc{x|y|data}	none | linear	none	Use a linear preprocessing of the table data values, which you specify using the scaling and shift properties.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
scaling{x|y|data}	double	1.0	Real scaling value for data preprocessing
shift{x|y|data}	double	0.0	Real shift value for data preprocessing
showrowstep	Positive integer	1	When retrieving filled data using the getTableData method, showrowstep controls whether to leave all but every showrowstep input cells empty, for example, every third cell in the first column. This refers to the input column only. Only applied when filterstringdata is on.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.

TABLE 7-114: VALID PROPERTY/VALUE PAIRS FOR TABLE SURFACE PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
source	table | evaluationgroup	table	Use table data from a table or an evaluation group..
table	none | table feature name	First available table	The table feature this plot refers to, if source is table.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0–1), if threshold is set to manual.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
xaxisdata	Parameters in table | none	none	For tables with filled data, xaxisdata controls which parameter is used on the x-axis.
yaxisdata	Parameters in table | none	none	For tables with filled data, yaxisdata controls which parameter is used on the y-axis. Cannot be the same parameter as in xaxisdata.
wireframe	on | off	off	Whether to plot filled elements or only their edges,

SEE ALSO

Table, Table (Plot), Height, AberrationHeight, HistogramHeight, TableHeight

TimeAverage, TimeIntegral

Create a time average or time integral data set.

SYNTAX

```
model.result().dataset().create(<dtag>,"TimeAverage");
model.result().dataset().create(<dtag>,"TimeIntegral");
model.result().dataset(<dtag>).set(property, <value>);
```

DESCRIPTION

`model.result().dataset().create(<dtag>,"TimeAverage")` creates a time average data set with the name *<dtag>*.

`model.result().dataset().create(<dtag>,"TimeIntegral")` creates a time integral data set with the name *<dtag>*.

The time average and time integral data sets make it possible to compute time averages and time integrals of some time-dependent data in another data set, for example.

The following properties are available:

TABLE 7-115: VALID PROPERTY/VALUE PAIRS FOR TIME AVERAGE AND TIME INTEGRAL DATA SETS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`data`	`none` | data set name	First compatible data set	The data set this feature refers to.
`innerinput`	`all` | `first` | `last` | `manual` | `manualindices` | `interp`	`all`	How to input the solution to use. `manual` indicates that `solnum` is used. `manualindices` indicates that `solnumindices` is used. `interp` indicates that `t` is used.
`minlen`	nonnegative double	`1e-4`	Minimum interval length relative to the length of the time interval.
`rtol`	nonnegative double	`1e-3`	Relative tolerance.
`solnum`	Integer array	All solutions	The solutions to use for extrapolation.
`solnumindices`	String or integer array	`Empty`	An alternative way to specify the solutions to use, allowing you to enter, for example, `range(1,1,20)`. Applicable when `innerinput` is `manualindices`.
`t`	double array	Empty	The times to use as intermediate layers in the extrusion.

ThroughThickness

Create a through-thickness plot to display the variation of a layered shell quantity in its thickness direction at specified points.

The ThroughThickness plot requires a license for the Composite Materials Module, AC/DC Module, or Heat Transfer Module.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"ThroughThickness");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(`*`<pgtag>`*`).create(`*`<ftag>`*`,"ThroughThickness")` creates a through-thickness plot feature named *`<ftag>`* belonging to the plot group *`<pgtag>`*.

A through-thickness plot is used to visualize the variation of a layered shell quantity in its thickness direction. Through-thickness lots can be added to 1D plot groups.

The following properties are available:

TABLE 7-116: VALID PROPERTY/VALUE PAIRS FOR THROUGH-THICKNESS PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`autodescr`	`on` | `off`	Model dependent	Whether the automatic legends should include the expression descriptions.
`autoexpr`	`on` | `off`	Model dependent	Whether the automatic legends should include the expressions.

TABLE 7-116: VALID PROPERTY/VALUE PAIRS FOR THROUGH-THICKNESS PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
autolegends	on | off	on	Whether to use the automatically computed legends or the legends defined in the legends property.
autounit	on | off	off	Whether the automatic legends should include the unit.
const	String array of property/value pairs	Empty	Parameters to use in the expressions
customlinecolor	RGB-triplet	{0,0,1} or last used edgecolor.	The color to use for the lines. Active when linecolor is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
innerinput	all | first | last | manual | manualindices | interp	all	How to input the solution to use. manual indicates that solnum is used. manualindices indicates that solnumindices is used. interp indicates that t is used.
interp	double row matrix	Empty on all levels.	The times to use, for transient levels. Available when data is not parent and the underlying data is transient.
legend	on | off	off	Whether to show legends
legendmethod	automatic | manual	automatic	Whether to use the automatic legends or the legends supplied in the legends property.
legendprefix	String		A prefix added to the automatic legend.
legends	String array	The last computed automatic legends	Manual legends active when legendmethod is set to manual.
legendsuffix	String		A suffix added to the automatic legend.

TABLE 7-116: VALID PROPERTY/VALUE PAIRS FOR THROUGH-THICKNESS PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
linecolor	custom | cycle | black | blue | cyan | gray | green | magenta | red | white | yellow	cycle	How to color the lines in the graph. Cycle indicates that the colors is different for each line.
linewidth	double	0.5	The line width.
linemarker	none | cycle | asterisk | circle | diamond | plus | point | square | star | triangle	none	The line markers, if any. Cycle indicates that the marker is different for each line.
looplevel	integer row matrix	All solutions on all levels	The solutions to use, per level.
looplevelindices	integer row matrix	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1, 20). Applicable when looplevelinput is manualindices on a level.
looplevelinput	String array with all | first | last | manual | manualindices | interp on each level	all on all levels	How to input the solution to use, per level. manual on a level indicates that looplevel is used on that level. manualindices on a level indicates that looplevelindices is used on that level. interp on a level indicates that interp is used on that level.
markerpos	interp | datapoints	interp	Controls whether the positions of the markers are in the data points of the plot, or interpolated depending on the number (set in markers). Markers are visible when linemarker is set.
markers	integer	8	The number of markers to show. Markers are visible when linemarker is set.
linestyle	none | cycle | solid | dotted | dashed | dashdot	solid	The line style, if any. Cycle indicates that the line style is different for each line.
outerinput	all | first | last | manual | manualindices	all	How to input the outer solutions to use. Applicable only for parametric sweep models. manual indicates that outersolnum is used. manualindices indicates that outersolnumindices is used.
outersolnum	nonnegative integer array	1	The index of the outer solutions to use. Applicable only for parametric sweep models. Since the various outer solutions can have different number of solnum, the solnum property is not used.

TABLE 7-116: VALID PROPERTY/VALUE PAIRS FOR THROUGH-THICKNESS PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
outersolnumindices	String or integer array	Empty	An alternative way to specify the outer solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when outerinput is manualindices.
posentry	coordinates | selection	selection	Determine the position using a selection or by providing coordinates.
plotonsecyaxis	Boolean	true	Plot on secondary y-axis, if twoyaxes is set to true in the parent plot group.
point3x	scalar	0	The x-coordinate for the position when posentry is set to coordinates.
point3y	scalar	0	The y-coordinate for the position when posentry is set to coordinates.
point3z	scalar	0	The z-coordinate for the position when posentry is set to coordinates.
prefixintitle	String	Empty	Added prefix to contribution to title.
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
smooth	true | false	false	Apply smoothing to the plot data.
solnum	integer array	All solutions	The solutions to plot. Available when data is not parent and the underlying data has multiple solutions.
solnumindices	String or integer array	Empty	An alternative way to specify the solutions to use, allowing you to enter, for example, range(1,1,20). Applicable when innerinput is manualindices.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.

TABLE 7-116: VALID PROPERTY/VALUE PAIRS FOR THROUGH-THICKNESS PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
t	double array	Empty	The times to plot. Available when data is not parent and the underlying solution is transient.
title	String	The auto-title	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
xdata	arc | reversedarc | expr	solution	x-axis data. expr uses the expression in xdataexpr. arc uses the curve's arc length, and reversedarc uses the arc length measured from the curve's endpoint.
xdataexpr	String	Model-dependent	Expression for x-axis data
xdatadescr	String	Model-dependent	Description of expression in xdataexpr.
xdataunit	String	Model-dependent	The unit to use for the expression in xdataexpr. If the old unit is not valid when the expression changes, the unit property is reset to default.
ydata	expr | thicknesscoordinate	thickness coordinate	Take the y-data from an expression or as the thickness coordinate.
ydataexpr	String	Model-dependent	Expression for y-axis data when ydata is set to expr.
ydatadescr	String	Model-dependent	Description of expression in ydataexpr.

ATTRIBUTES

Color

SEE ALSO

LineGraph

TubeData

Create a tube data plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"TubeData");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"TubeData")` creates a tube data plot feature named *<ftag>* belonging to the 2D or 3D plot group *<pgtag>*.

Tube data plots are used to visualize raw point data given as points, elements, and colors as tubes (see the examples below). Tube data plots can be added to 2D and 3D plot groups.

The following properties are available:

TABLE 7-117: VALID PROPERTY/VALUE PAIRS FOR TUBE DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`color`	`custom` | `black` | `blue` | `cyan` | `gray` | `green` |`magenta` | `red` | `white` | `yellow`	`red`	The uniform color to use. Active when `coloring` is `uniform`.
`colordata`	double 1D array		The color data for the tube data plot as a real N-vector.
`coloring`	`colortable` | `uniform`	`uniform`	How to color the tubes.
`colorlegend`	`on` | `off`	`on`	Whether to show color legend when `coloring` is set to `colortable`.
`colortable`	color table name	`Rainbow`	The color table to use when `coloring` is set to `colortable`. See Color Tables for a list of color tables.
`colortablerev`	`on` | `off`	`off`	Whether to reverse to color table when `coloring` is set to `colortable`
`colortablesym`	`on` | `off`	`off`	Whether to symmetrize the color range around 0 when `coloring` is set to `colortable`.
`description`	String		A label showing a short description of the stored data.
`pointdata`	double 2D array		The point data for the tube data plot, as x and y coordinates in 2D and x, y, and z coordinates in 3D in an sdim-by-N real matrix.
`radiusdata`	double 1D array		The radius data for the tube data plot as a real N-vector or a single double value for a fixed tube radius.
`rangecoloractive`	`on` | `off`	`off`	Whether to use the manual color range specified in `rangecolormin` and `rangecolormax`. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.
`rangecolormax`	double	Plot-dependent	The maximum color range value. Active when `rangecoloractive` is `on`.

TABLE 7-117: VALID PROPERTY/VALUE PAIRS FOR TUBE DATA PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
`rangecolormin`	double	Plot-dependent	The minimum color range value. Active when `rangecoloractive` is on.
`rangedatactive`	`on` | `off`	`off`	Whether to use the manual data range specified in `rangedatamin` and `rangedatamax`. Values outside the data range are not plotted.
`rangedatamax`	double	Plot-dependent	The maximum data value. Active when `rangedataactive` is on.
`rangedatamin`	double	Plot-dependent	The minimum data value. Active when `rangedataactive` is on.
`title`	String	The auto-title.	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `manual` | `none`	`none`	`auto` if the title contribution should be computed automatically. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.

ATTRIBUTES

None.

EXAMPLES

A method for creating a logarithmic tube spiral in 2D:

Code for Use with Java

```
String pgTag = model.result().uniquetag("pg");
ResultFeature pg = model.result().create(pgTag, 2);
ResultFeature plot = pg.create("tube1", "TubeData");
int N = 100;
double[][] p = new double[2][N];
double[] radius = new double[N];
for (int i = 0; i < N; i++) {
  double par = 0.05*i;
  p[0][i] = Math.exp(par)*Math.cos(3*par);
  p[1][i] = Math.exp(par)*Math.sin(3*par);
  radius[i] = 0.3;
}
plot.set("pointdata", p).set("radiusdata", radius);
```

A method for creating a logarithmic tube spiral in 3D:

Code for Use with Java

```
String pgTag = model.result().uniquetag("pg");
ResultFeature pg = model.result().create(pgTag, 3);
ResultFeature plot = pg.create("tube1", "TubeData");
int N = 1000;
double[][] p = new double[3][N];
double[] radius = new double[N];
double[] color = new double[N];
for (int i = 0; i < N; i++) {
  double par = 0.005*i;
  p[0][i] = Math.exp(par)*Math.cos(10*par);
  p[1][i] = Math.exp(par)*Math.sin(10*par);
  p[2][i] = 0.1*i;
  radius[i] = 0.2*Math.sqrt(i+1);
  color[i] = i;
}
```

```
plot.set("pointdata", p)
  .set("radiusdata", radius)
  .set("colordata", color)
  .set("coloring", "colortable");
```

Volume

Create a volume plot.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Volume");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Volume")` creates a volume plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

A volume plot shows an expression evaluated in all elements of a 3D volume.

The following properties are available:

TABLE 7-118: VALID PROPERTY/VALUE PAIRS FOR VOLUME PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
color	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	red	The uniform color to use. Active when coloring is uniform.
coloring	colortable | uniform	colortable	How to color this surface.
colorlegend	on | off	on	Whether to show color legend, when coloring is set to colortable.
colortable	color table name	Rainbow	The color table to use when coloring is set to colortable. See Color Tables for a list of color tables.
colortablerev	on | off	off	Whether to reverse to color table when coloring is set to colortable.
colortablesym	on | off	off	Whether to symmetrize the color range around 0 when coloring is set to colortable.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
customcolor	RGB-triplet	{1,0,0} or last used color.	The uniform color to use. Active when color is set to custom.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.

TABLE 7-118: VALID PROPERTY/VALUE PAIRS FOR VOLUME PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
elemfilter	random | expression	random	If filteractive is on: The expression to use for filtering when only a subset of the elements are shown.
elemscale	double in [0,1]	1	The scale factor with which each element is scaled.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
filteractive	on | off	off	Whether to use element filtering.
filterexpr	String	x	The expression to use for filtering when elemfilter is set to expression.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritdeformscale	Boolean	true	If inheritplot is not none: Determines if the deformation scale is inherited.
inheritplot	none | plot name	none	The plot that color, color range, and deformation scale are inherited from.
inheritrange	Boolean	true	If inheritplot is not none: Determines if the color and data ranges are inherited.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title.
rangecoloractive	on | off	off	Whether to use the manual color range specified in rangecolormin and rangecolormax. The color range specifies the minimum and maxim value in the plotted colors. Default is the minimum and maximum data values.

TABLE 7-118: VALID PROPERTY/VALUE PAIRS FOR VOLUME PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
rangecolormax	double	Plot-dependent	The maximum color range value. Active when rangecoloractive is on.
rangecolormin	double	Plot-dependent	The minimum color range value. Active when rangecoloractive is on.
rangedatactive	on | off	off	Whether to use the manual data range specified in rangedatamin and rangedatamax. Values outside the data range is not plotted.
rangedatamax	double	Plot-dependent	The maximum data value. Active when rangedataactive is on.
rangedatamin	double	Plot-dependent	The minimum data value. Active when rangedataactive is on.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
tetkeep	double in [0, 1]	1	The fraction of the elements to display.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
threshold	manual | none	none	Use a smoothing threshold.
thresholdvalue	double	0.1	Threshold value (0-1), if threshold is set to manual.

TABLE 7-118: VALID PROPERTY/VALUE PAIRS FOR VOLUME PLOTS

NAME	VALUE	DEFAULT	DESCRIPTION
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
wireframe	on | off	off	Whether to plot filled elements or only their lines.

ATTRIBUTES

Deform, Filter, Selection

Waterfall

Create a waterfall plot in a 3D plot group. The waterfall plot creates a waterfall diagram, which is a plot that can illustrate how an expression depends on two parameters in a sweep.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Waterfall");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Waterfall")` creates a waterfall plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

The following properties are available:

TABLE 7-119: VALID PROPERTY/VALUE PAIRS FOR WATERFALL PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
colortable	color table name	Rainbow	The color table to use when styletype is set to surface or both. See Color Tables for a list of color tables.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.

TABLE 7-119: VALID PROPERTY/VALUE PAIRS FOR WATERFALL PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String	Model-dependent.	The expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritplot	none | plot name	none	The plot that color is inherited from.
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.

TABLE 7-119: VALID PROPERTY/VALUE PAIRS FOR WATERFALL PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
solnum	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when data is not parent and the underlying data has multiple solutions.
solrepresentation	solnum | solutioninfo	solutioninfo	Indicates which method of selecting solutions is active.
styletype	both | line | surface	both	Use a line plot, a surface plot, or both.
suffixintitle	String	Empty	Added suffix to contribution to title.
t	double	Time corresponding to last selected solnum.	The time to use, for transient problems. Available when data is not parent and the underlying data is transient.
timeinterp	on | off	off	on if t is used to determine time steps, off if solnum is used.
title	String	The auto-title.	The title to use when titletype is manual.
titletype	auto | custom | manual | none	auto	auto if the title contribution should be computed automatically, possibly using the group's customization. custom if the title contribution should be computed automatically, but customized. manual if the manual title contribution should be used (the title property). none if no title contribution should be used.
typeintitle	on | off	on	Whether the title contribution should contain the type when titletype is custom.
unit	String	Model-dependent	The unit to use for the expression in expr. If the old unit is not valid when the expression changes, the unit property is reset to default.
unitintitle	on | off	on	Whether the title contribution should contain the unit when titletype is custom.
xdescr	String		A description for the x-axis data expression.
xdescractive	on | off	off	Enable a description for the x-axis data expression.
xexpr	String		Expression for the x-axis data.
xunit	String		The unit for the x-axis data expression.
ydescr	String		A description for the y-axis data expression.
ydescractive	on | off	off	Enable a description for the y-axis data expression.
yexpr	String		Expression for the y-axis data.
yunit	String		The unit for the y-axis data expression.

ATTRIBUTES

Color

Whirl

Create a whirl plot in a 3D plot group. This plot type is only available with a license for the Rotordynamics Module.

SYNTAX

```
model.result(<pgtag>).create(<ftag>,"Whirl");
model.result(<pgtag>).feature(<ftag>).set(property, <value>);
model.result(<pgtag>).feature(<ftag>).run();
```

DESCRIPTION

`model.result(<pgtag>).create(<ftag>,"Whirl")` creates a whirl plot feature named *<ftag>* belonging to the plot group *<pgtag>*.

The whirl plot creates a plot of the mode shapes of a rotor rotated about the rotor axis at discrete rotation intervals.

The following properties are available:

TABLE 7-120: VALID PROPERTY/VALUE PAIRS FOR WHIRL PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
colortable	color table name	Rainbow	The color table to use. See Color Tables for a list of color tables.
const	String array of property/value pairs	Empty	Parameters to use in the expressions.
data	none | parent | data set name	parent	The data set this feature refers to.
descr	String	Model-dependent.	The description of the expression in expr. Is used in the automatic title.
descriptionintitle	on | off	on	Whether the title contribution should contain the description when titletype is custom.
differential	on | off	on	Whether the expression should be linearized at the linearization point. Applicable only if evalmethod is harmonic.
evalmethod	linpoint | harmonic | lintotal | lintotalavg | lintotalrms | lintotalpeak	harmonic	Applicable only for solutions with a stored linearization point. Controls if the linearization point, the perturbation, or a combination should be used when evaluating the expression.
expr	String array	Model-dependent.	The x, y, and z components of the expression to plot.
expressionintitle	on | off	off	Whether the title contribution should contain the expression when titletype is custom.
inheritcolor	Boolean	true	If inheritplot is not none: Determines if the color is inherited.
inheritplot	none | plot name	none	The plot that color and tube radius scale are inherited from.
inherittubescale	Boolean	true	If inheritplot is not none: Determines if the tube radius scale is inherited.

TABLE 7-120: VALID PROPERTY/VALUE PAIRS FOR WHIRL PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
interp	double array	Time corresponding to last selected solnum for transient levels.	The time to use, for transient levels. Available when data is not parent and the underlying data is transient.
looplevel	array of nonnegative integers and strings	Last solution for transient or parametric solution for each level. Otherwise first solution for each level.	The index of the solution to use, per level, or interp, but only for transient solutions. Available when data is not parent and the underlying data has multiple solutions.
nplanes	nonnegative integer	4	Number of planes in the whirl plot.
nrings	nonnegative integer	4	Number of rings in the whirl plot.
outersolnum	nonnegative integer	1	The index of the outer solutions to use. Applicable only for parametric sweep models.
prefixintitle	String	Empty	Added prefix to contribution to title.
radiusexpr	String	Empty	The tube radius expression.
recover	off | pprint | ppr	off	The derivative recovery method (off, within domains, or everywhere).
refine	nonnegative integer	1	The element refinement to use, if resolution is set to manual. Bear in mind that this is the refinement used for the base data set, so the number of elements in the model can increase radically if the plot uses, for example, a revolve data set.
resolution	norefine | coarse | normal | fine | finer | extrafine | custom	normal	Controls the plot's resolution. A finer setting results in a higher resolution by modifying the internally computed default refinement. Use custom to enter your own refinement in the refine property.
ringcolor	custom | black | blue | cyan | gray | green | magenta | red | white | yellow	blue	The color to use for the rings in the whirl plot.
smooth	none | material | internal | everywhere | expression	material	Smoothing settings. With material, smoothing is done inside domains with the same material. With internal, smoothing is done inside geometry domains. With expression, the smoothing is based on the expression in smoothexpr.
smoothexpr	String	dom	The expression to use for smoothing when smooth is set to expression.

TABLE 7-120: VALID PROPERTY/VALUE PAIRS FOR WHIRL PLOTS

PROPERTY	VALUE	DEFAULT	DESCRIPTION
`solnum`	nonnegative integer	Last solution for transient or parametric solution. Otherwise first solution.	The index of the solution to use. Available when `data` is not `parent` and the underlying data has multiple solutions.
`suffixintitle`	String	Empty	Added suffix to contribution to title.
`t`	double	Time corresponding to last selected `solnum`.	The time to use, for transient problems. Available when `data` is not `parent` and the underlying data is transient.
`threshold`	`manual` | `none`	`none`	Use a smoothing threshold.
`thresholdvalue`	double	`0.1`	Threshold value (0-1), if `threshold` is set to `manual`.
`timeinterp`	`on` | `off`	`off`	`on` if `t` is used to determine time steps, `off` if `solnum` is used.
`title`	String	The auto-title	The title to use when `titletype` is `manual`.
`titletype`	`auto` | `custom` | `manual` | `none`	`auto`	`auto` if the title contribution should be computed automatically, possibly using the group's customization. `custom` if the title contribution should be computed automatically, but customized. `manual` if the manual title contribution should be used (the `title` property). `none` if no title contribution should be used.
`tuberadiusscale`	double	1	The scale factor applied to the tube radii if tuberadiusscaleactive is true.
`tuberadiusscaleactive`	Boolean	`false`	If true, `tuberadiusscale` is used, otherwise the scale factor is computed automatically.
`typeintitle`	`on` | `off`	`on`	Whether the title contribution should contain the type when `titletype` is `custom`.
`unitintitle`	`on` | `off`	`on`	Whether the title contribution should contain the unit when `titletype` is `custom`.

ATTRIBUTES

`Color`

8

Graphical User Interfaces

In this chapter you find reference information about functionality that is useful if you want to create your own Graphical User Interface (GUI) that calls the COMSOL® API. On Windows®, the Application Builder is the primary COMSOL tool for creating custom applications and user interfaces based on COMSOL Multiphysics models with the possibility to use the COMSOL API and Java® for enhanced and extended functionality. For more information, see the documentation for the Application Builder.

Using the functionality described in this guide, you can create custom GUIs that utilize the modeling and analysis capabilities in COMSOL Multiphysics and create 1D, 2D, and 3D plots directly in your applications.

In this chapter:

Getting Started

The COMSOL API is based on Java®. You must have access to a Java compiler to create and compile programs that can utilize the functionality provided by the COMSOL API.

You can either use a standard Java compiler or you can use an integrated development environment.

You can get a compiler from www.oracle.com. The Oracle website also have plenty of background information on the Java language. Especially the Java Tutorial can be recommended for users that have little or no prior experience in using the Java language.

It is highly recommended that you use an integrated development environment (IDE) for writing and compiling the Java programs. An IDE helps when writing the source code because it provides the user with code completion, syntax highlighting, and access to help text (JavaDoc). An IDE usually also provides an integrated debugger that makes it possible to run the program line by line in order to easier find any bugs in the programs while running.

One such IDE is Eclipse. Eclipse is free and can be downloaded from www.eclipse.org. On the download page, download the *Eclipse IDE for Java Developers*.

The following sections assume that you have basic knowledge of the Java language and knows how to, for example, compile a Java program.

See www.comsol.com/system-requirements for the supported Java versions.

Example Graphical User Interface

In this section:

Introduction

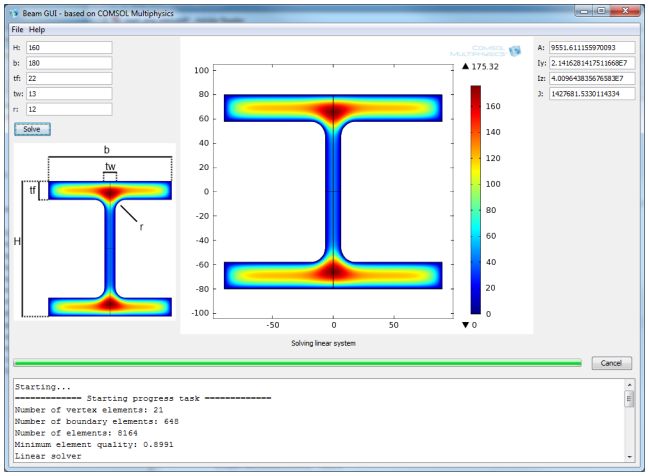
In the following sections, a GUI is built based on a model of a cross section of a beam. Beam models are used within the field of structural mechanics, but the application area is not important to the given example. The example model itself solves a simple Poisson type of equation (heat transfer) to calculate the area and moment of inertia for the beam. These calculated values can then later be used as input parameters in a real beam model. A reference for the modeling method in this example can be found in *Foundations of Solid Mechanics* by Y.C. Fung.

The example includes:

- Saving a model file for Java from an existing COMSOL Multiphysics model
- Integrating the Java file into a GUI built in Java®
- How to handle graphics in your own application
- How to handle progress information and, for example, stopping a solver
- How to hook up inputs in the GUI to the simulation
- How to show output from the simulation in the GUI
- Additional details such as adding a menu and icon to the application window

The example is based on the model stored in the `BeamModel.mph` file. The windows includes a lot of detail. The goal of creating a user-defined GUI is to be able to reduce the amount of clutter on the screen by only allowing suitable settings to be viewed and changed. This allows users who are not experienced in modeling to benefit from models created by others.

The final user interface looks like this



In this window only the necessary settings are provided on the left side. These settings are used to change the dimensions of the geometry. After the model has been solved the results are shown in the right side and can be copied to another application or report for further use.

Downloading Extra Material

Layout managers are used in Java® applications to create appealing GUIs that support automatic resizing. This demo uses the MIG Layout Manager. It is a free Java layout manager that removes a lot of the pain of using layout managers in Java.

The MIG Layout manager is free and can be downloaded from www.miglayout.com.

Creating the Code for the Model

In the `demo` folder under the COMSOL Multiphysics installation directory there are some files that can be used for creating the demonstration example. The example models for this demonstration is placed in the `demo\api\beammodel` directory. There is a model file called `BeamModel.mph`. This file contains the model to use for the GUI. Open COMSOL and open the model.

Spend some time familiarizing yourself with the model. Note especially that the model has a set of parameters under **Global Definitions** that are used to update the dimensions of the geometry, and that there is a set of variables defined under **Model>Defintions>Variables** that are used to define the outputs from the simulations.

Although any parameter or setting in the model can be changed using the COMSOL API it is recommended that input and output data are well defined as shown in this model. Such definitions make it easier to follow the data flow in the model.

You can export a model file for Java from the COMSOL Desktop. Before exporting, it is worthwhile to make the model history compact. Doing so makes sure that the exported Java file only contains the necessary steps that are needed to reproduce the model.

Use **Compact History** to make the model history compact. Then save the Java file using **Save As**. Choose **Model file for Java (*.java)** from the **Save as type** list, and name the file `BeamModel.java`. Then click **Save**.

Compacting the History and Creating a Copy Using Save As in the *COMSOL Multiphysics Reference Manual*

Construction of the Initial GUI with Graphics

Perform the following steps to set up Eclipse for handling your exported Java file and create a GUI:

1. Start Eclipse.
2. Create a new Java Project. Enter `BeamModelDemo` as the project name and click **Next**.
3. Go to the Libraries tab and click **Add External JARs**. Add all the JAR files placed in the `plugins` directory under the COMSOL Multiphysics installation directory (typically `C:\Program Files\COMSOL\COMSOL54\Multiphysics\plugins`). This allows Eclipse to find the definitions of the classes used by the COMSOL API and to run the code. In addition add the external Jar file `miglayout-4.0-swing.jar` (the numbers can be different for the file you downloaded). Click **Finish**.
4. Drag and drop your exported Java file to the `src` folder of your Eclipse project. Choose Copy files when Eclipse asks you and click OK.
5. Open the copied Java file by double-clicking it and navigate to the *Main method*. Remove the line in the Main method. A main method in this file is not required.
6. Navigate to the *run method*. The run method contains all settings necessary to set up the model and solve it. It even contains the definition of the Plot that is displayed in the application.
7. Remove this line that says `model.sol("sol1").runAll();` The model does not require solving when setting it up.
8. In order to be able to extract numerical results from the model add some Global nodes to the model. The Global nodes are only available in the COMSOL API and thus cannot be added using the COMSOL Desktop. Add the following lines to the bottom of the `run()` method; just above the `return` statement.

```
model.result().numerical().create("glA", "Global");
model.result().numerical("glA").set("expr", "A");
model.result().numerical().create("glIy", "Global");
model.result().numerical("glIy").set("expr", "Iy");
model.result().numerical().create("glIz", "Global");
model.result().numerical("glIz").set("expr", "Iz");
model.result().numerical().create("glJ", "Global");
model.result().numerical("glJ").set("expr", "J");
```

The file `BeamModel.java` now contains all the necessary settings to set up a model. This file is not changed again.

Add the `main()` method of the program that opens the graphics window (frame) and shows the model.

1. Select **New Java Class**. Name the new class `BeamModelDemo`. Select that this class should have a `public static void main(String[] args)` method. Click **Finish**.
2. Add a Model field to the `BeamModelDemo` class by adding these lines to the top of the class

```
private JFrame frame;
private Model model;
```

   Eclipse might complain that `JFrame` and `Model` are unknown at this time, and you have to add import statements in order to resolve the names. For the `Model` variable it is the `com.comsol.model` package that you should import. Eclipse is helpful and can provide such import statements automatically if you point to the offending new class name and press Ctrl+1. Throughout this demonstration example, add new classes for which such import statements have to be added.

3. Navigate to the main method and edit it such that it contains these lines

```
public static void main(String[] args) {
  BeamModelDemo demo = new BeamModelDemo();
  demo.init();
  demo.start();}
```

4. Create an init method in `BeamModelDemo`. It should only contain a single line, and the method should look like this:

```
public void init() {
  ModelUtil.initStandalone(true);
}
```

5 Create the start method. It is the main method to set up a model and the GUI used to display it. This method is updated frequently when setting up this demonstration model.

```
public void start() {
  frame = new JFrame("Beam GUI - based on COMSOL Multiphysics");
  frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
  frame.setSize(1000, 730);
  JPanel mainPanel = new JPanel();
  frame.getContentPane().add(mainPanel);
  mainPanel.setLayout(new BorderLayout());
  SwingGraphicsPanel graphicsPanel =
  new SwingGraphicsPanel("window1",     "Window1");
  mainPanel.add(graphicsPanel, BorderLayout.CENTER);
  frame.setVisible(true);

  model = BeamModel.run();
  model.sol("sol1").runAll();
  model.result("pg1").set("window", "window1");
  model.result("pg1").run();
}
```

6 Right-click the `BeamModelDemo.java` file in the **Package Explorer** and select **Run as>Run configuration**.

7 Select the **Environment** tab. Click the **New** button. Use the **Name** PATH (on Windows), `LD_LIBRARY_PATH` (on Linux), or `DYLD_LIBRARY_PATH` (on macOS) and enter the following text in **Value**: *<comsolinstalldir>*`/lib/`*<platformname>*, where *<comsolinstalladir>* is the directory where COMSOL Multiphysics is installed and *<platformname>* is one of `win64`, `glnxa64`, or `maci64` depending on your platform. LD_LIBRARY_PATH (on Linux) and DYLD_LIBRARY_PATH on macOS must also include *<comsolinstalldir>*`/ext/graphicsmagick/`*<platformname>*. Also, the following 3 environment variables:

MAGICK_CONFIGURE_PATH

MAGICK_CODER_MODULE_PATH

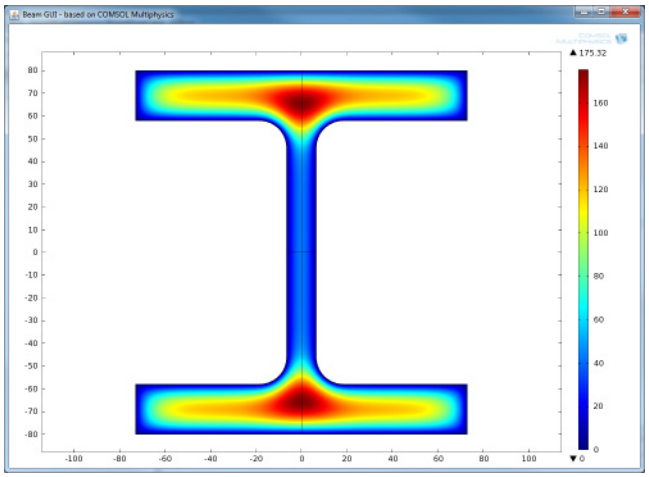
MAGICK_FILTER_MODULE_PATH

must all be set to the value *<comsolinstalldir>*`/ext/graphicsmagick/`*<platformname>*.

Also, the LC_NUMERIC environment variable should be set to C.

When done, click **Apply**.

8 Click **Run**. The application window opens and a COMSOL graphics panel displays. After several seconds, the model is solved and the 2D graphics with the result are presented.



The application window is missing some information and some ways to control the simulation.

Handling of Progress Information

It is possible to create a monitor for the progress of the solver. This monitor can also be used to cancel long running simulations if desired.

The progress information is made available using two different classes: `SwingProgressPanel` is used to display the progress in the GUI, and `SwingDemoProgressContext` is used to handle the communication between COMSOL Multiphysics and the areas the application that needs information about progress.

`SwingDemoProgressContext` extends `SwingProgressContext`, which is described in the reference section at the end of this chapter.

Both classes are added by copying two files instead of writing them from scratch.

1. Use the mouse to drag and drop these files to the src folder shown in the **Package Explorer** in Eclipse: `SwingDemoProgressContext.java` and `SwingProgressPanel.java`.
2. Open the `BeamModelDemo.java file` and navigate to the start method.
3. Add these lines before the call to `frame.visible`

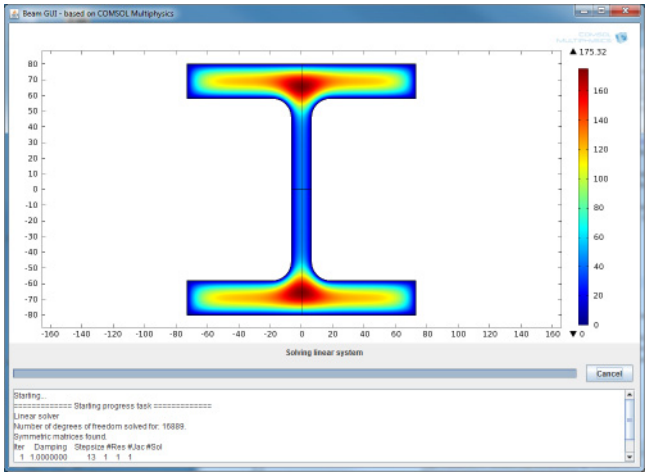
```
SwingProgressPanel progressPanel = new SwingProgressPanel();
mainPanel.add(progressPanel, BorderLayout.PAGE_END);
progressPanel.updateProgressLog("Starting\n");
ProgressWorker.setContext(new SwingDemoProgressContext(progressPanel));
```

4. These lines are added to the progress panel to the bottom of the main window and the context is set up between COMSOL and the user application.
5. In order to show any progress in the GUI, the solver must not run in the main thread. This means that a separate thread for the solver is created. Create the following solve method by removing the corresponding lines from the start method:

```
private void solve() {
  ProgressWorker.run(new Runnable() {
    public void run() {
      model.sol("sol1").runAll();
      model.result("pg1").set("window", "window1");
      model.result("pg1").run();
    }
  });
}
```

6. Remember to add a call to the solve method at the end of the start method.
7. Run the application by right-clicking `BeamModelDemo.java` in the Package Explorer and select **Run as>Java Application**.

8 The application window opens and shows progress information while starting and solving.



Setting Up Inputs From the GUI to the Model

To add some more dynamics to the application, add a method of inputting parameters to the model and create a Solve button.

The input data is provided by fields in the right side of the window.

Add these fields to the top of the class definition of the `BeamModelDemo` class:

```
JTextField editH;
JTextField editb;
JTextField edittf;
JTextField editr;
JTextField edittw;
```

A method `leftPanel` is created that sets up the various components.

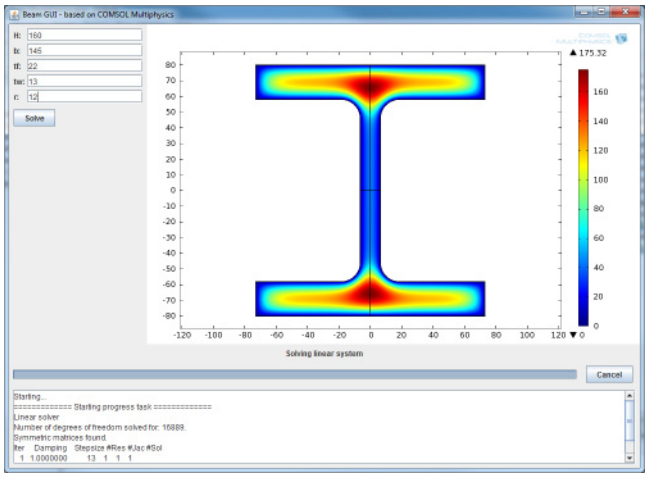
```
private JPanel leftPanel() {
  MigLayout layout = new MigLayout("wrap 2");
  JPanel panel = new JPanel(layout);

  JLabel label = new JLabel("H:");
  panel.add(label);
  editH = new JTextField(16);
  editH.setText("160");
  panel.add(editH);

  label = new JLabel("b:");
  panel.add(label);
  editb = new JTextField(16);
  editb.setText("145");
  panel.add(editb);

  label = new JLabel("tf:");
  panel.add(label);
  edittf = new JTextField(16);
  edittf.setText("22");
  panel.add(edittf);

  label = new JLabel("tw:");
  panel.add(label);
  edittw = new JTextField(16);
  edittw.setText("13");
```

```
    panel.add(edittw);

    label = new JLabel("r:");
    panel.add(label);
    editr = new JTextField(16);
    editr.setText("12");
    panel.add(editr, "wrap 10px");

    JButton solveButton = new JButton("Solve");
    panel.add(solveButton, "span, wrap 10px");

    solveButton.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
      solve();
    }
    });

    return panel;
  }
```

Add a call to `leftPanel` in the start method just before the definition of the `graphicsPanel` variable. Also comment out the call to the solve method at the end of the start method. Solving is handled manually by clicking the Solve button.

```
JPanel panel = leftPanel();
mainPanel.add(panel, BorderLayout.LINE_START);
```

Run the application by, for example, pressing Ctrl+F11



It is now possible to re-solve the model by pressing the **Solve** button, but the fields still needs to be hooked into the model.

1 Navigate to the solve method in the `BeamModelDemo.java` file. Add the following lines to the top of the method:

```
model.param().set("H", editH.getText()+"[mm]");
model.param().set("b", editb.getText()+"[mm]");
model.param().set("tw", edittw.getText()+"[mm]");
model.param().set("tf", edittf.getText()+"[mm]");
model.param().set("r", editr.getText()+"[mm]");
```

2 Save the file and start the application again.

3 Try to change the `H` parameter to, for example, `200` and press the **Solve** button.

4 The new model geometry and new simulation results display.

Displaying Results in the GUI

The aim of the GUI is to provide calculations of areas and moments of inertia based on the model. These results are added in a panel to the right of the graphics panel.

1 Add these fields to the top of the `BeamModelDemo` class file:

```
JTextField editA;
JTextField editIy;
JTextField editIz;
JTextField editJ;
```

2 Add a method `rightPanel` at the end of the `BeamModelDeom.java` that contains the output. Choose `JTextFields` to display the result. It is possible to copy text from these fields for use in other applications.

```
private JPanel rightPanel() {
  MigLayout layout = new MigLayout("wrap 2");
  JPanel panel = new JPanel(layout);

  JLabel label = new JLabel("A:");
  panel.add(label);
  editA = new JTextField(16);
  panel.add(editA);

  label = new JLabel("Iy:");
  panel.add(label);
  editIy = new JTextField(16);
  panel.add(editIy);
  label = new JLabel("Iz:");
  panel.add(label);
  editIz = new JTextField(16);
  panel.add(editIz);
  label = new JLabel("J:");
  panel.add(label);
  editJ = new JTextField(16);
  panel.add(editJ, "wrap 10px");

  return panel;
}
```

3 A small utility method is required in order to extract numerical data from the Global nodes. Add this method after the `rightPanel` method:

```
private String getScalar(NumericalFeature num) {
  double[][] array = num.getData(0);
  double A = array[0][0];
  return Double.toString(A);
}
```

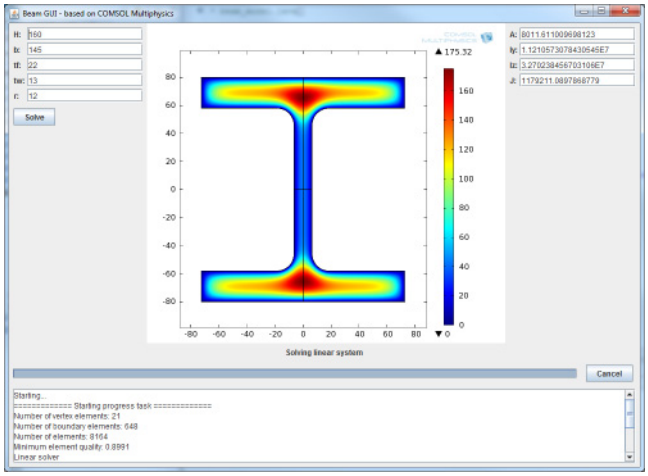
4 Add a few lines to extract the numerical results from the model after is being solved and show the numbers in the main window. Add the following lines to the solve method just after the call to the run method:

```
editA.setText(getScalar(model.result().numerical("glA")));
editIy.setText(getScalar(model.result().numerical("glIy")));
editIz.setText(getScalar(model.result().numerical("glIz")));
editJ.setText(getScalar(model.result().numerical("glJ")));
```

5 Add code for producing the `rightPanel` to the start method just below the addition of the graphicsPanel:

```
panel = rightPanel();
mainPanel.add(panel, BorderLayout.LINE_END);
```

6 Run the application again.



Other Details

The application by now is able to accept input from the user, simulate a model, and display results graphically as well as numerical results.

In order to finalize the model, add some additional features to the application. At the end, there is a short description of things that remains to be done.

ADDING A MENU

A menu is usually added.

1 Add `implements ActionListener` to the definition of the `BeamModelDemo` class such that the first line of the class definition reads

```
public class BeamModelDemo implements ActionListener {
```

2 Add a method that handles the event when the user performs actions with the menus. Here an action is added that can be used to exit the application and an about box is added that utilizes one of the `JOptionPane` dialog boxes.

```
public void actionPerformed(ActionEvent e) {
  String ac = e.getActionCommand();
  if (ac.equals("exit")) {
    System.exit(0);
  }
  else if (ac.equals("about")) {
    JOptionPane.showMessageDialog(frame,
    "Beam GUI Example\n"+
    "Simple DEMO example\n"+
    "Copyright 2011-2013",
    "About",
    JOptionPane.DEFAULT_OPTION);
  }
}
```

3 Add a method that defines the menu and menu items. The code adds a **File** and a **Help** menu where the exit and about actions are placed as menu items.

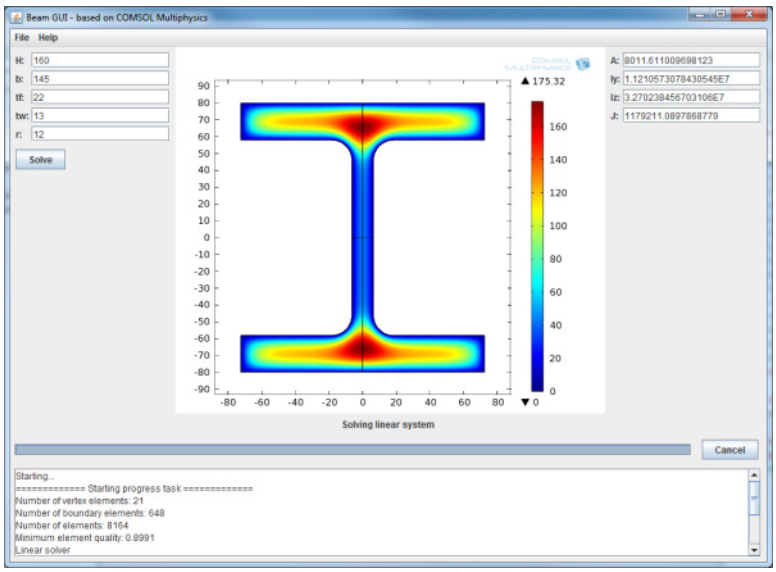
```
private JMenuBar menu() {
  JMenuBar menubar = new JMenuBar();

  JMenu menu = new JMenu("File");
```

```
    menubar.add(menu);

    JMenuItem item = new JMenuItem("Exit");
    item.setActionCommand("exit");
    item.addActionListener(this);
    menu.add(item);

    menu = new JMenu("Help");
    menubar.add(menu);

    item = new JMenuItem("About");
    item.setActionCommand("about");
    item.addActionListener(this);
    menu.add(item);

    return menubar;
  }
```

4 Add a call to menu in the start method just before the call to `setVisible`:

```
JMenuBar menubar = menu();
frame.setJMenuBar(menubar);
```

5 Start the application



ADDING AN ICON AND AN IMAGE

An application that has to be used by other people should have appealing appearance and graphics and a suitable icon. For this application add the COMSOL logo to the window. Choose any icon you want to use for your own application.

1 Add a `setIcon` method to the `BeamModelDemo` class

```
private void setIcon(String filename) {
  BufferedImage img;
  img = null;
  try {
    img = ImageIO.read(new File(filename));
  } catch (IOException e) {
    return;
  }
  frame.setIconImage(img);
}
```

2 Add this line to the top of the start method (right after the call to `setSize`)

```
setIcon("comsolicon.png");
```

3 Place the icon file `comsolicon.png` in your workspace directory for this project. Right-click `BeamModelDemo.java` in the **Package Explorer** and choose **Properties** in order to determine the location of this directory.

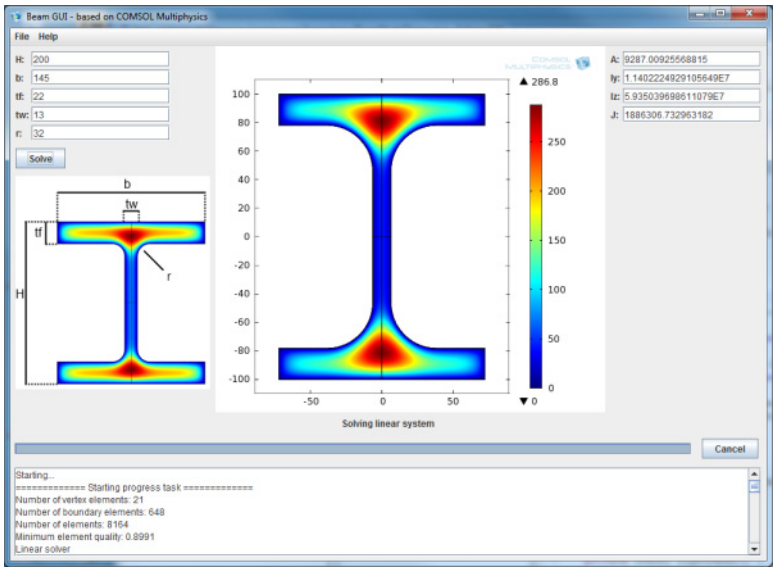
4 It is convenient to have an image that describes the parameters used in the panel on the left side of the window. Start by adding the `ImageComponent.java` file to the project by dragging it to the `src` folder in the **Package Explorer**.

5 Add these lines to the `leftPanel` method just before the line with `return panel`;

```
ImageComponent img =
  new ImageComponent("beam_dim_small.png");
panel.add(img, "span");
```

6 Place the `beam_dim_small.png` file in the workspace directory for this project.

7 Start the application.



LOOK AND FEEL

The appearance of a Java® Swing application by default does not look like other applications that are written specifically for the platform you are running on. You can improve the appearance by setting the Look and Feel for the Java application:

1 Add a `lookandfeel` method to the `BeamModelDemo` class:

```
private void lookandfeel() {
 try {
  UIManager.setLookAndFeel(
   UIManager.getSystemLookAndFeelClassName());
  }
  catch (Exception e) {
  }
}
```

2 Add a call to `lookandfeel` at the very top of the start method

```
lookandfeel();
```

3 Run the application. The application demonstration example is now complete.

FINISHING NOTES

The demonstration example is not an application that is ready to be sent to customers. For further development of the application, consider adding the following functionality:

- Error handling such that the application becomes insensitive to user's incorrect input and such that proper error messages are displayed in the event of an error or malfunction.
- For long running jobs, show an hour glass mouse pointer to show users that a time consuming task has started.
- The model object keeps the history that is recorded every time the model object is changed such that a model file for Java later can be saved that includes all actions on the object. If that is not required the history generation can be switched off, which saves memory.
- It is possible to have more than one model in an application. For example, it is possible to add a 3D beam model that utilizes the values calculated by the demonstration application.
- The graphics window can show 1D, 2D, and 3D graphics, so any results obtained in COMSOL Multiphysics can be shown in your own applications.
- Code can be added that remembers the choices made in the program. For example, to remember the location of the main window and the values entered in the fields.
- On-line help is missing.
- Calculated values could be copied to the clipboard or saved as a text file for easy sharing of the values.

GUI Classes

The following classes are available for working with graphical user interfaces:

- `ProgressContext`
- `ProgressWorker`
- `SWTGraphicsPanel`
- `SwingGraphicsPanel`

ProgressContext

Receive progress and log information from lengthy tasks and cancel them.

SYNTAX

```
progressUpdated(double progress);
progressDescriptionUpdated(String description);
progressLogUpdated(String message);
started();
finished(Throwable t);
cancel();
isCanceled();
```

DESCRIPTION

`ProgressContext` is the base class that you can extend to create a class that handles progress and log information. There are 5 different methods that you can override to receive calls when various events happen. The calls to these methods display on the background thread that the task is running on. The default implementation in `ProgressContext` for these methods does nothing.

If you are creating a GUI in SWT the class `SWTProgressContext` is also available to extend from. It receives the method calls for the methods overridden on the SWT event dispatching thread. This is convenient because calls to update SWT widgets must be made from that thread.

`progressUpdated(progress)` is the method to override if you want to receive information when the current progress is updated. `progress` is a value between 0 and 1.

`progressDescriptionUpdated(description)` is called when the description for what progress task that is currently running is changed.

`progressLogUpdated(message)` is called when a new line is added to the log of messages. This is mostly used for log information from the solvers.

`started()` is called when the progress task is about to start.

`finished(t)` is called when the progress task is finished. If an exception occurred while the progress task was running it is non-null. You can use the `isCanceled` method to check if the progress task was canceled.

`cancel()` is the method to call if you want to request cancellation of the currently running progress task. You typically call it from a listener for a cancel button in your GUI.

`isCanceled()` returns true if the `cancel` method has been called.

ProgressWorker

Run lengthy tasks on a separate thread and report progress and log information.

SYNTAX

```
ProgressWorker.setContext(ProgressContext context);
ProgressWorker.run(Runnable run);
ProgressWorker.run(Runnable run, ProgressContext context);
```

DESCRIPTION

`ProgressWorker.setContext(context)` sets that the `ProgressContext context` should receive progress information when the `run` method in `ProgressWorker` is called.

`ProgressWorker.run(runnable)` calls the `run` method on `runnable` on a separate thread and reports progress back to the registered `ProgressContext`.

`ProgressWorker.run(runnable, context)` calls the `run` method on `runnable` on a separate thread and reports progress back to `the ProgressContext context`.

SWTGraphicsPanel

Create an SWT Composite (panel) that can be used to plot COMSOL Multiphysics graphics into a custom GUI.

SYNTAX

```
SWTGraphicsPanel(Composite parent, String tag, String description);
```

DESCRIPTION

`SWTGraphicsPanel(parent, tag, description)` creates an SWT Composite that can be used in a GUI created using the Standard Widget Toolkit (SWT). `parent` is the SWT composite that is the parent of the panel in the GUI. `tag` is a unique tag used to identify the panel. The `"window"` property of a plot group in the model object should be set to this tag to plot into the panel.

SwingGraphicsPanel

Create an Swing JPanel that can be used to plot COMSOL Multiphysics graphics into a custom GUI.

SYNTAX

```
SwingGraphicsPanel(String tag, String description);
```

DESCRIPTION

`SWTGraphicsPanel(tag, description)` creates a Swing JPanel that can be used in a GUI created using Swing. `tag` is a unique tag used to identify the panel. The `"window"` property of a plot group in the model object should be set to this tag to plot into the panel.

This panel supports 1D, 2D, and 3D graphics.

9

The COMSOL File Formats

This chapter describes the COMSOL file formats including COMSOL Multiphysics® files in binary format and text format.

In this chapter:

File Formats

The following table shows the file types that COMSOL Multiphysics can read and write and provides pointers to documentation:

TABLE 9-1: FILE FORMATS SUMMARY

FILE FORMAT	EXTENSION	PRODUCT	READ	WRITE	DOCUMENTATION
COMSOL Model File	mph	MPH	Yes	Yes	N/A
Model files for Java	java	MPH	No	Yes	About the COMSOL Model File Formats
Compiled model files for Java (class files)	class	MPH	Yes	No	N/A
Model files for MATLAB (M-files)	m	LLML	No	Yes	About the COMSOL Model File Formats
Binary Data File	mphbin	MPH	Yes	Yes	Binary Data Files and Text Data Files
Text Data File	mphtxt	MPH	Yes	Yes	Binary Data Files and Text Data Files
Spreadsheet file	txt	MPH	Yes	Yes	Spreadsheet Data Format
Grid file	txt	MPH	Yes	Yes	Grid Data Format
Sectionwise file	txt	MPH	Yes	Yes	Sectionwise Data Format
Continuous color tables		MPH	Yes	No	Continuous Color Tables
Discrete color tables		MPH	Yes	No	Discrete Color Tables
Microsoft Excel® files	xlsx, xls, xlsb, xlsm	LLEXCEL	Yes	Yes	Supported Microsoft Excel File Types

Product keys:

- MPH: COMSOL Multiphysics
- LLML: COMSOL LiveLink™ *for* MATLAB®
- LLEXCEL: COMSOL LiveLink™ *for* Excel®

Data Formats

The data formats in COMSOL Multiphysics are used for exporting results data to file as well as representing input to interpolation functions in COMSOL. For all data formats, the exported file can contain a number of header rows starting with %, which contain information about the model and the exported data.

In this section:

- Spreadsheet Data Format
- Grid Data Format
- Sectionwise Data Format

In the *COMSOL Multiphysics Reference Manual:*

- Examples of Spreadsheet, Sectionwise, and Grid File Formats
- Exporting Data and Images

Spreadsheet Data Format

This data format is used for importing unstructured data and exporting results data:

TABLE 9-2: DATA

SECTION	DESCRIPTION
Data	Data values separated by spaces

Each row of the file defines the coordinates and data values for the function in one point. A file used to define a function of three variables can begin as follows:

```
0 0 0.12 0.34
0 1 0.52 1.50
1 0 0.67 0.91
...
```

The first variable (input argument) appears in the first (leftmost) column, the second variable in the second column, the third variable in the third column, and the function values in the fourth (rightmost) column. The variables can be any function inputs. For space-dependent functions $f(x, y, z)$ they are the x-, y-, and z-coordinates.

It is possible to define several functions in one file by providing more than one data column after the input variables (which, in many cases, are coordinates). When exporting several expressions to a file, COMSOL Multiphysics generates files with this structure.

You can use the % character to indicate that a row contains comments and not data.

Grid Data Format

The grid data format can only be used for import of data.

The following table shows the format for results data stored as grid points and corresponding data values:

TABLE 9-3: GRID, DATA

SECTION	NUMBER OF ROWS	DESCRIPTION
% Grid	1–3	x grid points separated by spaces y grid points separated by spaces (optional) z grid points separated by spaces (optional)
% Data	Number of y grid points (2D) or number of y grid points times number of z grid points (3)	Data values separated by spaces

Each row contains values for different x grid points for fixed values of y and z. The rows first increase the y grid value and then the z grid value. The grid points can also represent another independent variable that the data values depend on. For example, the "grid points" can be temperature values and the data values the thermal conductivity at these temperatures.

It is important to use a comment line starting with `%` to separate the grid points or other interpolation points and the data values that are associated with these coordinates or interpolation points.

It is possible to include more than one function in the file as long as a `% Data` header separates them one from the other.

In the *COMSOL Multiphysics Reference Manual:*

- Interpolation
- Examples of Spreadsheet, Sectionwise, and Grid File Formats
- Exporting Data and Images

Rock Fracture Flow: Application Library path **COMSOL_Multiphysics/Geophysics/rock_fracture_flow**

Sectionwise Data Format

The following table shows the format for results data stored as node coordinates, elements, and corresponding data values:

TABLE 9-4: NODES, ELEMENTS, DATA

SECTION	NO. COLUMNS	DESCRIPTION
`%Coordinates`	1–3	One to three columns containing x, y (optional), and z (optional)

TABLE 9-4: NODES, ELEMENTS, DATA

SECTION	NO. COLUMNS	DESCRIPTION
`%Elements`	3 (2D), 4 (3D)	Triangulation where each row contains the row indices of the points in the Coordinates section that make up a single element — triangular in 2D, tetrahedral in 3D
`%Data`	1	Column of data values

This format can also be used to import data for unstructured interpolation. It has the advantage over the Spreadsheet Data Format in that it also contains the exact mesh used to perform the interpolation.

Duplicate values (that is, evaluations with the same coordinates and the same values of the evaluated expressions) are removed before the sectionwise data is exported to file.

In the *COMSOL Multiphysics Reference Manual:*

- Examples of Spreadsheet, Sectionwise, and Grid File Formats
- Exporting Data and Images

Supported Microsoft Excel File Types

If your license includes the LiveLink™ *for* Excel®, you can import data to COMSOL from files with the following Excel® formats:

- For a client with Excel: Excel, Excel 97, Excel binary, and Excel macro
- For a client without Excel: Excel and Excel macro

Color Tables, Cycle Colors, and Color Themes

About Color Tables

Color table files are used when plotting. When COMSOL Multiphysics is loaded, it reads all files in the following directories:

- `data/colortables/` in the directory where COMSOL is installed.
- The user settings directory `.comsol/v54` under your local home directory.

Files that adhere to the format specified in this section are made available as color tables, including any user-defined color table files that you have added.

In this section:

- Continuous Color Tables
- Discrete Color Tables

For information about available color tables, see Selecting Color Tables in the *COMSOL Multiphysics Reference Manual*.

Continuous Color Tables

An example of a color table that defines a transition from blue to red:

```
% Continuous
0 0 1
1 0 0
```

Each line, from left to right, contains the red, green, and blue components (RGB) of a color. The components are floating-point values between 0 and 1. The table can contain an arbitrary number of colors.

Each color can contain an optional fourth component, which represents the length of the interval between the two colors. For N colors, there are N–1 intervals. An example of a color scale that defines a sharp transition from blue to magenta followed by a slow transition from magenta to red:

```
% Continuous
0 0 1 1
0.5 0 0.5 10
1 0 0
```

Discrete Color Tables

An example of a color table for which the lower half of the legend is blue and the upper half is red:

```
% Discrete
0 0 1
1 0 0
```

Each color can contain an optional fourth component, the length of the interval occupied by that color. For N colors, there are N intervals. An example of a color scale that defines a small blue interval, a long green interval, and a medium red interval:

```
% Discrete
0 0 1 1
0 1 0 10
1 0 0 5
```

About Cycle Colors

Cycle colors are used in graph plots where the color is set to cycle through a set of colors. The colors are defined in a text file. If there is a file `graphcyclecolors.txt` in the preferences directory (`.comsol\v54` in your user directory), then it is used. Otherwise, `/data/colors/graphcyclecolors.txt` under the COMSOL Multiphysics installation directory is used.

The file format is the following:

```
% Range maxRGB
R1 G1 B1
R2 G2 B2
R3 G3 B3
...
```

where *R1*, *G1*, and *B1* are the RGB (red, green, and blue) values for the first color; *R2*, *G2*, and *B2* are the RGB values for the second color; and so on. The range on the first row is the maximum value for an RGB component (*maxRGB* is an integer value). That row is optional; it defaults to 255 if not set.

About Color Themes

Color themes can be used to color selections in the **Graphics** window for easier identification of different parts of the model geometry. You can access and store color theme files in the following locations:

- `data/colorthemes` (similar to data/colortables).
- `.comsol/v54/colors`

It is recommended to use one of the existing color themes, which are designed to consider clashes between theme colors and selection colors. It is up to you to make sure the colors work well together if you modify an existing color theme or add your own.

The COMSOL Multiphysics software will use the default theme color for any color not read successfully from the color theme file. Likewise, if a theme used in a model is not available in the `data/colorthemes` folder, you visually get the default theme.

The color theme files contain two sections. The first section defines all the colors used by selections and contains keys for each color, similar to the preferences file. The second section contains the theme colors that can be used for geometry coloring. This section can contain an arbitrary number of colors, which will cycle automatically. The colors are defined using RGB data in the range of 0–255.

The names of the theme files will appear in the theme-selection lists in the COMSOL Desktop.

Below you find an example file for a custom color theme with suggested names:

```
% Selection colors

default_surface=200 200 200
default_line=0 0 0
selected_surface=140 140 242
selected_line=0 0 255
hover_surface=255 120 120 100
hover_line=255, 60, 60, 120
hover_surface_simple=242 140 140
hover_line_simple=255 0 0
hover_selected_surface=190 250 190 100
hover_selected_line=100 250 100 120
hover_selected_surface_simple=140 242 140
hover_selected_line_simple=0 153 0
feature_selection1_surface=250 222 87
feature_selection1_line=188 106 0
```

```
feature_selection2_surface=255 148 255
feature_selection2_line=155 58 165
feature_selection3_surface=247 147 30
feature_selection3_line=227 127 10
feature_selection4_surface=140 98 57
feature_selection4_line=120 78 37

% Theme colors

Red=255 0 0
Green=0 255 0
Blue=0 0 255
Yellow=255 255 0
Cyan=0 255 255
Magenta=255 0 255
Chartreuse=127 255 0
Azure=0 127 255
Rose=255 0 127
Orange=255 127 0
Spring green=0 255 127
Violet=127 0 255
Harlequin=63 255 0
Cerulean=0 63 255
Crimson=255 0 63
Lime=207 255 0
Capri=0 191 255
Cerise=255 0 191
Vermilion=255 63 0
Erin=0 255 63
Ultramarine=63 0 255
Amber=255 191 0
Aquamarine=0 255 191
Purple=191 0 255
```

It is possible to skip giving colors a name in the theme section, in which case they will be displayed as **Color 1**, **Color 2**, and so on. The syntax of the second section would then be:

```
255 191 0
0 255 191
191 0 255
...
```

These names only appear in the Linux and macOS version of the COMSOL Desktop, where the colors are displayed in a list. They do not appear in the Windows version.

The `simple` suffix in the selection color names means that the color is used for software and DirectX rendering, as well as for OpenGL when **Optimize for** is set to **Performance** in the **Preferences** dialog box (and possibly also in some other instances when some OpenGL requirements fail).

Binary Data Files and Text Data Files

A COMSOL Multiphysics file is used to store COMSOL data. The format is suitable for exchange of mesh or CAD data between COMSOL Multiphysics and other software systems. It is possible to save a COMSOL Multiphysics file in a text file format, using the extension .mphtxt, or a binary file format, using the extension .mphbin. The file formats contain the same data in the same order.

In this section:

File Structure

The COMSOL Multiphysics file format has a global version number, so that it is possible to revise the whole structure. The first entry in each file is the file format, indicated by two integers. The first integer is the major file version and the second is referred to as the minor file version. For the current version, the first two entries in a file is `0 1`.

The following sections describe the file structure of the supported version.

FILE VERSION 0.1

After the file version, the file contains three groups of data:

- A number of *tags* stored as strings, which gives an identification for each *record* stored in the file.
- A number of *types*, which are strings that can be used in serializing the object. The tag should be used as an indication of the contents of the file, but can also be an empty string.
- The *records* containing the serialized data in the file.

Example When using `model.mesh(<tag>).export(<filename>)` or **Mesh>Export to File** to save a COMSOL mesh, the tag equals the variable name (`m1`), the type is set to `obj` (but this is not used), and the record contains the serialization of the mesh object, including point coordinates and element data of the mesh. See Examples of the Serialization Format for more examples of COMSOL Multiphysics text files.

```
# Created by COMSOL Multiphysics Fri Aug 26 14:19:54 2005

# Major & minor version
0 1
######### Tags
1 # number of tags
2 m1

######## Types
1 # number of types
3 obj

######## Records

# A planar face object

0 0 1
```

```
4 Mesh # class
...
```

Records

The record contains the serialization data in the file and additional information on how to process the serialized data. It also has a version number.

The record is a wrapper for *serializable types* stored in the file. The reason for having this wrapper is to be able to use a version number, so that the serialization can be revised in the future while maintaining backward compatibility.

The following sections describe the format of the supported version:

RECORD VERSION 0

This record is a wrapper for *serializable types* stored in the file. The following table contains the attributes of the records:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
Integer		Version
Integer		Not used
Integer	type	Serialization type, 1 for Serializable
Serializable	obj	If type equals 1, this field follows

Serialization type 1 indicates that the following field is a subtype to `Serializable`. COMSOL uses type equal to 0 internally, but such files are only used for temporary purposes.

Terminology

The following data types are used in the serialization:

- *Boolean* refers to an 8-bit signed character which must be 0 or 1.
- *Character* refers to an 8-bit signed character.
- *Integer* refers to a 32-bit signed integer.
- *Double* refers to a 64-bit double.

Matrices are stored in row-major order. In this documentation brackets are used to indicate a matrix. Hence, `integer[3][4]` means that 12 integers representing a matrix are store in the file. The first three entries corresponds to the integers in the first row of the matrix, and so on.

Text File Format

COMSOL Multiphysics text file, using the file extension .mphtxt, are text files where values are stored as text separated by whitespace characters.

Lexical conventions:

- Strings are serialized as the length of the string followed by a space and then the characters of the string, for example, "`6 COMSOL`". This is the only place where whitespace matters.
- The software ignores everything following a # on a line except when reading a string. This makes it possible to store comments in the file.

Binary File Format

COMSOL Multiphysics binary file, using the extension .mphbin, are binary files with the following data representation:

- Integers and doubles are stored in little-endian byte order.
- Strings are stored as the length of the string (integer) followed by the characters of the string (integers).

Serializable Types

In this section:

Attribute

SUPPORTED VERSIONS

0

SUBTYPE OF

Serializable

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	n	Number of attribute fields
Serializable[n]		Each entity field is stored as a serializable

DESCRIPTION

An Attribute is a general purpose class from which different subtypes can be derived. Each such subtype should then be serialized using the serialization of the Attribute class, which means that all that it should add to the serialization is the version number.

Attributes are used in COMSOL Multiphysics for internal purposes, and these attributes are not documented. However, because Attribute has a strict serialization structure, the serialization of these attributes is well documented.

EXAMPLE

This is a serialization of an attribute used internally in COMSOL Multiphysics. It is serialized as a vector of integers.

```
11 AssocAttrib # class
0 0 # version
1 # nof attribute fields
9 VectorInt # class
18 3 2 2 2 1 0 1 1 1 1 1 1 0 1 1 1 1 0
```

BezierCurve

SUPPORTED VERSIONS

0

SUBTYPE OF

BezierMfd

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	DESCRIPTION
integer	Version
BezierMfd	Parent class containing common data

DESCRIPTION

A rational Bézier curve is a parameterized curve of the form

$$\mathbf{b}(t) = \frac{\sum_{i=0}^{p} \mathbf{b}_i w_i B_i^p(t)}{\sum_{i=0}^{p} w_i B_i^p(t)} \quad , 0 \le t \le 1$$

where the functions

$$B_i^p(t) = \binom{p}{i} t^i (1-t)^{p-i}$$

are the *Bernstein basis* functions of *degree* p, $\mathbf{b}_i = (x_1, \ldots, x_n)$ are the control vertices of the n-dimensional space, and w_i are the weights, which should always be positive real numbers to get a properly defined rational Bézier curve. A rational Bézier curve has a direction defined by the parameter t.

EXAMPLE

The following illustrates a linear Bézier curve.

```
11 BezierCurve # class
0 0 # version
2 # sdim
0 2 1 # transformation
1 0 # degrees
2 # number of control points
# control point coords and weights
0 0 1
1 1 1
```

TRANSFORMATION

The line, present here and in other examples below,

```
0 2 1 # transformation
```

has the following interpretation:

0 is the serialization version; 2 is the space dimension; 1 is the identity transform. (If the last digit is 0, there would be an additional 16 doubles for the matrix and two Boolean values.)

SEE ALSO

`BSplineCurve`

BezierMfd

SUPPORTED VERSIONS

0

SUBTYPE OF

`Manifold`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	d	Space dimension
Transform		Transformation class
integer	m	Degree in first parameter
integer	n	Degree in second parameter
integer	k	Number of control points
double[k][d+1]	P	Matrix of control points with the weights in the last column

DESCRIPTION

The `BezierMfd` type is the abstract base class for the different type of Bézier surfaces and curves that are supported. These can all be represented in using the generalized equation

$$\mathbf{S}(s,t) = \frac{\sum_{i=0}^{m}\sum_{j=0}^{n}\mathbf{b}_{i,j}w_{i,j}B(s,t)}{\sum_{i=0}^{m}\sum_{j=0}^{n}w_{i,j}B(s,t)}$$

where B are functions as described in the respective entry, and $\mathbf{b}$ are the control point coordinates in `P` and w are the weights stored in the last column of `P`.

SEE ALSO

`BSplineMfd`

BezierSurf

SUPPORTED VERSIONS

0

SUBTYPE OF

`BezierMfd`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	DESCRIPTION
integer	Version
BezierMfd	Parent class containing common data

DESCRIPTION

A rectangular rational Bézier patch of degree p-by-q is described by

$$\mathbf{S}(s,t) = \frac{\sum_{i=0}^{p}\sum_{j=0}^{q}\mathbf{b}_{i,j}w_{i,j}B_i^p(s)B_j^q(t)}{\sum_{i=0}^{p}\sum_{j=0}^{q}w_{i,j}B_i^p(s)B_j^q(t)}, 0 \le s,t \le 1 \ ,$$

where B_i^p and B_j^q are the Bernstein basis functions of degree p and q, respectively, as described in the entry of `BezierCurve`. This surface description is called rectangular because the parameter domain is rectangular; that is, the two parameters s and t can vary freely in given intervals.

SEE ALSO

`BSplineSurf`, `BezierTri`

BezierTri

SUPPORTED VERSIONS

0

SUBTYPE OF

`BezierMfd`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	DESCRIPTION
integer	Version
BezierMfd	Parent class containing common data

DESCRIPTION

Another form of surface description is the triangular patch, also called a *Bézier triangle*. A triangular rational Bézier patch is defined as

$$\mathbf{S}(s,t) = \frac{\sum_{i+j\le p} \mathbf{b}_{i,j} w_{i,j} B^p_{i,j}(s,t)}{\sum_{i+j\le p} w_{i,j} B^p_{i,j}(s,t)}, \quad 0 \le s,t \le 1$$

which differs from the Bézier curve description only by the use of *bivariate* Bernstein polynomials instead of *univariate*, for the curve case. The bivariate Bernstein polynomials of degree p are defined as

$$B^p_{i,j}(s,t) = \frac{p!}{i!j!(p-i-j)!} s^i t^j (1-s-t)^{p-i-j}, \quad i+j \le p$$

where the parameters s and t must fulfill the conditions

$$\begin{cases} 0 \le s,t \\ s+t \le 1 \end{cases}$$

which form a triangular domain in the parameter space, therefore the name of this surface description.

SEE ALSO

`BezierSurf`

BSplineCurve

SUPPORTED VERSIONS

0

SUBTYPE OF

`BSplineMfd`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	DESCRIPTION
integer	Version
BSplineMfd	Parent class containing common data

DESCRIPTION

The `BSplineCurve`, describes a general spline curve, using B-spline basis functions, as defined in `BSplineMfd`. Splines on this form are often referred to as B-splines.

A pth-degree spline curve is defined by

$$\mathbf{C}(u) = \frac{\sum_{i=0}^{n} N_i^p(u) w_i \mathbf{P}_i}{\sum_{i=0}^{p} N_i^p(u) w_i}, a \le u \le b$$

where $\mathbf{P}_i$ are the control points., the wi are the weights and the N_i^p are the pth degree B-spline basis functions defined in the nonperiodic and nonuniform knot vector

$$U = \{a, \ldots, a, u_{p+1}, \ldots, u_{m-p-1}, b, \ldots, b\}$$

For non-rational B-splines, all weights are equal to 1 and the curve can be expressed as

$$\mathbf{C}(u) = \sum_{i=0}^{n} N_i^p(u) w_i \mathbf{P}_i, a \le u \le b$$

SEE ALSO

BezierCurve

BSplineMfd

SUPPORTED VERSIONS

0

SUBTYPE OF

Manifold

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	d	Space dimension
Transform		Transformation class
integer		Dimension (1 if curve, 2 if surface)
integer	p, q	Degree in each dimension (1 or 2 integers)
Boolean		If rational equal to1
integer		Number of knot vectors (1 for curves, 2 for surfaces)
integer	m1	Length of first knot vector
double[m1]	U	First knot vector
integer	m2	Length of second knot vector (not for curves)
double[m2]	V	Second knot vector (not for curves)
integer	n1	Number of control points in first parameter direction
integer	n2	Number of control points in second parameter dimension

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer	n3	Number of coordinates per control point
double [n1][n2][n3]	P	Matrix of coordinates where the last dimension is increased by 1 to store the weights if the manifold is rational

DESCRIPTION

The `BSplineMfd` type is the abstract base type for `BSplineCurve` and `BSplineSurf`, which represent general spline curves and surfaces, respectively.

They are represented using *B-spline basis functions*. Let $U = \{u_0, \ldots, u_m\}$ be a nondecreasing sequence of real numbers; U is called the *knot vector* and the elements u_i of U are called *knots*. The ith B-spline basis function of p-degree, $N_i^p(u)$, is defined as

$$N_i^0(u) = \begin{cases} 1 & u_i \le u < u_{i+1} \\ 0 & \text{otherwise} \end{cases}$$

$$N_i^p(u) = \frac{u - u_i}{u_{i+p} - u_i} N_i^{p-1}(u) + \frac{u_{i+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1}^{p-1}(u)$$

A general B-spline can be described by

$$\mathbf{S}(u,v) = \frac{\sum_{i=0}^{n} \sum_{j=0}^{m} N_i^p(u) N_j^q(v) w_{i,j} \mathbf{b}_{i,j}}{\sum_{i=0}^{n} \sum_{j=0}^{m} N_i^p(u) N_j^q(v) w_{i,j}}, a \le u \le b, c \le v \le d$$

where

$$U = \{a, \ldots, a, u_{p+1}, \ldots, u_{m-p-1}, b, \ldots, b\}$$

and

$$V = \{c, \ldots, c, v_{p+1}, \ldots, v_{m-p-1}, d, \ldots, d\}$$

are the two knot vectors stored in the entry, and $\mathbf{b}$ and w are the control points coordinates and weights stored in `P`.

For periodic splines, the first and last parameter values in the knot vectors are not duplicated.

BSplineSurf

SUPPORTED VERSIONS

0

SUBTYPE OF

`BSplineMfd`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	DESCRIPTION
integer	Version
BSplineMfd	Parent class containing common data

DESCRIPTION

The generalization of B-spline curves to surfaces is a tensor product surfaces given by

$$\mathbf{S}(u,v) = \frac{\sum_{i=0}^{n}\sum_{j=0}^{m} N_i^p(u)N_j^q(v)w_{i,j}\mathbf{P}_{i,j}}{\sum_{i=0}^{n}\sum_{j=0}^{m} N_i^p(u)N_j^q(v)w_{i,j}}, a \le u, v \le b$$

SEE ALSO

`BezierSurf`

Ellipse

SUPPORTED VERSIONS

0

SUBTYPE OF

`Manifold`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	d	Space dimension
Transform		Transformation class
double[d]	center	Center coordinate
Boolean		Equal to 1 if clockwise rotation (only if d==2)
double[d]	normal	Normal vector coordinates,
double[d]	M	Major axis
double	rat	Ratio of minor axis length to major axis length
double	offset	Parameter at the end of major axis
Boolean		Equal to 1 if ellipse is degenerated

DESCRIPTION

This manifold defines an ellipse in the two or three dimensional space.

In 2D, an ellipse is defined by a center point `center`, a vector defining the major axis `M` of the ellipse (including the magnitude of the major axis), the radius ratio of the minor axis length to the major axis length `rat`, the direction of the ellipse, and the parameter offset at the major axis `offset`.

In 3D, an ellipse is defined by a center point `center`, a unit vector normal to the plane of the ellipse `normal`, a vector defining the major axis of the ellipse `M` (including the magnitude of the major axis), the radius ratio, and the parameter offset at the major axis `offset`. The direction of the ellipse is defined by the right hand rule using the normal vector.

An ellipse is a closed curve that has a period of 2π. It is parameterized as:

```
point = center + M cos(t - offset) + N sin(t - offset)
```

where `M` and `N` are the major and minor axes, respectively.

EXAMPLE

```
7 Ellipse # class
0 0 # version
2 # sdim
0 2 1 # transformation
0 0 # center
0 # reverse?
2 0 # major axis
0.5 # minor axis length / major axis length
0 # parameter value at end of major axis
0 # degenerated?
# Attributes
0 # nof attributes
```

For information about the line with `# transformation`, see Transformation.

Geom0

SUPPORTED VERSIONS

1

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	type	Geometry type
double		Relative geometry tolerance
integer	p	Number of points (0 or 1)
integer	na	Number of attributes
Attribute[na]		Vector of attributes

DESCRIPTION

The type represent a 0D geometry class.

The type can be 0 for solid or –1 for general object.

EXAMPLE

A solid 0D geometry object.

```
5 Geom0 # class
1 0 1e-010 1
```

```
0 # nof attributes
```

Geom1

SUPPORTED VERSIONS

1, 2

SUBTYPE OF

Serializable

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	type	Geometry type
Boolean		1 if void regions are labeled, 0 otherwise. Not present in version 1.
double		Geometry tolerance
integer	nv	Number of vertices
double[nv]	vtx	Vector of vertex coordinates
integer[nv][2]	ud	Matrix of integers giving domains on up and down side of each vertex

DESCRIPTION

The type represent a 1D geometry class.

The type can be 0, 1, or –1 for point, solid, or general objects, respectively.

EXAMPLE

A solid 1D object.

```
5 Geom1 # class
2 # version
1 # type
1 # voidsLabeled
1e-010 # gtol
3 # number of vertices
# Vertex coordinates
0
1
3
# Vertex up/down
1 0
2 1
0 2
# Attributes
0 # nof attributes
```

Geom2

SUPPORTED VERSIONS

1, 2

SUBTYPE OF

Serializable

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer		Type
Boolean		1 if void regions are labeled, 0 otherwise. Not present in version 1.
double		Relative geometry tolerance
double		Relative resolution tolerance
integer	nv	Number of vertices
integers/doubles [nv][4]	vertex	Matrix of vertex data
integer	ne	Number of edges
integers/doubles [ne][8]	edge	Matrix of edge data
integer	nc	Number of curves
Manifold[nc]	curve	An array of Manifold objects

DESCRIPTION

The type represent a 2D geometry class.

The type can be 0, 1, 2, or –1 for point, curve, solid or general objects, respectively.

EXAMPLE

```
5 Geom2 # class
2 # version
1 # type
1 # voidsLabeled
1e-010 # gtol
0.0001 # resTol
2 # number of vertices
# Vertices
# X Y dom tol
0 0 -1 NAN
1 2.2999999999999998 -1 NAN

1 # number of edges
# Edges
# vtx1 vtx2 s1 s2 up down mfd tol
1 2 0 1 0 0 1 NAN
1 # number of manifolds
11 BezierCurve # class
0 0 # version
2 # sdim
0 2 1 # transformation
1 0 # degrees
2 # number of control points
0 0 1
1 2.2999999999999998 1
0 # nof attributes
```

For information about the line with `# transformation`, see Transformation.

Geom3

SUPPORTED VERSIONS

1, 2

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	type	Type
Boolean		1 if void regions are labeled, 0 otherwise. Not present in version 1.
double		Relative geometry tolerance
double		Relative resolution tolerance
integer	nv	Number of vertices
integers/doubles [nv][5]	vertex	Matrix of vertex data
integer	npv	Number of parameter vertices
integers/doubles [npv][6]	pvertex	Matrix of parameter vertex data
integer	ne	Number of edges
integers/doubles [ne][7]	edge	Matrix of edge data
integer	npe	Number of parameter edges
integers/doubles [nep][10]	pedge	Matrix of parameter edge data
integer	nf	Number of faces
integers/doubles [nf][4]	face	Matrix of face data
integer	nm	Number of 3D manifolds, curves, and surfaces
Manifold[nmfd]	mfd	Vector of manifolds
integer	npc	Number of parameter curves
Manifold[npc]	pcurve	Vector of parameter curves

DESCRIPTION

The type represent a 3D geometry class.

The type can be 0, 1, 2, 3, or –1 for point, curve, shell, solid, or general objects, respectively.

Manifold

SUPPORTED VERSIONS

0

SUBTYPE OF

`Serializable`

FIELDS

This is an abstract class with no fields.

DESCRIPTION

A manifold is the common supertype for curve and surface types. It is used by the geometry types.

SEE ALSO

`Geom0`, `Geom1`, `Geom2`, `Geom3`

Mesh

SUPPORTED VERSIONS

1

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	d	Space dimension (if equal to 0 no more fields)
integer	np	Number of mesh points
integer		Lowest mesh point index
double[d][np]	p	Mesh points
integer	nt	Number of element types (fives the number of repeats of the following fields)
string		Element type
integer	nep	Number of nodes per element
integer	ne	Number of elements
integer[ne][nep]	elem	Matrix of point indices for each element
integer	ndom	Number of geometric entity values
integer[ndom]	dom	Vector of geometric entity labels for each element

DESCRIPTION

The geometric entity numbering for points, edges, and boundaries must start from 0 and the geometric entity numbering for domains must start from 1 when defining a mesh through a COMSOL Multiphysics mesh file.

EXAMPLE

The following displays a mesh with triangular elements on a unit square. Neither point nor edge elements are present.

```
4 Mesh # class
2 # sdim
5 # number of mesh points
0 # lowest mesh point index
# Mesh point coordinates on unit square
0 0
1 0
1 1
0 1
0.5 0.5
1 # number of element types
3 tri # type name
3 # number of nodes per element
4 # number of elements
```

```
# Elements, 4 triangular elements
0 1 4
3 0 4
2 3 4
1 2 4
4 # number of domains
# Domains
1
1
2
2
```

MeshCurve

SUPPORTED VERSIONS

1

SUBTYPE OF

`Manifold`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer		Space dimension
Transform		Transformation
integer	np	Number of points
double[np][d]	p	Matrix of point coordinates
double[np]	par	Vector of point parameters
Manifold	intcurve	Interpolating curve

DESCRIPTION

Mesh structures can also be used to define manifolds. Because meshes contain a number of nodes and, in the case of COMSOL Multiphysics, corresponding parameter values, a good geometric representation can be obtained using a suitable interpolation method for evaluating the values of the manifolds and its derivatives on parameter values that are inside the intervals between the given nodes. Mesh curves are handled by cubic spline interpolation.

The matrix `p` and the vector `par` corresponds to the structures corresponding structures in an edge mesh representation. For the MeshCurve, they serve as the interpolation data to obtain `intcurve`.

SEE ALSO

`BSplineCurve`

MeshSurf

SUPPORTED VERSIONS

1

SUBTYPE OF

`Manifold`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer		Space dimension
Transform		Transformation
integer	nv	Number of vertices
double[nv][3]	p	Matrix of mesh vertex coordinates
double[nv][2]		Matrix of mesh vertex parameters
integer	nt	Number of triangles
integers[nv][3]	elem	Matrix of vertex indices for each element

DESCRIPTION

Mesh structures for surface meshes can be used to make a geometric definition of unstructured data. Since a mesh type in COMSOL Multiphysics have coordinates as well as parameter values for each element, interpolation can be employed to create smooth surfaces.

A quadratic interpolation is used to define a parametric surface from a surface mesh.

The matrix `p` of coordinates and the triangles `elem` with indices into p are used as the interpolation data.

SEE ALSO

`Mesh`

Plane

SUPPORTED VERSIONS

1

SUBTYPE OF

`Manifold`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	d	Space dimension
Transform		Transformation
double[d]	p	The point in the plane with parameter value (0,0)
double[d]	n	Normal vector
double[d]	b	Direction of first parameter axis

DESCRIPTION

This manifold defines a plane in the three dimensional space. It is represented by a point, a unit vector normal to the plane, and the vector of the u derivative.

A plane is open in both parameter directions and neither periodic nor singular at any point. It is parameterized as:

```
pos = p + u*b + v*(n x b)
```

EXAMPLE

```
5 Plane # class
0 0 # version
3 # sdim
0 3 1 # transformation
1.3 0.80000000000000004 1.6000000000000001 # root point
-6.1257422745431001e-017 0 1 # normal
-1 0 -6.1257422745431001e-017 # derivatives
0 # degenerated?
```

For information about the line with `# transformation`, see Transformation.

PolChain

SUPPORTED VERSIONS

1

SUBTYPE OF

`Manifold`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	d	Space dimension
Transform		Transformation
integer	n1	First dimension of matrix of point coordinates (equal to d)
integer	n2	Second dimension of matrix point coordinates, number of points
doubles	pol	n1-by-n2 matrix of point coordinates

DESCRIPTION

Polygon chains are piecewise linear curves that are used as approximations of curves in the decomposition algorithm. They have an implicit parameter representation; that is, $[(i-1)(p-1), i(p-1)]$ on the ith interval in a polygon chain with p points. This is not a suitable representation because the derivatives can vary substantially along the curve.

SEE ALSO

`MeshCurve`

Selection

SUPPORTED VERSIONS

0

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	DESCRIPTION
integer	Version.
string	Selection label. The string is encoded in UTF-8.
string	Tag of corresponding object (mesh) in file.
integer	Dimension of selection (0: vertex; 1: edge; 2: face; 3: domain in 3D).
integer	Number of entities.
integer[]	The indices of the entities for the selection. The integers specify the 0-based indices of the entities (1-based for domains).

DESCRIPTION

Selections can appear in files containing a mesh. Each selection refers to a set of entities that needs to be defined by the mesh in the file.

EXAMPLE

The following example displays a domain selection in 3D named Fluid, specifying domains 1 and 3:

```
0 # Version
5 Fluid # Label
5 mesh1 # Geometry/mesh tag
3 # Dimension
2 # Number of entities
# Entities
1
3
```

Serializable

SUPPORTED VERSIONS

0

FIELDS

This is the abstract base type of all other types. It has no fields.

DESCRIPTION

Serializable is the abstract base type. It is used to indicate that a field can contain all supported types, as is the case for the Attribute type.

SEE ALSO

`Attribute`

Solution

SUPPORTED VERSIONS

1

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer		Solution object version
integer		Solution type
integer		Equal to one if it is ok to interpolate between solution vectors. Zero otherwise
string[]		Parameter names
integer		Number of degrees of freedom
integer		Mesh case number
integer		Size of parameter list
integer	nU	Number of data types in object
integer[nU]	iU	Number of solution vectors of each type
dcmplx[nU][iU]		Solution data identifier
integer[3]		DOF indices
Vector		Values of static DOFs
double		Parameter values
Vector		Values of dynamic DOFs without stored time derivatives
Vector		Values of dynamic DOFs with stored time derivatives
Vector		Time derivatives of corresponding DOFs

The first section of solution object specific data contains the following parts and in the following order:

- Internal solution object version number. At the time of writing the version number is 5.
- Solution type. The solution type is one of stationary solution(=0), parametric solution(=1), time-dependent solution(=2), and eigenvalue solution(=3).
- Whether or not interpolation between solution vectors is ok.
- Parameter names. Text file specific information: The first integer gives the number of parameter names (a single empty parameter name also registers as a 1 here). Thereafter each parameter is stored preceded by its length.
- Total number of degrees of freedom. This number includes both variables solved for and variables not solved for.
- Mesh case number.
- Size of the parameter list. This also becomes the number of stored dynamic solution vectors described below (if any such components are present).

The second section of solution specific data stores information about the type of each DOF and the values of any static DOFs. The data is stored in the following order:

- Internal solution object version number. At the time of writing the version number is 5.
- Number of different data types used in the present version of the solution object. At the time of writing the data types are: ordinary solution data, reaction forces data, adjoint sensitivity data, forward sensitivity data, functional sensitivity data, and linearization point data (and they are stored in this order).
- Number of stored solutions of each type. This number specifies the number of solutions per parameter value and not the total number of solution vectors of a certain type. Text file specific information: Space-separated vector of integers with information about the number of stored solutions of each type (ordinary solution data, reaction forces data, and so on).
- Solution data identifiers. Text file specific information: Space-separated vector of complex numbers (stored as real part followed by a space and the imaginary part) containing solution data identifiers. First, the identifiers for

all solutions of the first type is stored (where the number of solutions of the first type is given by the first integer of the preceding line). Then the identifiers for all solutions of the second type follows and so forth.

- Each DOF can be one of three types: static, dynamic without stored time derivatives, and dynamic with stored time derivatives. Information about which DOFs belong to which type is stored in three integer vectors. Text file specific information: The first vector contains the number of static DOFs followed by the indices of these DOFs. The second vector contains the number of dynamic DOFs stored without time derivatives followed by the indices of these DOFs. The third vector contains the number of dynamic DOFs stored with time derivatives followed by the indices of these DOFs.
- Vectors containing values of the static DOFs for one data type. Text file specific information: The first number gives the number of static vectors stored for the current data type. Thereafter the actual vectors are stored preceded by their lengths.

One DOF index data structure and one static DOFs values data structure is needed for each data type. The DOF indices and static vectors sections are therefore repeated `nU` times.

The third section of solution specific data stores information about the dynamic part of the solution. In total this section contains as many subsections as the size of the parameter list. Each subsection contains the following information and in the following order:

- Internal solution object version number. At the time of writing the version number is 5.
- Number of different data types used in the present version of the solution object. At the time of writing the data types are: ordinary solution data, reaction forces data, adjoint sensitivity data, forward sensitivity data, functional sensitivity data, and linearization point data (and they are stored in this order).
- Parameter values for the data in the current subsection. The number of parameter values here is the same as the number of parameter names.
- Vector containing values of dynamic DOFs stored without time derivatives for one data type and the corresponding parameter values. Text file specific information: The first number gives the number of vectors stored for the current data type and DOF type. Thereafter the actual vectors are stored preceded by their lengths.
- Vector containing values of dynamic DOFs stored with time derivatives for one data type and the corresponding parameter values. Text file specific information: The first number gives the number of vectors stored for the current data type and DOF type. Thereafter the actual vectors are stored preceded by their lengths.
- Vector containing values of time derivatives for one data type and the corresponding parameter values. Text file specific information: The first number gives the number of vectors stored for the current data type and DOF type. Thereafter the actual vectors are stored preceded by their lengths.

Within each subsection dynamic DOF value data are stored for one data type at a time.

Example of text file output of a simple stationary solution object. The underlying setup is a simple one-dimensional geometry containing a single second order Lagrange element with two uncoupled unknown variables. Both variables are solved for:

```
# Created by COMSOL Multiphysics Tue Jun 30 13:08:00 2009


# Major & minor version
0 1
1 # number of tags
# Tags
4 sol1
1 # number of types
# Types
3 obj

# --------- Object 0 ----------
```

```
0 0 1
8 Solution # class

5 # solution object version
0 # solution type
0 # interpolation between solnums is ok
1 0  # parameter names
6 # number of DOFs
0 # mesh case number
1 # size of parameter list

5 # solution object version
6 # number of data types
# number of solutions
1 1 0 0 0 0
# solution data identifier
NAN NAN NAN NAN
# DOF indices
6 0 1 2 3 4 5
0
0
# static vectors
1 6 1 1 1.375 1.0625 1 1
# DOF indices
4 0 1 4 5
0
0
# static vectors
1 4 -1.5 -0.500 -1.500 -0.500
# DOF indices
0
0
0
# static vectors
# DOF indices
0
0
0
# static vectors
# DOF indices
0
0
0
# static vectors
# DOF indices
0
0
0
# static vectors

5 # solution object version
6 # number of data types
1 1 0 # parameter values
# DOFs without time derivatives
1 0
# DOFs with time derivatives
1 0
# time derivatives
1 0
# DOFs without time derivatives
1 0
# DOFs with time derivatives
1 0
```

```
# time derivatives
1 0
```

The object only contains static solution data and that the only data types that are present are ordinary solution data and reaction forces data. The reaction forces data vector contains four entries since the setup has two unknown variables and both have been solved for in the example.

A second example uses the same setup as the previous one with the difference that a parametric solve with the parameters `p1` and `p2` has been performed. The parameter list was selected as `0 0 0.1 0.2` and only one of the two variables is solved for:

```
# Created by COMSOL Multiphysics Tue Jun 30 13:08:29 2009


# Major & minor version
0 1
1 # number of tags
# Tags
4 sol1
1 # number of types
# Types
3 obj

# --------- Object 0 ----------

0 0 1
8 Solution # class

5 # solution object version
1 # solution type
0 # interpolation between solnums is ok
2 2 p1 2 p2 # parameter names
6 # number of DOFs
0 # mesh case number
2 # size of parameter list

5 # solution object version
6 # number of data types
# number of solutions
1 1 0 0 0 0
# solution data identifier
NAN NAN NAN NAN
# DOF indices
3 1 3 5
3 0 2 4
0
# static vectors
1 3 0 0 0
# DOF indices
0
2 0 4
0
# static vectors
1 0
# DOF indices
0
0
0
# static vectors
# DOF indices
0
0
0
# static vectors
```

```
# DOF indices
0
0
0
# static vectors
# DOF indices
0
0
0
# static vectors

5 # solution object version
6 # number of data types
1 2 0 0 # parameter values
# DOFs without time derivatives
1 3 1 1.375 1
# DOFs with time derivatives
1 0
# time derivatives
1 0
# DOFs without time derivatives
1 2 -1.5 -1.500
# DOFs with time derivatives
1 0
# time derivatives
1 0

5 # solution object version
6 # number of data types
1 2 0.100 0.200 # parameter values
# DOFs without time derivatives
1 3 1 1.375 1
# DOFs with time derivatives
1 0
# time derivatives
1 0
# DOFs without time derivatives
1 2 -1.5 -1.500
# DOFs with time derivatives
1 0
# time derivatives
1 0
```

Half the DOFs end up in the static part and half in the dynamic part since only one variable is being solved for. This also has the consequence that the only appearing reaction force data in the stored solution object is in the dynamic part and that these vectors only have two components.

Straight

SUPPORTED VERSIONS

1

SUBTYPE OF

Manifold

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	VARIABLE	DESCRIPTION
integer		Version
integer	d	Space dimension
Transform		Transformation
double[d]	root	The point from which the ray starts
double[d]	dir	The direction in which the ray points
double	pscale	Parameter scale

DESCRIPTION

This manifold defines an infinite straight line in the two or three dimensional space. It is represented by a point and a unit vector specifying the direction. A straight also has a scale factor for the parameterization, so the parameter values can be made invariant under transformation. If not specified the value of this parameter is set to 1.0.

A straight line is an open curve that is not periodic. It is parameterized as:

```
pos = root + u*pscale*dir
```

where `u` is the parameter.

EXAMPLE

```
8 Straight # class
0 0 # version
3 # sdim
0 3 1 # transformation
1.3 0.8 0.0 # root point
-1 0 0 # direction
1 # parameter scale
```

For information about the line with `# transformation`, see Transformation.

SEE ALSO

`Plane`

Transform

SUPPORTED VERSIONS

1

SUBTYPE OF

`Serializable`

FIELDS

The class is

ENTITY/OBJECT	VARIABLE	DESCRIPTION
integer	d	Space dimension
Boolean		1 if transformation is a unit transformation, 0 otherwise. If the value is 1, no more fields are present
double [d+1][d+1]	M	Values in transformation matrix

ENTITY/OBJECT	VARIABLE	DESCRIPTION
Boolean		1 if determinant is positive, 0 otherwise
Boolean		1 if matrix is isotropic, 0 otherwise

DESCRIPTION

The transformation class is defined by the transformation matrix, which operates as a premultiplier on column vectors containing homogeneous coordinates thus

$$\begin{bmatrix} x' & y' & z' & s' \end{bmatrix} = M \cdot \begin{bmatrix} x & y & z & s \end{bmatrix}'$$

where the conventional 3D coordinates are

$$\begin{bmatrix} \frac{x}{s} & \frac{y}{s} & \frac{z}{s} \end{bmatrix}$$

The matrix thus consists of

$$\begin{bmatrix} & & T_x \\ & \mathbf{R} & T_y \\ & & T_z \\ 0 & 0 \; 0 & S \end{bmatrix}$$

where $\mathbf{R}$ is a nonsingular transformation matrix, containing the rotation, reflection, nonuniform scaling, and shearing components; $\mathbf{T}$ is a translation vector; and S is a global scaling factor greater than zero.

VectorDouble

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	VARIABLE	DESCRIPTION
integer	n	Number of elements
double[n]	d	Elements

DESCRIPTION

This is a wrapper for a vector of doubles that can be used to store fields in the `Attribute` class.

SEE ALSO

`Attribute`

VectorInt

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	VARIABLE	DESCRIPTION
integer	n	Number of elements
integer[n]	d	Elements

DESCRIPTION

This is a wrapper for a vector of integers that can be used to store fields in the `Attribute` class.

SEE ALSO

`Attribute`

VectorString

SUBTYPE OF

`Serializable`

FIELDS

The class is defined by the following fields:

ENTITY/ OBJECT	VARIABLE	DESCRIPTION
integer	n	Number of elements
string[n]	d	Elements

DESCRIPTION

This is a wrapper for a vector of strings that can be used to store fields in the `Attribute` class.

SEE ALSO

`Attribute`

Examples of the Serialization Format

To illustrate the use of the serialization format, some text files are listed in this section.

- A Mesh with Mixed Element Types
- A Planar Face

A Mesh with Mixed Element Types

For an example of a file containing a 3D mesh with tetrahedral and prism elements, see `mesh_example_4.mphtxt` in `\models\COMSOL_Multiphysics\Meshing_Tutorials`.

A Planar Face

The following listing is a complete representation of a planar 3D face.

```
# Created by COMSOL Multiphysics Fri Aug 26 14:19:54 2005

# Major & minor version
0 1
######### Tags
1 # number of tags
# Tags
2 b1

######## Types
1 # number of types
# Types
3 obj

######## Records

# A planar face object

0 0 1
5 Geom3 # class
1 # version
2 # type
1e-010 # gtol
0.0001 # resTol
4 # number of vertices
# Vertices
# X Y Z sub tol
0 0 0 -1 1e-010
1 0 6.1257422745431001e-017 -1 1e-010
0 1 0 -1 1e-010
1 1 6.1257422745431001e-017 -1 1e-010
4 # number of parameter vertices
# Parameter vertices
# vtx s t fac mfd tol
1 0 0 -1 1 NAN
2 1 0 -1 1 NAN
3 0 1 -1 1 NAN
4 1 1 -1 1 NAN

4 # number of edges
# Edges
# vtx1 vtx2 s1 s2 sub mfd tol
1 2 0 1 -1 2 NAN
2 4 0 1 -1 3 NAN
4 3 0 1 -1 4 NAN
3 1 0 1 -1 5 NAN
4 # number of parameter edges
# Parameter edges
```

```
# edg v1 v2 s1 s2 up down mfdfac mfd tol
1 1 2 0 1 1 0 1 1 NAN
2 2 4 0 1 1 0 2 1 NAN
3 4 3 0 1 1 0 3 1 NAN
4 3 1 0 1 1 0 4 1 NAN

1 # number of faces
# Faces
# up down mfd tol
0 0 1 NAN

5 # number of 3D manifolds
# Manifold #0
5 Plane # class
0 0 # version
3 # sdim
0 3 1 # transformation
0 0 0 # root point
-6.1257422745431001e-017 0 1 # normal
1 0 6.1257422745431001e-017 # derivatives
0 # degenerated?

# Manifold #1
8 Straight # class
0 0 # version
3 # sdim
0 3 1 # transformation
0 0 0 # root point
1 0 6.1257422745431001e-017 # direction
1 # parameter scale

# Manifold #2
8 Straight # class
0 0 # version
3 # sdim
0 3 1 # transformation
1 0 6.1257422745431001e-017 # root point
```

For information about the lines with `# transformation`, see Transformation.

Index