

# ArtiSynth User Interface Guide

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## Contents

<b>1</b>	<b>Introduction</b>	<b>6</b>
<b>2</b>	<b>Loading and Simulating Models</b>	<b>6</b>
2.1	Loading from the Models menu . . . . .	6
2.2	Loading by class path . . . . .	6
2.3	Loading from a file . . . . .	6
2.4	Simulating a model . . . . .	7
<b>3</b>	<b>The Viewer</b>	<b>7</b>
3.1	Viewer Toolbar . . . . .	7
3.2	Viewpoint Control . . . . .	7
3.3	Adding Additional Viewers . . . . .	8
3.4	Orthographic vs. Perspective Projection . . . . .	8
3.5	Viewer Grid . . . . .	8
3.5.1	Grid units and properties . . . . .	8
3.6	Clipping Planes . . . . .	9
3.6.1	Adding and removing . . . . .	10
3.6.2	Moving . . . . .	10
3.6.3	Offsets . . . . .	10
3.6.4	Enabling/disabling . . . . .	10
3.6.5	Slicing mode . . . . .	10
3.6.6	Other features . . . . .	10
3.7	Indicating 3D Positions with the Mouse . . . . .	11
<b>4</b>	<b>Component Navigation and Selection</b>	<b>11</b>
4.1	The Component Hierarchy . . . . .	11
4.1.1	Component names and numbers . . . . .	11
4.1.2	Component path names . . . . .	11
4.2	Navigation Panel Selection . . . . .	12
4.2.1	Large numbers of nameless components . . . . .	12
4.3	Viewer Selection . . . . .	12
4.3.1	Box selection . . . . .	14
4.3.2	Selection filtering . . . . .	14
4.4	Selection Display and Parent Selection . . . . .	14
4.5	Highlighting Selected Components . . . . .	14

<b>5</b>	<b>Geometric Manipulation</b>	<b>14</b>
5.1	Dragger Fixtures	15
5.2	Manipulation Tools	15
5.2.1	Constrained manipulation	16
5.2.2	Changing manipulator position and orientation	16
5.3	Pull Manipulation	16
<b>6</b>	<b>Editing Properties</b>	<b>16</b>
6.1	Property Panels	17
6.1.1	Inheritable properties	18
6.2	Render Properties	18
6.2.1	Render property settings	18
<b>7</b>	<b>The Timeline</b>	<b>19</b>
7.1	Basic Structure	19
7.1.1	Play controls	20
7.1.2	Tracks	20
7.2	Waypoints and Breakpoints	21
7.2.1	Waypoints	21
7.2.2	Breakpoints	21
7.3	Tracks and Probes	21
7.3.1	Creating, moving, and deleting tracks	22
7.3.2	Muting tracks	22
7.3.3	Expanding tracks	22
7.3.4	Grouping tracks	22
7.4	Numeric Probe Displays	22
7.4.1	Setting the range	23
7.4.2	Visibility control	23
7.4.3	Editing data	23
7.4.4	Interpolation control	24
7.4.5	Large displays	24
<b>8</b>	<b>Visual Display</b>	<b>25</b>
8.1	Point Tracing	25
8.1.1	Rendering only the trace(s)	25
<b>9</b>	<b>Probes</b>	<b>25</b>
9.1	Saving and Loading Probes and Their Data	26
9.1.1	Saving probes	26
9.1.2	Saving probes in a different directory	26
9.1.3	Loading probes	26
9.1.4	Loading probes from a different directory	26

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<b>10 Adding and Editing Numeric Probes</b>	<b>26</b>
10.1 Adding Output Probes . . . . .	26
10.1.1 Creating a simple probe . . . . .	27
10.1.2 General output probes . . . . .	27
10.1.3 Using the probe editor . . . . .	28
10.2 Adding Input Probes . . . . .	28
10.2.1 Creating a simple probe . . . . .	29
10.2.2 General input probes . . . . .	29
10.2.3 Using the probe editor . . . . .	30
10.3 Setting Probe Properties . . . . .	30
<b>11 Making Movies</b>	<b>31</b>
11.1 Region To Capture Options . . . . .	31
11.2 Record Options . . . . .	31
11.3 Output Options . . . . .	32
11.4 Output Size Options . . . . .	33
<b>12 Control Panels</b>	<b>34</b>
12.1 Creating Control Panels . . . . .	34
12.1.1 Composite property widgets . . . . .	35
12.1.2 Widgets for sub-properties . . . . .	35
12.2 Editing Control Panels . . . . .	36
12.3 Live Updating . . . . .	36
<b>13 Component Editing</b>	<b>37</b>
13.1 Generic Edit Operations . . . . .	37
13.1.1 Deletion . . . . .	37
13.1.2 Duplication . . . . .	37
13.1.3 Undo . . . . .	37
13.2 Editing Panels . . . . .	37
13.3 Specifying Position, Orientation, and Scaling . . . . .	38
13.4 Editing MechModels . . . . .	38
13.4.1 Adding finite element models . . . . .	39
13.4.2 Adding rigid bodies . . . . .	39
13.4.3 Adding frame markers . . . . .	40
13.4.4 Adding particles . . . . .	42
13.4.5 Adding axial springs and muscles . . . . .	43
13.4.6 Adding rigid body connectors . . . . .	44
13.4.7 Attaching particles to particles . . . . .	45
13.4.8 Attaching particles to rigid bodies . . . . .	46

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13.4.9	Collision handling . . . . .	46
13.5	Editing Rigid Bodies . . . . .	48
13.5.1	Geometry and inertia . . . . .	48
13.6	Editing FEM Models . . . . .	49
13.6.1	Adding FEM markers . . . . .	50
13.6.2	Adding muscle bundles . . . . .	51
13.7	Editing Muscle Bundles . . . . .	51
13.7.1	Adding fibres . . . . .	51
13.7.2	Adding element references . . . . .	51
13.7.3	Automatically Setting Elements and Directions . . . . .	53
13.7.4	Removing fibres and element references . . . . .	54
13.8	Editing Muscle Exciters . . . . .	54
13.9	Editing Root Models . . . . .	54
<b>14</b>	<b>Customizing the Models Menu</b>	<b>55</b>
14.1	Plaintext Format . . . . .	55
14.2	XML Format . . . . .	55
14.2.1	The root element . . . . .	56
14.2.2	Models . . . . .	56
14.2.3	Separators . . . . .	56
14.2.4	Labels . . . . .	57
14.2.5	Sub-menus . . . . .	57
14.2.6	Packages . . . . .	57
14.2.7	Plaintext files . . . . .	59
14.2.8	Importing other XML files . . . . .	59
14.2.9	Hiding Elements . . . . .	59

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## 1 Introduction

This manual describes the ArtiSynth user interface, and how it can be used to edit models and interactively monitor and control their simulation.

## 2 Loading and Simulating Models

The first thing an ArtiSynth user is likely to want is to load a demonstration model, and explore and simulate it.

A number of predefined demonstration models come bundled with the ArtiSynth distribution. These are generally simple models that illustrate particular simulation capabilities. More complex anatomical models, including those used in various research projects, are available in the separate project `artisynth_models`, which must be downloaded separately from ArtiSynth (see [www.artisynth.org/models](http://www.artisynth.org/models) for instructions).

An ArtiSynth model is defined by a subclass of the ArtiSynth `RootModel` component, which build the model, serves as the root container for all its components, and implements the `advance()` method which allows the model to be simulated.

There are several ways to load models.

### 2.1 Loading from the Models menu

Some models can be loaded directly using the Models menu located in the ArtiSynth menu bar. By default, this expands to a number of submenus:

Demos	all models listed in the <code>.demoModels</code> file
All Demos	every model found under the package <code>artisynth.demos</code> , arranged hierarchically
Models	all models listed in the <code>.mainModels</code> file
All Models	every model found under the packages <code>artisynth.models</code> , arranged hierarchically

The files `.demoModels` and `.mainModels` are searched for in the list of directories specified by the `ARTISYNTH_PATH` environment variable (which if not present defaults to the current directory, the user's home directory, and the ArtiSynth install directory).

Note: the submenus Models and All Models will not appear if the contents associated with them are empty, which may occur if no ArtiSynth model packages have been installed.

Each submenu expands out to identify a set of models. Selecting one of the models will cause it to be loaded into ArtiSynth and displayed in the viewer. Hovering over one of the entries will display the full classname of the associated `RootModel`.

It is possible to customize the contents of the Models menu; see Section 14.

### 2.2 Loading by class path

As mentioned above, models are defined by subclasses of `RootModel`. A model may therefore be loaded into ArtiSynth by specifying the classname of its `RootModel`. To do this, go to the File menu and choose Load from class ..., which will bring up a dialog that permits you to enter the classname. The dialog supports expansion using the <TAB> key.

### 2.3 Loading from a file

Finally, it is possible to load a model from a file. Selecting Load model ... from the File menu will bring up a File browser that lets you select and load a model from an ArtiSynth model file. ArtiSynth model files are ascii-based documents that contain a hierarchical description of all the model's component, and should be identified by the extension `.art`.



Figure 1: The ArtiSynth play controls. From left to right: step size control, current simulation time, and the reset, play/pause, and single-step buttons.



Figure 2: The viewer toolbar.

Note: saving and loading models from files is not highly supported at this time, due to the still rapidly evolving character of ArtiSynth and that fact that at present most models are built by Java code contained in the model's `RootModel`.

## 2.4 Simulating a model

Once a model is loaded, simulation of the model can be started, paused, single-stepped, or reset using the play controls (Figure 1) located at the upper right of the ArtiSynth window frame.

An extended set of play controls is available in the ArtiSynth timeline (Section 7.1.1).

## 3 The Viewer

The viewer provides interactive graphical rendering of the ArtiSynth model and permits selection of its components. A viewer is integrated into the ArtiSynth main frame; additional viewers can be created if necessary.

### 3.1 Viewer Toolbar

Each viewer is provided with a toolbar (Figure 2) equipped with icons for controlling the viewpoint (Section 3.2) and clipping planes (Section 3.6). The toolbar for the main viewer appears vertically at the lower left of the main frame, while toolbars for additional viewers appear horizontally at the top. Each is an instance of Java's `JToolBar`, and so can be moved and docked accordingly.

### 3.2 Viewpoint Control

The view point can be controlled interactively by dragging the middle mouse button:

#### MIDDLE mouse

Rotates the view point about the center of the frustum.

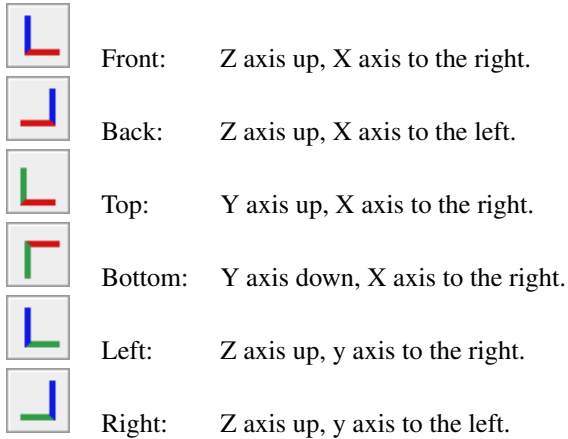
#### SHIFT MIDDLE mouse

Translates the view point in a plane perpendicular to the line of sight.

#### CTRL MIDDLE mouse or mouse WHEEL

Zooms in or out by moving the viewpoint along the line of sight. Rotate wheel forward or drag mouse forward with CTRL and middle mouse button pressed to zoom in. Rotate or drag backwards to zoom out.

Predetermined viewpoints can also be selected using the *align axis* button located on the viewer control bar. Clicking on this button produces an icon menu showing six different axis-aligned views. Each view is indicated by the two axes perpendicular to the line of sight, with the X, Y, and Z axes illustrated by red, green, and blue lines respectively:



The align axis button itself displays the most recently selected axis-aligned view.

### 3.3 Adding Additional Viewers

Additional viewers can be created by selecting View > New viewer from the main menu. Each viewer provides independent viewing and selection control for the current model.

We are considering adding an option whereby the main viewer can be split into four independent viewing panels, providing orthogonal projections of the front, side, and top, along with a general perspective projection. This arrangement is common in CAD and geometric modeling applications.

### 3.4 Orthographic vs. Perspective Projection

The user can toggle between orthographic and perspective projection by selecting View > Orthographic view or View > Perspective view from the main menu. Toggling can also be achieved using the 'o' key within the viewer.

### 3.5 Viewer Grid

Hitting the 'g' key within the viewer enables or disables a grid (Figure 3). Grid cells are square and appear in two resolutions, with *major cells* subdivided into a number of *minor cells*. Major cells are typically rendered more brightly than minor cells. By default, the grid computes the cell sizes automatically based on the current viewer zoom-level. However, it is possible to set an explicit grid resolution (see 3.5.1).

The grid is located in the plane perpendicular to the line of sight of the most recently selected axis-aligned view. To change the grid plane, select a new axis aligned viewpoint (Section 3.2).

#### 3.5.1 Grid units and properties

When the grid is enabled, a box labeled Grid: appears in the toolbar on top of the main ArtiSynth frame which gives the current resolution of the grid, displayed as  $S/N$ , where  $S$  is the size of each major grid cell and  $N$  is the number of subdivisions per cell. If there are no subdivisions, then the  $/N$  is omitted. For example, in Figure 3, this appears as Grid: 1/10, which means that the major grid cells have a size of 1.0 and are each divided into 10 subdivisions. The numeric value of the ratio  $S/N$  gives the minor cell size.

By default, the grid automatically resizes itself to the current viewer zoom level, choosing well-rounded numbers for the grid cell size. Auto-sizing can be enabled or disabled by right clicking on the Grid: label and choosing Turn auto-sizing on or Turn



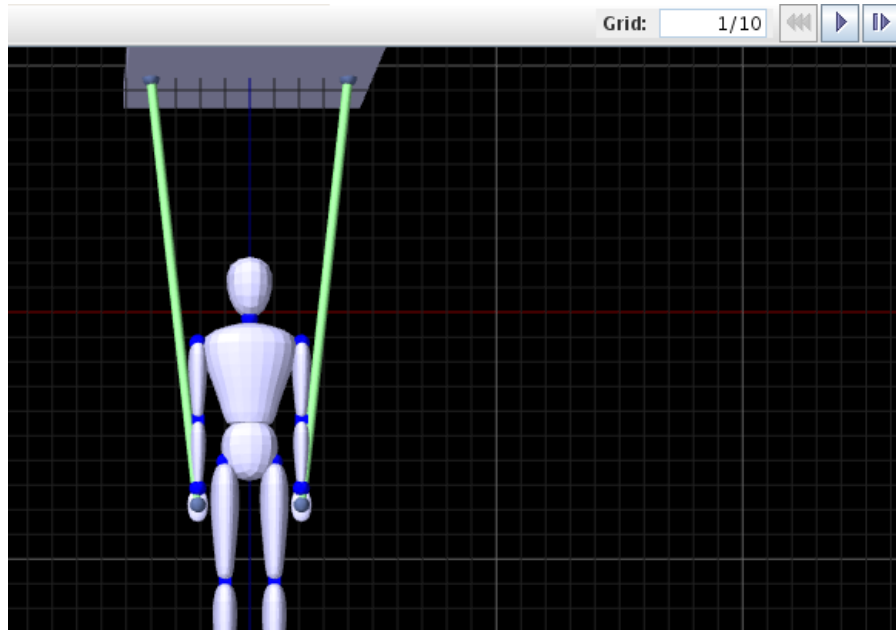


Figure 3: Viewer showing the grid.

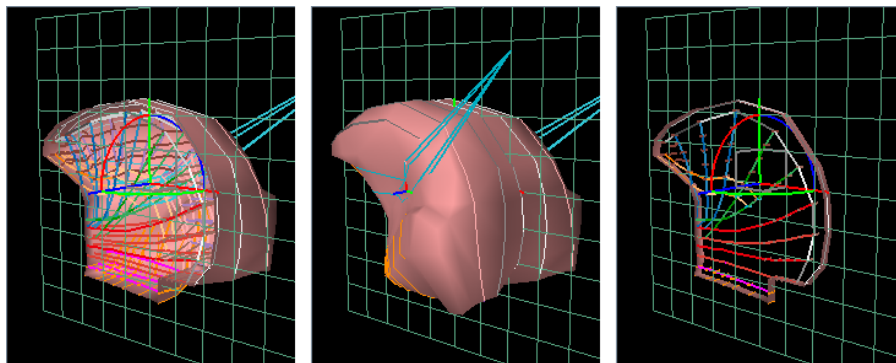


Figure 4: Clipping plane showing interior of tongue model (left), disabled (center), and in slice mode (right).


auto-sizing off, as appropriate. The user can also specify an explicit value for the grid resolution by entering the desired  $S/N$  value (or just an  $S$  value) into the `Grid:` box. Specifying an explicit value will disable auto-sizing, unless  $S$  is specified as 0 or the special value  $*$  is entered, both of which will renable auto-sizing.

The grid has a number of properties that can be set by right clicking on the `Grid:` label and choosing `Set properties`. This will bring up a property dialog. Properties that can be set include the minimum size, the minimum minor cell size in pixels (when auto-sizing), colors for the major and minor cell divisions, and colors for the horizontal ( $x$ ) and vertical ( $y$ ) axes. Some of these colors are optional and can be set to `null`, in which case a default color is computed or the associated feature is not displayed.

### 3.6 Clipping Planes

The user can add clipping planes to the viewer. These are useful for restricting what is rendered and allowing a better view of interior structures, as shown in (Figure 4).

### 3.6.1 Adding and removing

To add a clipping plane, left click on the add clip plane button  located on the viewer toolbar. This will create a clipping plane located in the plane perpendicular to the current line of sight.

It will also add to the viewer toolbar a clip plane icon  for controlling the clipping plane. Right clicking on this icon will bring up an option menu.

To delete a clipping plane, right click on its icon and select Delete.

### 3.6.2 Moving


A clip plane is associated with a coordinate system and can be moved and/or rotated by dragging on the trans-rotate transformer located at its coordinate system origin. The clip region is the half space lying in the direction of the +z axis.

The transformer itself can be made invisible/visible by right clicking on the clip plane icon and selecting Hide transformer or Show transformer.

### 3.6.3 Offsets

The clipping region is the half space lying in the direction of the +z axis of the plane's local coordinate system. By default, clipping is actually offset by a small distance along the +z axis, so that small objects (such as points) lying in the x-y plane remain visible. The amount of this offset is controlled by the plane's offset property, which is set to a nominal default value. To control this property directly, right click on the clip plane icon and select Set properties. This will bring up a panel which allows the offset to be adjusted.

### 3.6.4 Enabling/disabling

Left clicking on the clip plane icon will enable/disable clipping. Disabling clipping allows the plane to be used as a regular movable grid. When clipping is disabled, the icon will change to the form .

### 3.6.5 Slicing mode

Clipping planes can be placed in a *slicing mode*, whereby half-spaces in both the positive and negative z directions are clipped. The result is a small slice about the local x-y plane (Figure 4, right). The width of this slice is controlled by the plane's offset property, as described above.

To enable or disable slicing, right click on the clip plane icon and select Enable slicing or Disable slicing.

### 3.6.6 Other features

#### Properties

Various properties associated with the plane, such as its color, line width, cell resolution, etc., can be set explicitly by the user. To do this, right click on the icon, select Set properties, and edit the resulting property panel. Most properties are the same as those described for the main viewer grid in 3.5.1.

#### Grid visibility

To make the grid invisible/visible, right click on the icon and select Hide grid or Show grid.

#### Alignment with world axes

The clip plane can be aligned so that its normal lies along the positive or negative direction of either the x, y, or z world axes. Right click on the icon and select the appropriate option. Clipping is performed so that the half-space lying in the direction of the normal is clipped.

### Alignment with current line of sight

To align the clipping plane so that it is perpendicular to the current line of sight, right click on the icon and select Reset.

## 3.7 Indicating 3D Positions with the Mouse

It is possible to use a viewer in combination with a mouse to specify the position of a 3D point in space. This is commonly employed in the editing operations described in Section 13.

To specify a point, the user left-clicks the mouse in the viewer, at the screen position located over the point's desired position. The 3D position is then determined by intersecting the ray indicated by the mouse click with some appropriate surface or plane. Typically, a plane perpendicular to the viewing direction and passing through the model's center is used. Alternatively, some interactions provide a constrain to plane option, which causes the ray to be intersected with a viewer clipping plane (Section 3.6), providing more precise control over the point's position. This requires that the viewer presently contain at least one clipping plane. If more than one clipping plane is present, the first one is used.

In other applications, the desired point may be known to lie on a 3D surface, in which case the position is determined by intersecting the ray with a 3D surface mesh.

## 4 Component Navigation and Selection

An ArtiSynth model is composed of a hierarchical arrangement of model components (each of which implements the interface `ModelComponent`), some of which may themselves be models. The graphical interface allows users to navigate this hierarchy and select individual components. Selected components can then be edited, or have specific properties modified or attached to probes or control panels.

### 4.1 The Component Hierarchy

An example component hierarchy is shown in Figure 5. At the top is a *root model* (class `RootModel`), in this case named `Rigid Body Spring`. The root model in turn contains a list of models, one of which is a mechanical model named `msmod`, which here contains particles and rigid bodies.

It is important to note that in the component hierarchy, any collection of components is itself a component (usually an instance of `ComponentList`). This provides automatic “grouping” of components of like type, but does introduce additional levels into the hierarchy. Hence the particle `red` is a child not of `msmod`, but rather the component list `particles`.

#### 4.1.1 Component names and numbers

Model components may be assigned a string name; at the time of this writing names may not begin with a digit, have zero length, contain the characters `'.'` or `'/'`, or equal the reserved word `this`. Components which do not have an assigned name are called *nameless*.

All components have a *number*, even if they do not have a name. The number is assigned automatically when the component is added to the parent, and is guaranteed to be persistent until the component is removed from the parent.

#### 4.1.2 Component path names

The names and/or numbers of a component's ancestors can be used to form a *component path name*. This path has a construction completely analogous to Unix file path names, with the `'/'` character acting as a separator. Absolute paths start with `'/'` and begin with the root model. Relative paths omit the leading `'/'` and can begin lower down in the hierarchy. The absolute path name of the `red` particle in Figure 5 would be

```
/Rigid Body Spring/models/msmod/particles/red
```

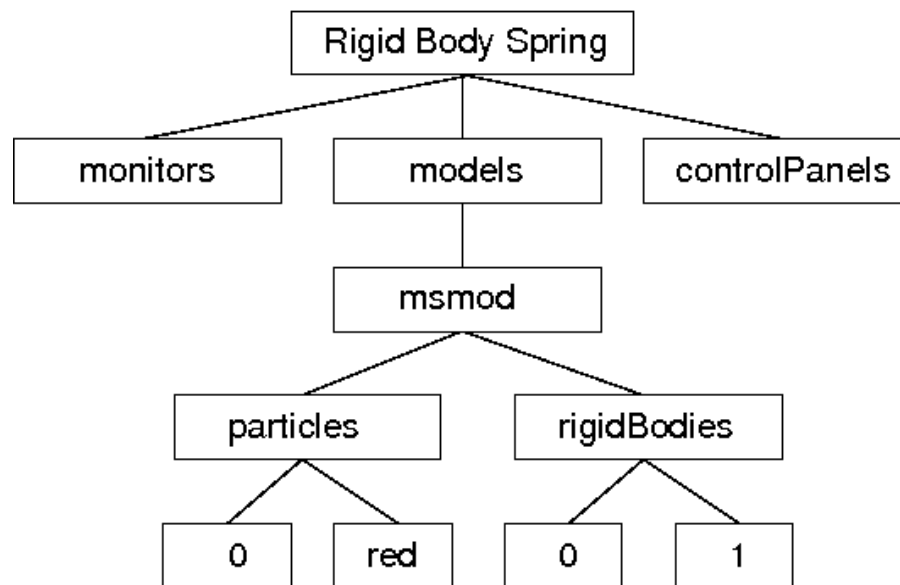


Figure 5: A sample component hierarchy.

For nameless components in the path, their numbers can be used instead:

```
/Rigid Body Spring/models/msmod/rigidBodies/1
```

Numbers can be used even for components that have names. Hence a path name consisting only of numbers, as in

```
/0/0/0/3/1
```

is legal, although it most likely to appear only in machine-generated output.

## 4.2 Navigation Panel Selection


A navigation panel in the main ArtiSynth frame allows direct navigation of the component hierarchy. The panel can be open or closed by clicking on the menu bar icon .

Figure 6 shows an navigation panel containing a superset of the hierarchy diagrammed in Figure 5.

Left clicking on any component in navigation panel selects that component. Clicking while pressing the **CTRL** key allows selection of multiple components. Clicking while pressing the **SHIFT** key allows selection of a range of components.

### 4.2.1 Large numbers of nameless components

In some cases, such as finite element models, the number of child components can be very large (on the order of thousands). In order to keep the navigation panel size manageable, the number of nameless children displayed is limited to a set number (currently 100). If the number of nameless children exceeds this number, the display will be augmented with an expand icon »>. Clicking on this will expand the display to include all nameless components, and the expand icon will be replaced by a contract icon <<. Clicking on the contract icon will cause the extra nameless components to be hidden again. This is illustrated in Figure 7.

## 4.3 Viewer Selection

Components that are rendered in the viewer can generally be selected by left clicking on them (the exception would be for a few renderable components that do not support selection). Holding the **CTRL** key allows the selection of multiple components.

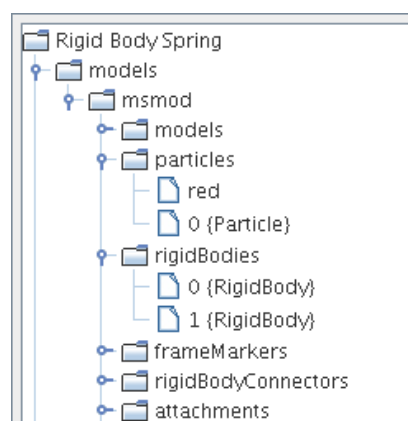


Figure 6: An typical navigation panel display.



Figure 7: Expansion of nameless components in the navigation panel.



Figure 8: The selection filter widget.



Figure 9: The selection display widget.

#### 4.3.1 Box selection

Left-clicking and dragging in the viewer allows the selection of all components drawn within the resulting drag box. Because this often results in the selection of more components than desired, it may be useful to employ a selection filter (Section 4.3.2).

#### 4.3.2 Selection filtering

It is possible to limit viewer selection to components of a specific type. This can be done using the selection filter widget at the bottom left of the main ArtiSynth frame Figure 8.

To enable filtering, type into the widget text box the class name of the component type you wish to restrict filtering to. It is generally only necessary to enter the leaf name of the class (e.g., `Particle` or `AxialSpring`), and the system will then find the full class name by searching the ArtiSynth class path.

Once filtering is enabled, only components which are instances (including subclasses) of the specified type will be selectable. Previously selected filters can be recalled using a history list accessible using the leftmost arrow button on the selection widget. To remove selection filtering, enter the special filter `*`, either by typing this in the text box, or using the history list.

### 4.4 Selection Display and Parent Selection

The selection display Figure 9 at the bottom of the main ArtiSynth frame shows the full path name of the last component added to the selection list. This is useful for identifying components in detail.

If no components are selected, then the selection display is blank.

The selection display also allows the selection of a component's parent, by clicking on the leftmost "up" arrow. This is useful in the commonly occurring situation where a composite component is not rendered and therefore not selectable in the viewer. For instance, suppose we wish to select an FEM model. One can select any renderable descendent of the model, such as a node or element, and then use the selection display to select successive parents until the model itself is selected.

### 4.5 Highlighting Selected Components

Selected components are rendered in the viewer using a special selection color (yellow at the time of this writing). It is important to note that descendents of a selected component are **not** presently rendered in any special way. For instance, if an FEM is selected, it's nodes and elements will be rendered normally.

While this has the potential to be confusing, we have not yet found this to be problematic, as the navigation panel and selection display provide alternative indicators as to what is currently selected.

## 5 Geometric Manipulation

It is possible to modify component locations, orientations, and geometry using the transformation tools located at the left side of the main ArtiSynth frame. Tools will only transform those *transformable* components which implement the [Transformable-Geometry](#) interface. The behavior may also vary depending on whether or not simulation is in progress.

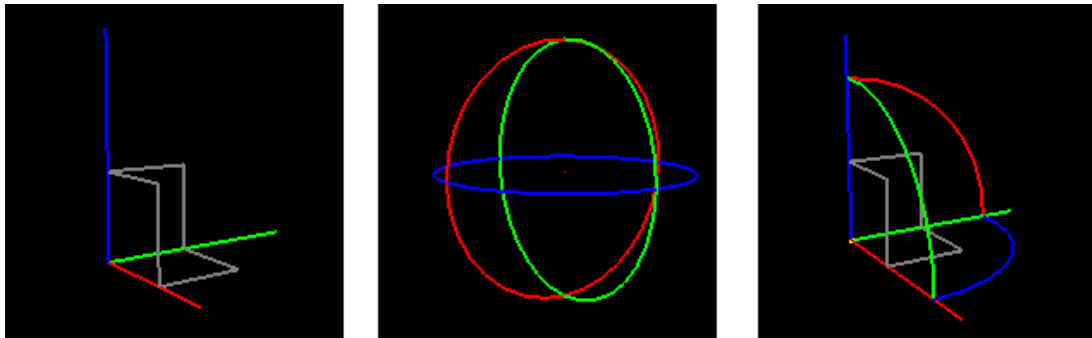


Figure 10: Dragger fixtures: translator, rotator, and transrotator.

## 5.1 Dragger Fixtures

The transformation tools employ the dragger fixtures shown in Figure 10, which allow 3D geometrical transformations to be performed within the viewer.

### Translator

Effects a translation. The x, y, and z axes are indicated by red, green, and blue lines. Dragging any line causes a one-dimensional motion along the associated axis. Dragging one of the boxes causes a two-dimensional motion in the associated plane.

### Rotator

Effects a rotation. Rotation about the x, y, and z axes is indicated by red, green, and blue circles. Selecting and dragging along one of these circles produces a rotation about the corresponding axis.

### TransRotator

Combines the translator and rotator into a single tool. One difference is that the axes of the transRotator move with any rotation, and so operations are done with respect to the transRotator coordinate frame at the beginning of the drag.

## 5.2 Manipulation Tools

A number of manipulation tools use the dragger fixtures described above to translate, rotate, and scale components. Once a tool is activated, then selecting one or more transformable components will cause the corresponding dragger fixture to appear in the viewer at the components' location. If a single component is selected and that component is associated with a coordinate frame (by implementing the [HasCoordinateFrame](#) interface), then the dragger's initial position and orientation are aligned with this coordinate frame. Otherwise, the dragger is initially placed at the center of the components' bounding box and its orientation is aligned to world coordinates.

To request that a dragger's initial orientation is *always* aligned with world coordinates, choose Init draggers in world coordinates in the ArtiSynth Settings menu. To restore the default behaviour, choose Init draggers in local coordinates.



Selection:

Normal selection mode. Turns off manipulation.



Translation:

Translates selected components using the translator dragger.



Rotation:

Rotates selected components using the rotator dragger.

**TransRotation:**

Translates and rotates selected components using the transRotate dragger. The transformation reference frame moves with the tool.

**Constrained translation:**

Translates selected components using the translate dragger while ensuring that they are constrained to remain on a surface mesh. Only components with an associated surface mesh (such as FrameMarkers attached to a RigidBody) can be manipulated this way.

**Scaling:**

Scales selected components using the transrotator fixture. Instead of translating, translational drag operations scale the component along the x, y, or z axes, or in the x-y, y-z, or z-x planes. Rotational operations, if used in conjunction with an appropriate modifier key, can be used to change the orientation of the scaling axes, as described in [5.2.2](#).

**Pulling:**

Pulls on points and rigid bodies using a spring-like force when simulation is running. See [Section 5.3](#).

### 5.2.1 Constrained manipulation

Pressing the `SHIFT` modifier key causes drag operations to be constrained to discrete step sizes. Rotation operations are constrained to intervals of five degrees, while translation operations are constrained to either the grid spacing (if a grid is selected, see [3.5](#)), or to a suitable well-rounded number depending on the viewer's zoom level.

### 5.2.2 Changing manipulator position and orientation

Pressing the `CTRL` modifier key (or the `ALT` key on some systems) causes the dragger fixture to move independently of the selected objects. This allows its position and orientation relative to the selected objects to be changed. This is particularly useful for changing the orientation of the scaling directions in the scaling tool.

## 5.3 Pull Manipulation

A "pull" manipulator allows a user to interactively apply a spring-like force to either a point or rigid body by clicking on it and then dragging ([Figure 11](#)). To enable pull manipulation, select the *pulling* tool ([Section 5.2](#)).

Pull manipulation is only effective when simulation is running. It works by adding a special `PullController` to the current root model. When attached to the root model, the controller attempts to estimate an appropriate spring stiffness based on the overall mass and dimensions of the first underlying `MechModel`.

If necessary, the stiffness setting can also be adjusted manually by selecting `PullController > properties` in the `Settings` menu. Render properties for the pull controller can be set from this menu also.

## 6 Editing Properties

Most ArtiSynth model components have properties which can be changed onscreen through the graphical interface. Properties include a diverse set of attributes ranging from stiffness and damping for `AxialSprings`, position and velocity for particles and rigid bodies, or whether or not a component is dynamic.

The underlying software architecture of the property interface is described in the [maspack documentation](#).



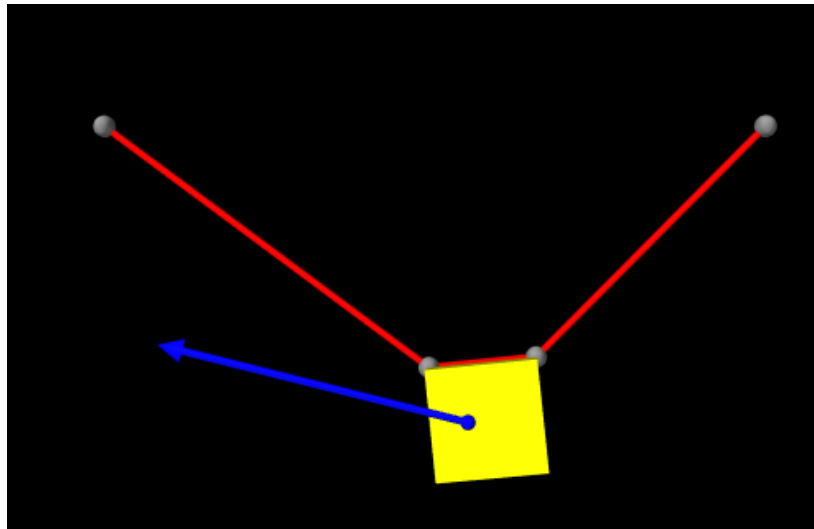


Figure 11: Applying pull manipulation (blue arrow) to a rigid body attached to a multi-point spring.

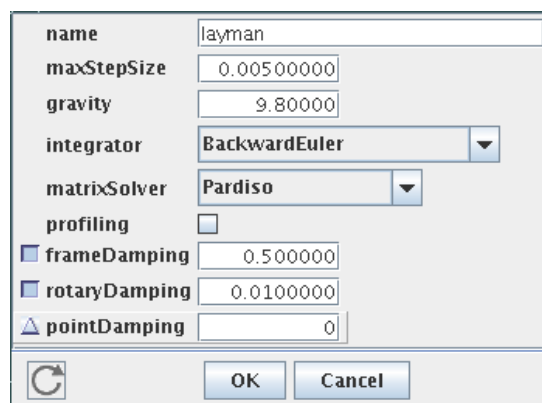


Figure 12: A typical property panel.


## 6.1 Property Panels

To edit properties for a set of components, select the components in question, then right click in either the viewer or the navigation panel, and select Edit properties. This will create a *property panel* for all properties which are common to the selected components. All typical property panel is shown in Figure 12.

Property panels are initialized with the current values of the selected components, providing a view of the current property state. A blank property value will be displayed when more than one component is selected and the corresponding property value differs across components.

Some properties are *read only*. In this case, the corresponding widget in the property panel will display the value but will be disabled.

Property panels are non-modal and persistent. They can be deleted by closing them or clicking the OK button. Clicking the Cancel button will cause the properties to be reset to their values at the time to panel was created.

Normally, a property panel will refresh its widget values whenever the model view is rerendered. In particular, this will happen repeatedly while simulation is running. To disable the automatic refresh, click the live updating button  at the lower left of the panel.

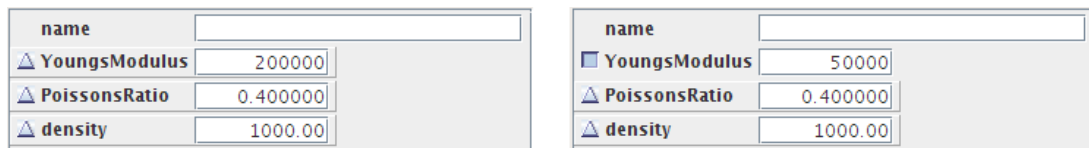


Figure 13: Property panel showing YoungsModulus as inherited (left) and explicitly set (right).

### 6.1.1 Inheritable properties

Some properties are inheritable. The value of an inheritable property can be *explicitly* set or it can be inherited. If inherited, then it inherits its value from ancestor components further up the hierarchy. More specifically, if a property's value is inherited, then the value is obtained from the nearest ancestor in which the same property exists and is explicitly set. If no such ancestor exists, then the property is set to a default value.

The inherited/explicit status of an inheritable property is controlled by an additional button placed at the left of the property widget (Figure 13). Clicking this button toggles the inherited/explicit status. If set to inherited, then the property's value is determined from the hierarchy and the updated value is placed in the widget. Setting the value in the widget itself will cause the inheritable status to be set to explicit, and the value of inherited instances of the same property in descendent nodes will be updated accordingly.

## 6.2 Render Properties

Render properties are associated with any component that is renderable. They are defined in the class `RenderProps`. Because of their complexity, they are adjusted through a separate panel from the standard property panel.

To adjust the property panel for a set of components, select the components in question, using either the viewer window or navigation panel, and then right click in either the viewer or the navigation panel. Several options may appear in the context menu:

### Edit render props

This will create a special property panel allowing the render properties for the selected components to be set (see Section 6.2.1).

### Clear render props

This will actually remove the render properties from the selected components (i.e., their render properties will be set to `null`). Nominally, this means that the components will not be rendered, *unless* their parents take responsibility for rendering children without render properties. The latter behaviour is common for lists of particles, springs, finite elements, etc., in order to avoid the need for defining render properties in a large number of objects.

### Set visible

This option will appear if any of the selected objects are invisible. Selecting it will set the render properties so that all components are visible.

### Set invisible

This option will appear if any of the selected objects are visible. Selecting it will set the render properties so that all components are invisible.

### 6.2.1 Render property settings

There are a large number of render property settings. Loosely speaking, they are divided into generic settings, along with those related to faces, lines, and points. How these are used depends on what is being rendered. Mesh rendering typically uses the face settings, along with the line settings to render edges if the `drawEdges` property is set `true`. Line settings are also used for rendering axial springs and the edges of FEM elements. Point settings are used for rendering any subclass of `Point`, including `Particle` and `FemNode`.

Not all render properties may appear in a render panel; usually, only those properties relevant to the selected components will be presented.

**Generic properties:**

**visible:** Whether or not the component is visible.

**alpha:** The transparency for polygonal faces (range 0 to 1. Default is 1, for opaque).

**shading:** How polygons are shaded (FLAT, GOURARD, PHONG).

**shininess:** Shininess parameter for polygons (range 0 to 32).

**Face related properties:**

**faceStyle:** Which polygonal faces are drawn (FRONT, BACK, FRONT\_AND\_BACK, NONE).

**faceColor:** Color used for drawing faces.

**backColor:** Color used for drawing backs of faces. If null, `faceColor` is used.

**drawEdges:** If true, face edges of the polygons are drawn explicitly.

**textureProps:** Sets texture mapping properties for the face. If null, no texture mapping is performed.

**Line related properties:**

**lineStyle:** How lines are drawn (CYLINDER, LINE, or ELLIPSOID).

**lineColor:** The color for lines.

**lineSize:** Line size in pixels when LINE style is selected.

**lineRadius:** Cylinder radius when CYLINDER or ELLIPSOID style is selected.

**lineSlices:** Number of slices used to render CYLINDER or ELLIPSOID style lines.

**Point related properties:**

**pointStyle:** How points are drawn (SPHERE or POINT).

**pointColor:** The color for points.

**pointSize:** Point size in pixels when POINT style is selected.

**pointRadius:** Sphere radius used when SPHERE style is selected.

**pointSlices:** Number of slices used to render SPHERE style spheres.

## 7 The Timeline

The *timeline* is a panel that allows the user to graphically arrange temporal sequences of probes and waypoints to control the simulation.

### 7.1 Basic Structure

The basic structure of the timeline is shown in Figure 14.

The *toolbar* at the top contains the following widgets:

**Zoom controls**

Shrinks or expands the timescale.

**Play controls**

Starts, pauses, or resets the simulation.

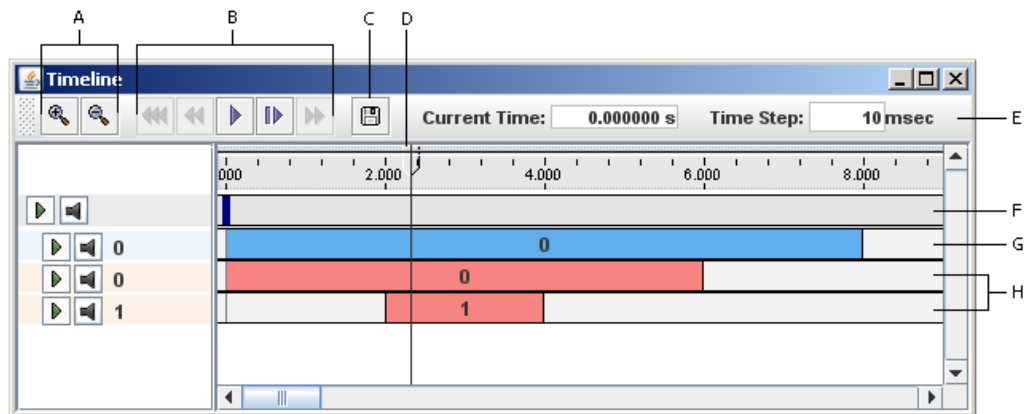


Figure 14: The timeline panel, containing: (A) zoom controls, (B) play controls, (C) save button, (D) time cursor, (E) toolbar, (F) waypoint track, (G) input track, (H) output track.

### Save button

Saves the data for all probes with attached files.

### Time box

Shows the current simulation time.

### Time step box

Shows the length of time associated with a “single step” command.

## 7.1.1 Play controls

The play controls are in turn comprised of the following buttons:

	Reset:	Resets the simulation to the beginning at time 0.
	Rewind:	Moves the simulation time backward to the nearest previous waypoint (see Section 7.2).
	Play:	Starts the simulation.
	Pause:	Takes the place of the play button and pauses the simulation.
	Single step:	Advances the simulation by a single step, specified in the time step box.
	Fast forward:	Moves the simulation time forward to the nearest following waypoint (see Section 7.2).

## 7.1.2 Tracks

The timeline proper is divided into a number of tracks. At the top is the *waypoint track*, which is used to arrange waypoints and breakpoints. Below that are a variable number of *input* and *output* tracks, which are used respectively for arranging *input probes* and *output probes*.

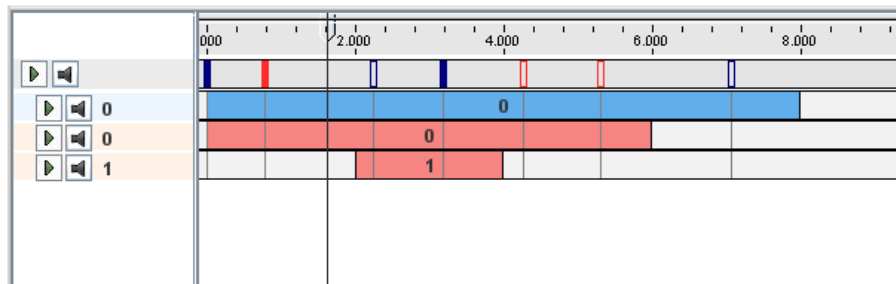


Figure 15: Waypoints (blue) and breakpoints (red) arranged in the waypoint track.

## 7.2 Waypoints and Breakpoints

### 7.2.1 Waypoints

Waypoints save the model state when the simulation passes through them, allowing the timeline to be reset to that point (using the fast forward/backward buttons) at a later time without having to recompute the simulation from the beginning.

Waypoints are arranged along the waypoint track at the top of the timeline and are indicated by a small rectangular blue box (Figure 15). A solid box indicates a waypoint that contains a valid state and thus can be advanced to using the fast forward/backward buttons.

To add a waypoint, context click on the model track. A popup menu will show a number of options, including **Add Waypoint Here**, which adds a waypoint at the current location of the time cursor, and **Add Waypoint(s)**, which will bring up a dialog prompting for a specific time to add a Waypoint. The "Add Waypoint" dialog also contains a repeat field, which will cause additional waypoints to be added with a spacing indicated by the time value, and an option to create breakpoints instead of waypoints.

Once created, waypoints can be moved by dragging them. They can also be deleted by context clicking on them and selecting the **Delete Waypoint** option.

To delete all the waypoints, context click on the model track and select **Delete Waypoints**.

### 7.2.2 Breakpoints

Breakpoints are waypoints that also cause the simulation to stop. They are displayed in red instead of blue.

Breakpoints can be added in the same way as waypoints, i.e., by right clicking on the model track and selecting **Add Breakpoint Here** or **Add Waypoint(s)**.

Waypoints can be converted into breakpoints (and vice versa) through the context menu.

## 7.3 Tracks and Probes

Probes are arranged on tracks located beneath the waypoint track. Input probes must be placed on input tracks and output probes must be placed on output tracks. Furthermore, probes on the same track are not allowed to overlap.

### Note:

In the future, additional restrictions may be placed on what type of probe can be placed on what track.

Probes can be moved horizontally to different times as well as vertically onto different tracks. They can also be stretched by dragging the edges of the probe and cropped by holding the control key while stretching.

On the left side of the timeline is the track panel, which contains a number of track control widgets (Figure 16).

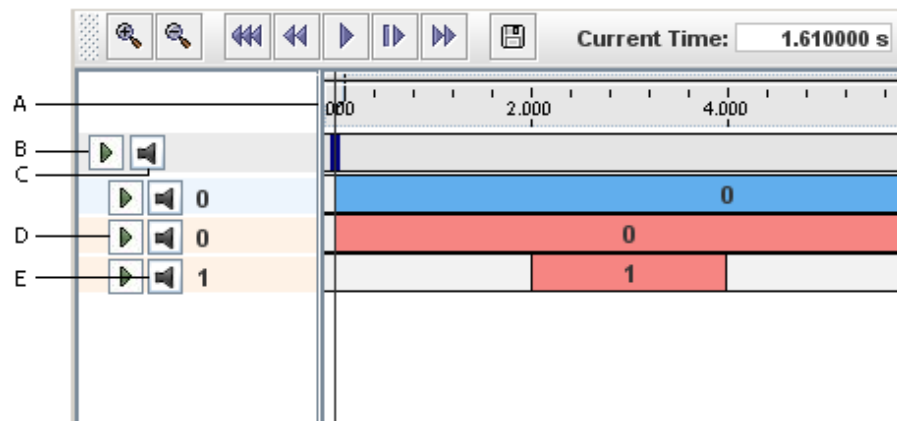


Figure 16: Close up of the track panel, showing: (A) track panel, (B) expand all button, (C) mute all button, (D) expand button, (E) mute button.

### 7.3.1 Creating, moving, and deleting tracks

New tracks may be added by context clicking in the waypoint track and selecting Add Input Track or Add Output Track.

The vertical location of a track can be moved by left clicking on it in the left panel and dragging it up or down to a new location.

A track can be deleted by context clicking on the track in the track panel and selecting Delete Track.

### 7.3.2 Muting tracks

A track can be *muted* or *unmuted* by clicking on its grey mute button in the track panel (Figure 16). All probes on a muted track are ignored during simulation.

All tracks can be muted, thus disabling all probes, by clicking on the mute all button in the grey panel above the tracks.

### 7.3.3 Expanding tracks

A track can be *expanded* or *collapsed* by clicking on its green expand button in the track panel (Figure 16). Expanding a track creates an additional area in which the data associated with the track's probes may be displayed (see Figure 17). The way in which this data is displayed is probe-specific. Probes containing numeric data usually show their data graphically, as described in Section 7.4.

### 7.3.4 Grouping tracks

Multiple contiguous tracks can be selected by clicking on them while holding the control key. Furthermore, they can be *grouped* together or *ungrouped* by selecting the appropriate option from the context menu. Grouped tracks can be collapsed, moved simultaneously and muted together.

## 7.4 Numeric Probe Displays

Data associated with numeric probes is displayed as a graph within the display (Figure 17). If the probe contains a vector with more than one value, each entry in the vector is drawn using a different color (up to a limit, after which colors are recycled).

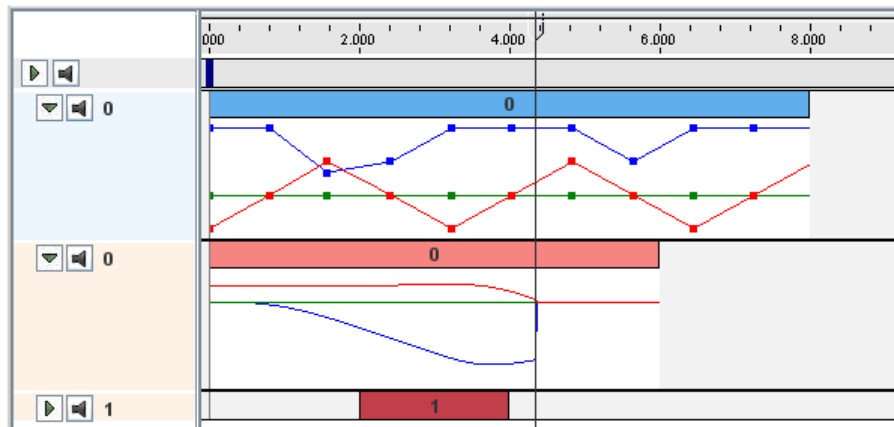


Figure 17: Expanded input and output tracks showing numeric data.

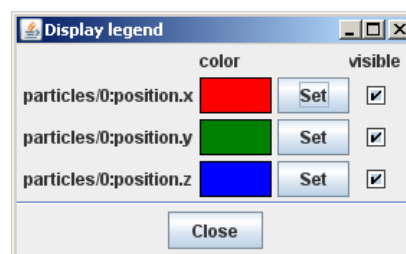


Figure 18: Legend tool for controlling display visibility.

#### 7.4.1 Setting the range

The range of the displayed data can be set by context clicking in the display and selecting **Set Display Range**. This pops up a dialog that lets the user either set the range explicitly, or enable automatic range computation by selecting the **Auto range** box. The range of a display can also be fit to the current data set by context clicking in the display and selecting **Fit Display Range**.

#### 7.4.2 Visibility control

As mentioned above, each entry in a numeric probe's data vector is rendered in a different color (up to a limit). If the vector has a large dimension (say more than three), or if there is much overlapping of values, then the result can be difficult to visualize.

To manage this problem, numeric displays provide a *legend* tool that allows the user to control the color, drawing order, and visibility for each vector entry (Figure 18).

To create the legend tool, context click in the display panel and select **Legend**. Each row in the legend tool is associated with an entry in the data vector. The dimensions of the vectors are listed, followed by the color the entry is drawn in and a toggle controlling its visibility. Entries are rendered in bottom-to-top order, so those at the top will be most visible.

- To change an entry's color, click the **Set** button, which will bring up a color menu.
- To make an entry visible or invisible, use the **Visible** toggle box.
- To change the order in which an entry is drawn, click and drag the entry vertically within the panel.

#### 7.4.3 Editing data

Data for number input probes can be changed by adding, deleting, or moving knot points in the display.

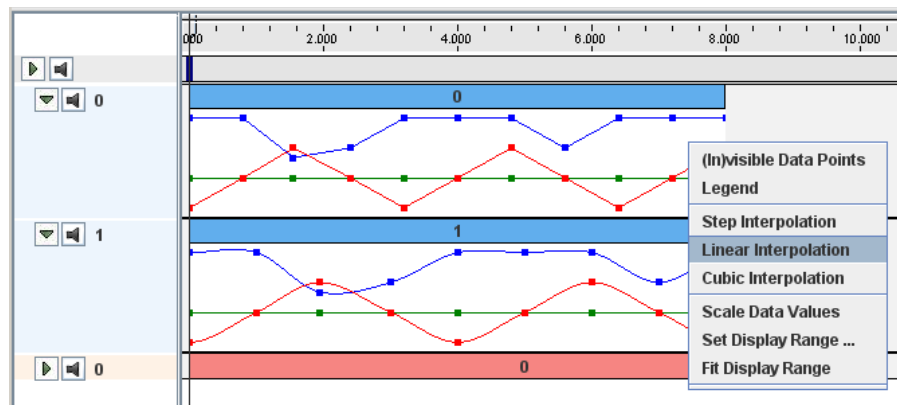


Figure 19: Linear and cubic interpolation.

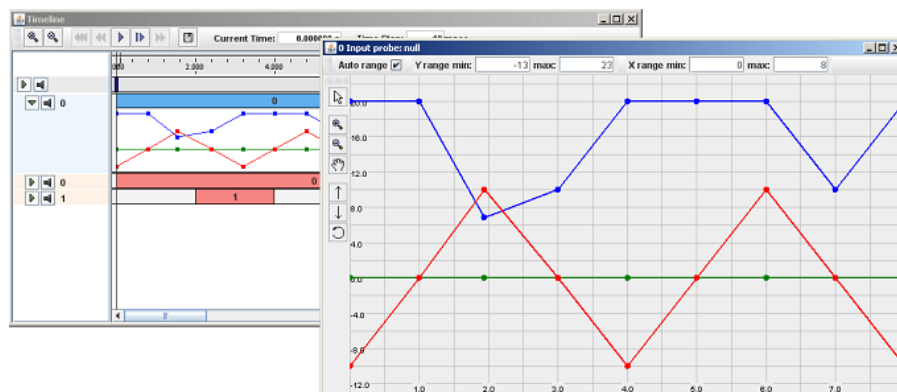


Figure 20: A large display for a numeric probe.

- To move a knot point, left click on the knot and drag it.
- To add a knot point, place the mouse at the desired location and double left-click.
- To delete a knot point, right click on the knot and select Delete Data Point.
- To edit a knot point, right click on the knot and select Edit Data Point.

All knot points can be made invisible/visible by context clicking in the display and selecting (In)visible Data Points.

#### 7.4.4 Interpolation control





The data between knot points in a numeric probe is interpolated. Three types of interpolation are currently available: Step, linear, and cubic (Figure 19). For input probes, the interpolation can be set by right-clicking in the display and selecting the desired one.

#### 7.4.5 Large displays




A large display for a numeric probe can be created by context clicking on the probe icon and selecting Large Display. This will create a large numeric display in a separate panel, allowing more precise inspection of data (Figure 20).

In addition to the functionality of the smaller displays, large displays have additional buttons for controlling the domain and range of the displayed data. These are located on the left side of the display and include four mode control buttons:



	Zoom In:	Enables a mode in which the user can zoom in on the display using a drag box.
	Zoom Out:	Enables a mode in which left clicking in the display will cause it to zoom out.
	Move Display:	Enables a mode in which a (zoomed-in) display can be moved using the middle mouse button.
	Normal:	Clears any mode set by the previous three buttons.

There are also three buttons for controlling the vertical display range:

	Increase Range:	Increases the vertical range.
	Decrease Range:	Decreases the vertical range.
	Fit Range:	Fits the vertical range to the current data.

On the top of the display are the fields for manually setting the displayed range and domain. There is once again the option to enable automatic range computation through the Auto range box.

## 8 Visual Display

### 8.1 Point Tracing

Tracing can be enabled for individual points within an ArtiSynth model. This causes the point to remember the path it followed since tracing was enabled, and to render this within the viewer as strip of line segments.

Tracing is enabled by setting a point's `tracing` property to `true` in the point's property panel (see Section 6.1). When enabled, the point keeps a list of all the positions that it has occupied since since tracing was first enabled, and renders them as a series of line segments in the viewer.

Disabling the tracing property causes the trace data to be discarded and it's rendering to be removed.

When tracing is enabled, the point's render properties are expanded to include line properties. Adjusting these allow the user to control how the trace path is rendered. When tracing is disabled, these line properties are removed.

Since a point's render properties are modified when tracing is enabled or disabled, any existing open rendering property panels for the point will no longer work correctly. Instead, the panel should be closed and reopened.

#### 8.1.1 Rendering only the trace(s)

It may be desirable to restrict rendering to view only the traces paths, perhaps along with a few selected model components. For instance, this might be necessary when producing graphs for a paper.

An easy way to do this is to edit the render properties for the desired points, and set the `visible` property to be explicitly `true`. Then, edit the render properties for the top-level model in the scene, and set its `visible` property to be explicitly `false`. This will make invisible all model components whose `visible` property is inherited. Since the traced points were explicitly set to be visible, they (and their traces) will remain visible. If the points themselves are rendered as spheres, they can be made to disappear by setting their `pointStyle` property to `POINT`, or by setting their `pointRadius` property to something very small.

## 9 Probes

*Work on this section is still in progress*

## 9.1 Saving and Loading Probes and Their Data

The system's current probe configuration, along with the associated probe data, can be saved in the current *probe directory*. Within this directory, the information about probes is stored in a file called `probeData.art`. Actual probe data is stored in the probe's attached file, if one is present. Attached files are named by the `attachedFile` property of the probe, and describe the name of the file relative to the current probe directory.

When ArtiSynth starts up, the current probe directory defaults to the directory `probeData`, relative to the working directory from which the application was started. In future releases, when the ability to save and restore workspaces is implemented, the current probe directory may instead be initialized from saved workspace data.

### 9.1.1 Saving probes

Probes can be saved using the `Save probes` command from the `File` menu. This will save the current probe configuration in the probe directory (creating this directory if necessary). It will also save data for individual probes in their attached files, if such files are present.

A probe will not always have a file associated with it. Numeric probes will always have files associated with them; if a file is not named explicitly, a file name will be generated automatically when the probe is added to the system. This generated file name will be unique with respect to all probes currently configured and all files in the current probe directory.

### 9.1.2 Saving probes in a different directory

To save probes in a different directory, one can use the command `Save probes in` from the `File` menu. This will prompt the user for a different directory, which will be created if necessary. The new directory will persist and the current probe directory.

### 9.1.3 Loading probes

Probes can be loaded from the current probe directory using the `Load probes` command in the `File` menu. The existing probe configuration will be cleared and the new configuration will be obtained from the file `probeData.art`, which must be present in the directory. Probes with attached files will be initialized from the data in those files.

### 9.1.4 Loading probes from a different directory

To load probes from a different directory, one can use the command `Load probes from` in the `File` menu. This will prompt the user for a different directory, which must currently exist and which must contain the file `probeData.art`. The probe configuration will then be reset from the data in this new directory, which will persist as the new current probe directory.

## 10 Adding and Editing Numeric Probes

Numeric input and output probes can be interactively added to a simulation. Output probes allow you to record a vector of values derived from one or more model component properties. Input probes allow you to use a vector of input data to drive one or more model component properties.

### 10.1 Adding Output Probes

To add a numeric output probe, go to the main menu and choose `edit > add output probe`. This will create a numeric output probe editor, as shown in Figure 21.

The editor contains three main panels:

- A *property panel* at the upper left in which allows you to add or edit the properties of model components whose values will be used in computing the final output probe value. Each property is associated with a component/property widget, which allows you to first select a component and then choose one of its properties.

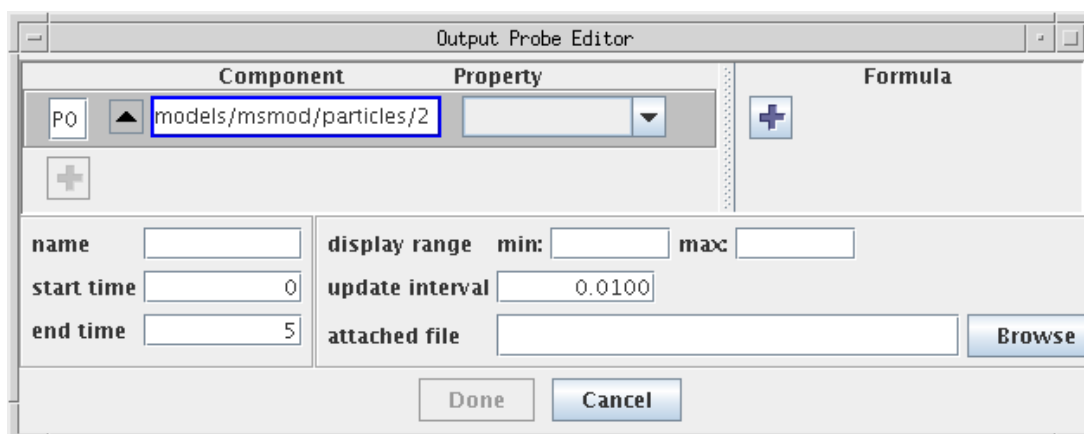


Figure 21: Probe editor for an uninitialized numeric output probe.

- A *formula panel* at the the upper right which allows you to add or edit formulae which convert the values from the properties into numeric values for the output probe.
- A *probe property panel* at the bottom which allows properties of the probe itself to be set.

### 10.1.1 Creating a simple probe

Creating an output probe that simply records the value of a single numeric property is fairly easy. Starting with the output probe editor in Figure 21:

1. Select a component, either externally through the navigation panel (Section 4.2), the viewer (Section 4.3), or the selection display (Section 4.4), or by entering its path name into the component/property widget. Once a component is selected, the left-most “up” arrow can be used to select that component’s parent.
2. Select a property for the component from the property selection box at the right of the component/property widget.
3. Adjust any required properties for the probe itself (Section 10.3).
4. Click Done.

### 10.1.2 General output probes

In general, output probes define a general map from the numeric values of  $n$  model component properties to a generalized output vector formed by the concatenation of  $m$ -subvectors formed by  $m$  formulae, as shown in Figure 22. In the simple case of Section 10.1.1, there is a single property, one sub-vector equal to the output vector, and a formula which is just the property value itself.

Each of the  $n$  properties has a numeric value which is represented by a variable  $p_i$  and which is a vector of some dimension (scalars being considered vectors of dimension 1). The dimension of the  $p_i$  depends on the property and is displayed to the right of the property selection box on the component/property widget.

Each of the  $m$  formulae is an arithmetic expression, implemented in Jython, which may involve one or more of the variables  $p_i$ . The output from each formula is itself a vector of dimension  $d_j$ , which is displayed at the right of each formula panel. The simplest formula is just a single variable  $p_i$ , in which case  $d_j$  equals the dimension of  $p_i$ . The concatenation of all the output vectors from all the formulae produces the output vector associated with the probe, which has a dimension  $\sum_m d_j$ .

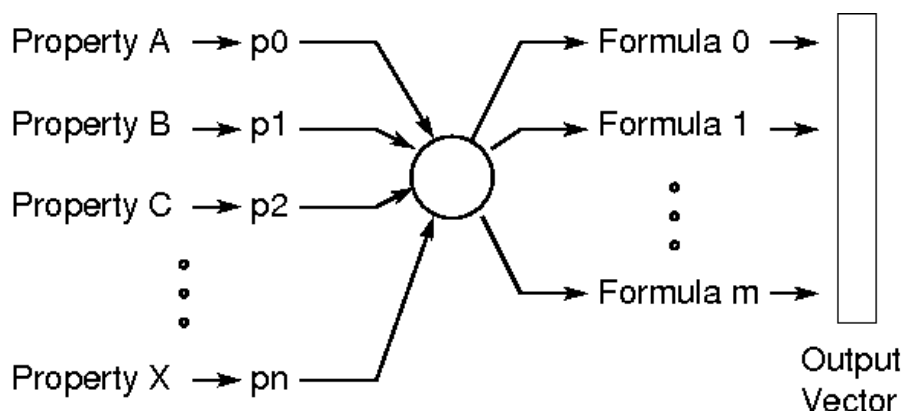


Figure 22: General mapping for an output probe.

### 10.1.3 Using the probe editor

What the probe editor allows you to do is create the above mentioned map by selecting the properties of model components, assigning variable names to them, and creating formulae using these variables. When all the selected components form a coherent mapping, the Done button will be enabled and the probe can be completed. When one or more parts of the mapping is unspecified or incomplete, the associated widgets will be highlighted and the Done button will be disabled.

Extra properties can be added by requesting additional component/property widgets using the "+" button in the property panel. Similarly, extra formulae can be requested using the add button in the formula panel.

Properties and formulas can also be deleted; simply right click on the associated widget and choose delete.

Property variable names appear in a box at the left of the component/property widget. Variable names can be changed by editing this box. Name changes will be propagated into the formulae.

In order to streamline the probe creation process, the editor will try to guess certain desired actions. In particular, when the user chooses a property with a given component/property widget for the first time, the editor assigns a variable name to that property and creates a formula panel containing that variable. The variable name and formula panel can be changed if necessary.

#### Note:

The selection manager is connected to at most one component/property widget at a time. The component field for this widget is indicated with a blue border; external selections will affect only that widget. Left clicking on a component/property widget will cause it to be connected to the selection manager.

## 10.2 Adding Input Probes

To add a numeric input probe, go to the main menu and choose edit > add input probe. This will create a numeric input probe editor, as shown in Figure 23.

The editor contains three main panels:

- An *input panel* at the upper left which allows you to add or edit input variables. Each of these variables represents a sub-vector of the probe's numeric input vector.
- A *formula/property panel* at the upper right which allows you to add or edit numeric properties (using component/property widgets), along with formulae to determine values for these properties based on the input variables.
- A *probe property panel* at the bottom which allows properties of the probe itself to be set.

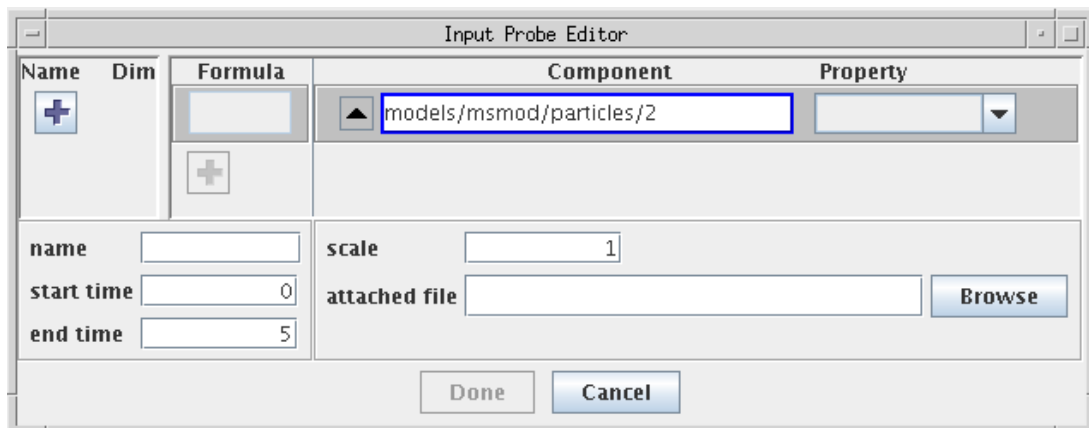


Figure 23: Probe editor for an uninitialized numeric input probe.

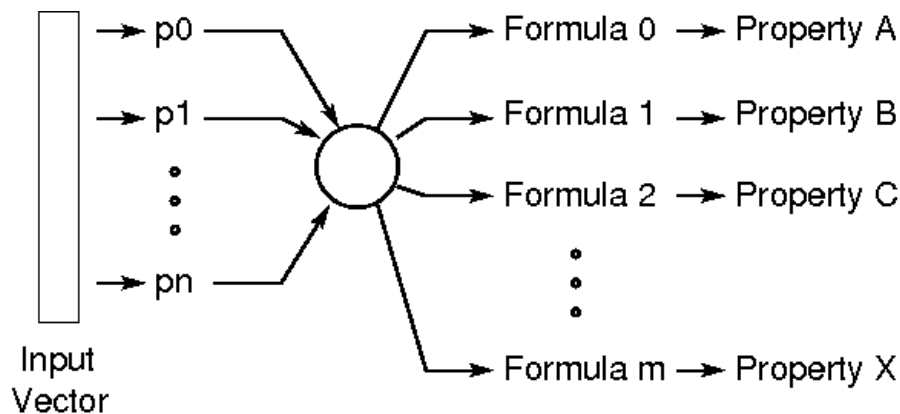


Figure 24: General mapping for an input probe.

### 10.2.1 Creating a simple probe

Creating an input probe that simply sets a single numeric property from the probe's input vector is fairly easy, and is exactly analogous to creating a simple output probe (Section 10.1.1). Starting with the input probe editor in Figure 23:

1. Select a component, either externally, or using the component/property widget.
2. Select a property for the component from the property selection box at the right of the component/property widget.
3. Adjust any required properties for the probe itself (Section 10.3).
4. Click Done.

### 10.2.2 General input probes

In general, input probes define a general map from the probe's input vector (which is subdivided into  $n$  input variables of dimension  $d_i$ ) to the values of  $m$  properties, where each value is determined by an independent formula based on the input variables (Figure 24). In the simple case of Section 10.2.1, there is one input variable which equals the input vector, and it drives a single property using a formula which is just the value of the input vector.

Each input variable is a vector of dimension  $d_i$  (scalars being considered vectors of dimension 1), and the sum of all the  $d_i$  equals the dimension of the input vector.

Each of the formulae controlling the properties is an arithmetic expression, implemented in Jython, which may involve one or more of the input variables  $p_i$ . The output from each formula is itself a vector whose dimension must match the associated numeric property. The simplest formula is just a single variable  $p_i$ , in which case its dimension equals the dimension of  $p_i$ .

### 10.2.3 Using the probe editor

The probe editor allows you to create the above mentioned map by creating input variables, selecting properties, and creating formulae to drive these properties. When all the selected components form a coherent mapping, the Done button will be enabled and the probe can be completed. When one or more parts of the mapping is unspecified or incomplete, the associated widgets will be highlighted and the Done button will be disabled.

Extra properties can be added by requesting additional component/property widgets using the "+" button in the formula/property panel. Similarly, extra input variables can be requested using the add button in the formula panel.

Properties and input variables can also be deleted; simply right click on the associated widget and choose delete.

Each input variable is associated with a widget containing two text fields, the left one defining the variable's name and the right one its dimension. The name or dimension can be changed by editing these fields. Changes will be propagated into the formulae; formulae that are found to be incompatible with the changes will be cleared.

In order to streamline the probe creation process, the editor will try to guess certain desired actions. In particular, when the user chooses a property with a given component/property widget for the first time, the editor creates an input variable whose dimension matches the property, and a simple formula consisting solely of the input variable. The input variable and formula can be changed if necessary.

#### Note:

The selection manager is connected to at most one component/property widget at a time. The component field for this widget is indicated with a blue border; external selections will affect only that widget. Left clicking on a component property widget will cause it to be connected to the selection manager.

## 10.3 Setting Probe Properties

The lower part of the probe editor contains a set of fields for editing various probe properties.

#### name

The name of the of the probe.

#### start time

Start time for the probe, in seconds.

#### stop time

Stop time for the probe, in seconds.

#### scale

Specifies the scale  $s$  for this probe, which relates the internal probe time  $t_p$  to the external simulation (or timeline) time  $t$ . If  $t_{\text{start}}$  is the time at which the probe starts on the timeline, then  $t = t_p s + t_{\text{start}}$ .

#### attached file

Names the *attached file* for this probe, used for storing the probe's data. See Section 9.1.

#### display range

Minimum and maximum range values used for the graphical display of the probe's data. If these values are left blank, then the range is computed automatically.

#### update interval

(Output probes only). A time interval, in seconds, specifying how often data should be output to the probe.

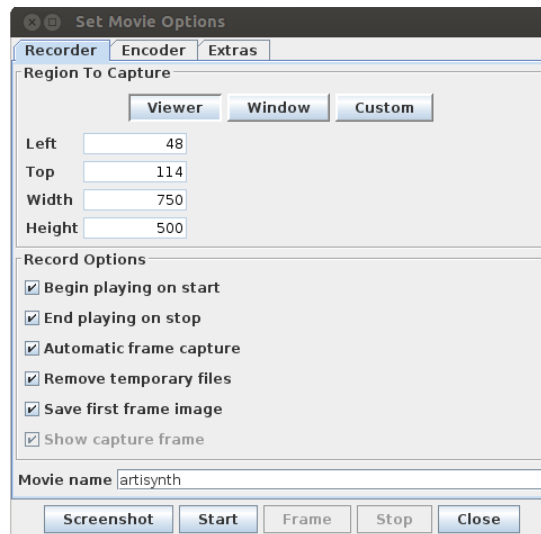


Figure 25: Movie options panel (recorder tab).

## 11 Making Movies

ArtiSynth includes a panel to aid in capturing simulations as movies. This panel is opened from the main viewer window by navigating through View > Show movie panel. When capturing a movie, pictures are saved to `ARTISYNTH_HOME/tmp` periodically as `frameXXXXX.ext`, where `XXXXX` represents the sequential number of the frame (with each `X` representing a digit), and the `.ext` represents the file extension (determined by the Frame File selection in the encoder panel). Because the frame files aren't unique, recordings will overwrite frames from prior movies, and if **Remove temporary files** is selected, only the final products are left. When the recording is stopped, these pictures are then compressed into a movie file using either mencoder, or an internal algorithm. The resulting movie is saved to the `$ARTISYNTH_HOME/tmp` with the file name specified at the bottom of the recorder panel.

### 11.1 Region To Capture Options

These options define the area of the desktop recorded. The default capture area is the main viewer of ArtiSynth. **Viewer** sets the capture area exclusively and strictly to the main viewer, and excludes the toolbar and window. This is useful for recording model demonstrations. The **Window** option includes the main viewer and the toolbar and window surrounding it. The **Custom** option allows the user to manually set the coordinates, width and height of the region to capture through the given fields. It also displays the capture frame, which can be stretched and moved to adjust what is recorded.

When the **Viewer** mode is selected, there are additional options available in the Output Size section. This allows you to create higher (or lower) resolution videos, independent of the viewer's visible resolution. The `# samples` specifies the size of the multi-sample buffer, which is used for anti-aliasing. This is the only mode that continues to work correctly when a screen-saver is activated.

### 11.2 Record Options

These options determine how the movie recorder works with ArtiSynth, and how it deals with the frame files.

#### Begin playing on start

When the start button is clicked, the simulation will begin to run.

#### End playing on stop

When the stop button is clicked, the simulation stops running.

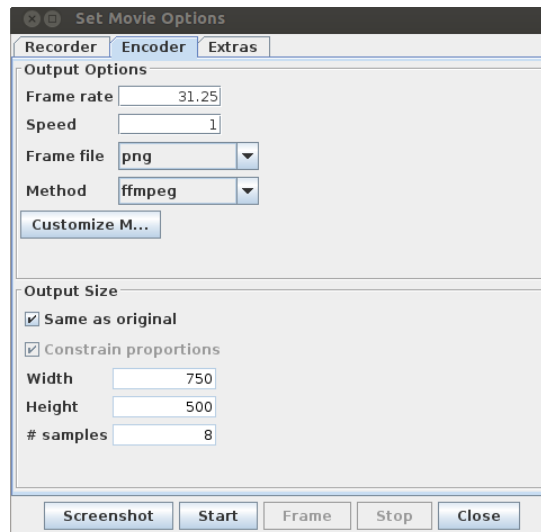


Figure 26: Movie options panel (encoder tab).

### Automatic frame capture

Frames are automatically captured according to the movie's frame-rate while the model is run. If this is disabled, it is up to the user to click on the Frame button to capture the next frame.

### Remove temporary files

When selected, the temporary frames are deleted after the movie is made.

### Save first image

This saves the first frame taken. These frames are useful for representing the movie in websites.

### Show capture frame

Opens a transparent window that reveals what will be captured. The window is stretchable and movable when the capture option is set to Custom and provides a method to graphically modify the capture area's X coordinate, Y coordinate, width, and height.

## 11.3 Output Options

These options control the frequency of the frames and how they are combined into a movie.

### Frame rate

This is the number of frames recorded per second of movie.

### Speed

This is the ratio of the movie's speed to reality's speed. While the demo is recording, the calculations may slow down the simulation, but the movie will not be affected.

#### **Important:**

If the Frame Rate or Speed is set so that the increments between the frames is smaller than the calculation steps used in the, then ArtiSynth will decrease the calculation increments in order to capture the frames, slowing the simulation.

### Frame File

This is the format the frames will be stored in. If the internal method (see below) is used, then the frames must be stored as jpegs.



## Method

This is the algorithm used to compress the temporary pictures into a movie.

- **internal** Use ArtiSynth's built in algorithm to compress the pictures into an animated jpeg.
- **mencoder** Use Mencoder to compress pictures into a divx movie (can be played on MediaPlayer with a plugin).
- **mencoder\_osx** This option is specific for use on MacOS.
- **ffmpeg** Use the FFMPEG command-line utility to generate the movie.
- **animated\_gif** Uses an algorithm built into ArtiSynth to generate an animated gif. By hitting the Customize Method button, you can set the number of times to loop (-1 for infinity) and the frame rate (defaults to capture frame rate).
- **avconv** Uses the avconv utility that has replaced FFMPEG on some linux systems to generate the movie.

The customize button right of the method box opens a window where the specific command calling mencoder can be edited. The variables identified with the '\$' are the input parameters for the mencoder, and are based on information provided to the movie panel.

## \$FMT

Controls the format of the frames. Modifying this is the same as changing `Frame File`.

## \$OUT

The name of the output file. Modifying this is the same as changing the `name` field.

## \$FPS

Determines the frame rate mencoder uses when it compiles the movie. By default, this is the same as the `Frame Rate` option.

## 11.4 Output Size Options

These options are only used when the capture area is set to **Viewer** and control the size of the output video, allowing the contents of the viewer to be magnified.

### Same to original size

The output video is created at the original size.

### Constrain proportions

The output video is created with constrained proportions, such that the ratio between height and width are maintained.

### Width

Defines the width of the output video.

### Height

Defines the height of the output video.

### # samples

Sets the number of samples to use for the multi-sample buffer. This only applies in **Viewer** mode, and is used to perform anti-aliasing.

**Note:** If your movie comes out black or only shows a section of the viewer correctly in **Viewer** mode, then it is likely your graphics card does not support multi-sample buffers. On machines with multiple graphics cards (e.g. laptops with both discrete and integrated graphics), make sure the java process is set to use the discrete card. Otherwise, set `# samples = 1` to disable the multi-sample buffer.

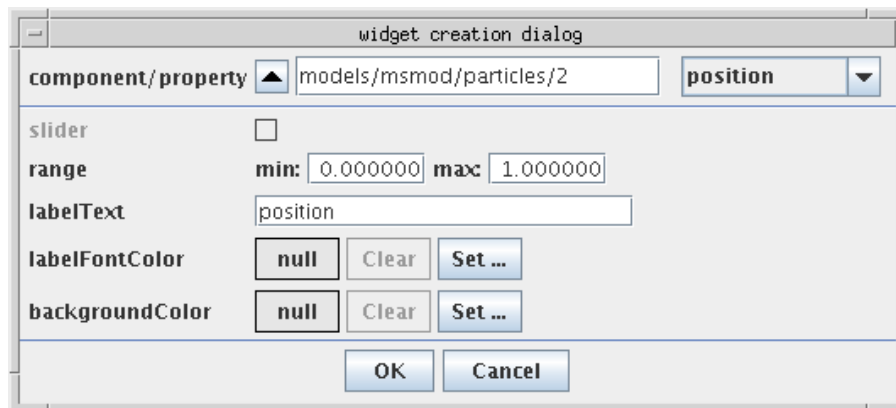


Figure 27: Widget creation dialog.

## 12 Control Panels

Control panels are essentially custom-built property panels that are attached to the root model and let the user interactively set or adjust various properties while the simulation is in progress. Most of the panels that appear with the various ArtiSynth demos are in fact control panels specially created for the demo in question.

The properties controlled by a control panel do not need to come from the same object; instead, they can come from a variety of objects. However, unlike with property panels, it is not possible (at the time of this writing) for a control panel widget to control a property across multiple objects.

The problem of controlling the same property in multiple objects may be addressed in future by the introduction of *component groups*.

### 12.1 Creating Control Panels

To create a control panel, select Edit > Add control panel from the ArtiSynth main menu. This will cause a blank control panel to appear.

To add a widget to this panel, right click inside the the panel and select Add widget. This will cause a widget creation dialog to appear, as shown in Figure 27.

The top-most widget in this dialog is a component/property selector. The component section is a selection display identical in function to that described in Section 4.4: the path of the most recently selected component is displayed, and its parent may be selected by clicking on the “up” button at the left. If no component is selected, you will need to select one using the navigation panel or the viewer. Once a component is selected, the combination box on the right will provide a selection of properties that may be selected for the widget. Once a property is selected, other options in the dialog may be used to tune the appearance of the widget:

#### slider

Enabled for properties with a scalar numeric value. Setting it to true will create a widget with a slider.

#### range

Specifies the range for the slider, if one is selected.

#### labelText

The name of the widget in the panel. By default, this is the name of the property.

#### labelFontColor

Font color for the widget name. If null, then the default color is used.



Figure 28: Composite property widgets.

**backgroundColor**

Background color for the widget. If `null`, then the default background is used.

**12.1.1 Composite property widgets**

A [CompositeProperty](#) is a Property which contains sub-properties. If a composite property is selected, the control panel will create a *composite property widget*, three of which are shown in Figure 28.

Clicking the set button of a composite property widget will create another panel presenting all the sub-properties. The composite property widget is disabled until this panel is closed.

In some instances, a composite property can be set to `null`. In such cases, the widget will provide an additional component, which

- if the current property value is **not** `null`, will be a `clear` button which sets the value to `null` (second widget, <Figure 28).
- if the current property value **is** `null`, will be a display label indicating this fact (third widget, <Figure 28).

**12.1.2 Widgets for sub-properties**

It is possible to attach widgets to the sub-properties of a composite property, provided that the composite property has a non-null value.

In particular, when a non-null composite property is selected from the component/property widget, the user has the option of either

- clicking the Done button and selecting the composite property, which will create a composite property widget as described in the previous section, or
- selecting one of the composite property's sub-properties.

When a non-null composite property is selected, the property's name will move over into the component field of the component/property selector, and the combination box will be cleared and reset to allow the selection of the sub-properties.

For example, in Figure 29, we first select `renderProps`, which is a composite property of `models/msmod/particle/2`, and then (in the lower panel) select the sub-property `visible`. When `renderProps` is selected, its name is moved to the component panel, where it appears as

```
models/msmod/particle/2:renderProps
```

**Note:**

The ':' character is used to separate components from properties in component/property paths

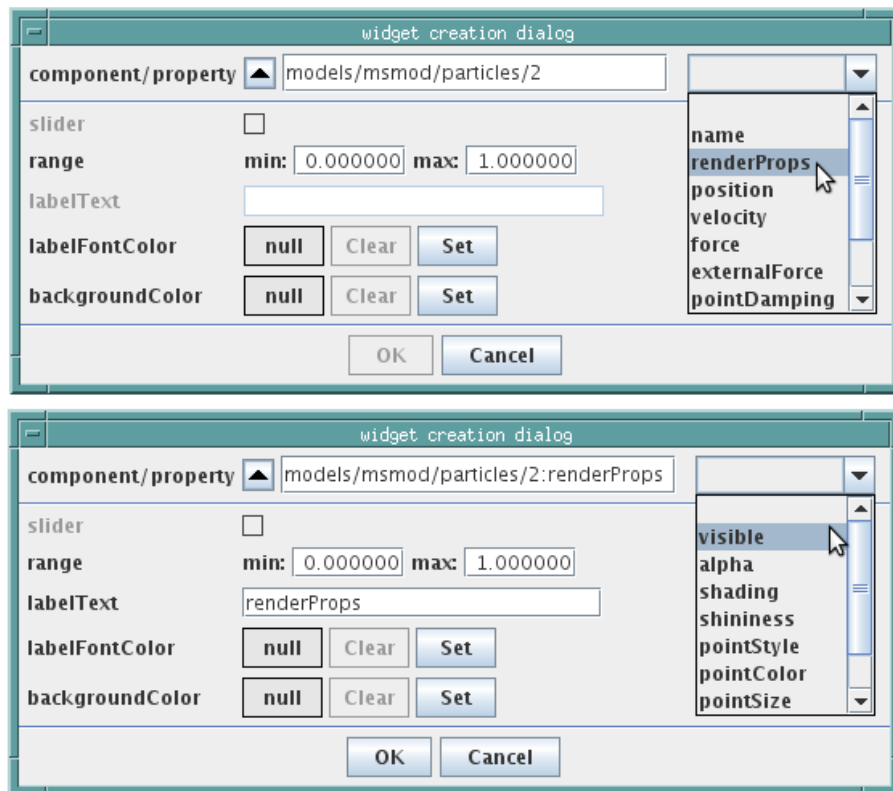


Figure 29: Selecting property renderProps (top), then one of it's subproperties (bottom).

## 12.2 Editing Control Panels

An existing control panel can also be edited. Specifically,

- Individual widgets can be moved, deleted, or have their properties set.
- Separators can be added between widgets.
- Global aspects of the control panel itself can be set.

To edit an individual widget, you first select it by left-clicking on it. This will cause it to become highlighted. You can then:


- **Move** the widget by dragging it to a different vertical location within the panel;
- **Delete** the widget by right-clicking and choosing delete;
- **Set properties** of the widget by right-clicking and choosing properties;

To add a separator, select a widget above where you want the separator, right-click and choose add separator.

To set global aspects of the control panel itself, right-click inside the lower-most *option pane* (the small panel at the bottom and that may, in some cases, contain option buttons such as Close or Done), and choose from the provided menu.

## 12.3 Live Updating

By default, a control panel is set up to update the values of its widgets every time the viewers are rerendered. This allows one to observe property values as they evolve in time.

If you do *not* want live updating of property values, then you can disable this by clicking on the *live update icon* , which is located in the lower left of the option panel.

## 13 Component Editing

Component editing in ArtiSynth is driven by the current *selection context*: depending on what items are currently selected, different editing options will appear in the context menu. These options may allow you to add, edit, or delete components.

### 13.1 Generic Edit Operations

#### 13.1.1 Deletion

A set of selected components can be deleted provided that

- their parent components are editable
- none of their ancestors are selected

If the currently selected components are deletable, then a delete option will appear in the context menu (obtained by right-clicking in the viewer or navigation panel). Selecting this will delete the components.

If the selected components are referred to by other components, then those components will be deleted also. In this case, a dialog will be presented to the user advising of this fact and requesting confirmation.

#### 13.1.2 Duplication

A set of selected components may be *duplicated* provided that

- their parent components are editable
- none of their ancestors are selected
- they implement [CopyableComponent](#)

If the currently selected components are duplicable, then a duplicate option will appear in the context menu. Selecting this will enable duplication of the components: the viewer cursor will change to cross-hairs, and the user may indicate the location for the duplicated components by left-clicking in the viewer (see Section 3.7). Duplication may be canceled by right-clicking.

Sometimes, when the components to be duplicated refer to other components, those referred components will be duplicated also. This is done when the referred components are required. For example, when duplicating an [AxialSpring](#), the two points it is attached to will also be duplicated, because AxialSprings are not permitted to exist without attached points. Such cases are indicated to the user, after the duplicate option has been selected, by expanding the current selection to include all such additional components.

#### 13.1.3 Undo

Many of the operations described here are *undoable*, by choosing the Undo option from the Edit menu. The menu option will indicate the name of the operation to be undone.

### 13.2 Editing Panels

Many editing operations involve the creation of *editing* panels (such as Figure 32, etc.) which persist beyond the invocation of a context menu. Often, these panels are created *exclusively*, so that only one can be in existence at once. This is done by having the panel acquire a lock in the ArtiSynth editing manager. The panels are not modal, so the user can still interact with the viewer and other GUI components, but other exclusive editing panels can not be created until the current one is closed. This avoids problems associated with having two “edits” active on a the model at once.

If an exclusive editing panel is open, then other exclusive editing options will still be shown in the context menu but will be disabled.

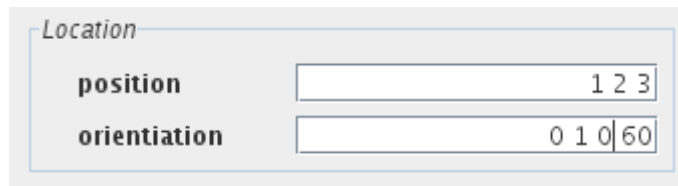


Figure 30: Panel for specifying the location of a coordinate frame.

### 13.3 Specifying Position, Orientation, and Scaling

Sometimes, an editing panel will allow you to specify the translation and rotation associated with a [RigidTransform3d](#). Typically, this will happen when there is a need to specify the location of a spatial coordinate frame, as in the example of Figure 30.

Here, the translation and rotation correspond to the fields `position` and `orientation`. The `position` field is straightforward: it is just three numbers giving the position of the coordinate frame origin with respect to the base (usually world) coordinates. In Figure 30, this is the vector (1, 2, 3).

The `orientation` field is more complex. It corresponds to the rotation of the coordinate frame with respect to base coordinates, and is represented using an *axis-angle* format of four numbers giving the axis of the rotation, followed by the angle of rotation about this axis, in degrees. (This relies on the fact that any 3D rotation can be specified as a single rotation about a single axis.) Hence the numbers

0 1 0 60

in Figure 30 correspond to a rotation of 60 degrees about the y axis. Alternatively, the numbers

1 1 0 45

would correspond to a rotation of 45 degrees about the axis (1, 1, 0). (Note that the axis does not need to be a unit vector.) Finally, no rotation, or more precisely, the *identity* rotation, is usually represented as

1 0 0 0

i.e., *zero* rotation about the x-axis. In more general situations, one may specify not only translation and rotation but also scaling, corresponding to a more general [AffineTransform3d](#). This often occurs when reading a mesh from a file: one may wish to apply an affine transform to scale, rotate, and translate the mesh that is been read in. In such cases one will also be presented with a `scale` field, which accepts either a single number (to denote uniform scaling), or three numbers (to denote non-uniform scaling about the x, y, and z axes).

### 13.4 Editing MechModels

A [MechModel](#) is the central ArtiSynth component for mechanical simulation. It contains sets of mechanical components, including particles, rigid bodies, axial springs, rigid body connectors, as well as sub-models including other `MechModels` and finite element (FEM) models. Most of these components can be added to a `MechModel` graphically, as described below.

To add a component to a `MechModel`, select the `MechModel` and choose the appropriate edit action shown in the context menu. A `MechModel` cannot be selected in the viewer, but can be selected using the navigation panel (Figure 6), or by first selecting one of its visible components in the viewer and navigating up the hierarchy to it using the up arrow of the selection display (Section 4.4).

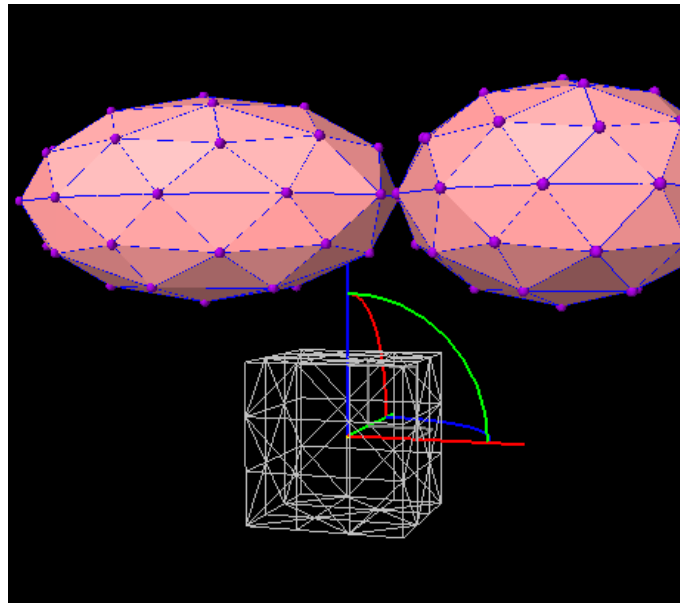


Figure 31: Wireframe preview of the FEM in the viewer.

#### 13.4.1 Adding finite element models

To add a [FemModel](#) to a MechModel, select the MechModel and choose "Add FemModel ..." in the context menu. This will open the editing panel shown in Figure 32, which allows the user to provide information about the model's properties and geometry.

Default values are provided for almost all of this information; the only information that *must* be specified by the user is the model's position (corresponding to the origin of its volumetric mesh). This can be done either by left-clicking in the viewer (Section 3.7), or by entering coordinates in the position field of the Location subpanel. Once a position is specified, a wireframe preview of the FEM appears in the viewer (Figure 31), showing its geometry and allowing it to be moved or rotated using an attached transformer. The user is then free to continue editing the properties and geometry information, until the model is in the desired form, at which point it can be added to the MechModel by clicking the Add button.

From top to bottom, the FemModel panel contains:

- An *instruction box* containing directions for the user.
- A *General Properties* subpanel, which allows the user to set properties for the FemModel. For brevity, some of these properties are hidden and can be expanded by clicking the more... button.
- A *Location* subpanel, allowing the position and orientation to be set manually. The position corresponds to the mesh origin, while the orientation is a rotation applied to the mesh, specified in *axis-angle* format (see Section 13.3).
- A *Geometry* panel, allowing specification of the mesh geometry type and various properties specific to this type. Mesh types currently supported include Grid, Tube, Torus, Sphere, Extrusion, AnsysMesh, TetgenMesh and UCDMesh. For many of these, the associated element type can also be specified: Tet (tetrahedron), Hex (hexahedron), QuadTet (quadratic tetrahedron), QuadHex (quadratic hexadredron), and Wedge.
- An *option* panel, containing the Add button, a Clear button which resets the displayed fields to default values, and a Cancel button which closes the panel without adding a FemModel.

#### 13.4.2 Adding rigid bodies

To add a [RigidBody](#) to a MechModel, select the MechModel and choose "Add RigidBody ..." in the context menu to open an editing panel for rigid bodies, as shown in Figure 33.

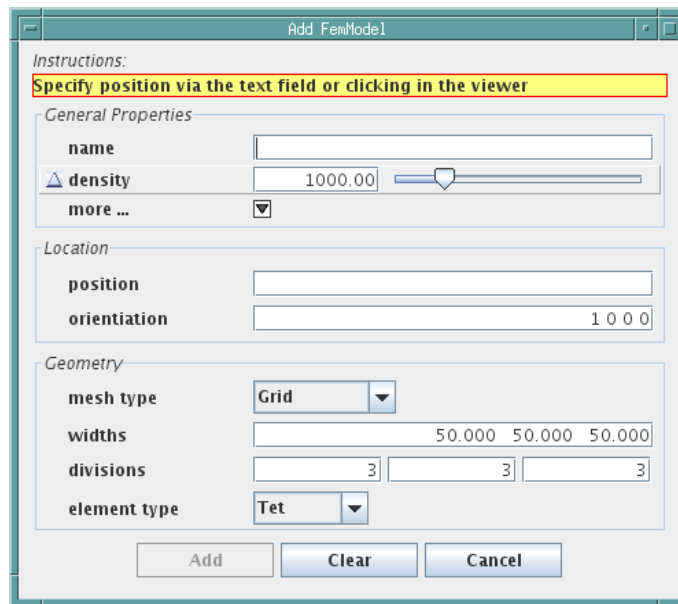


Figure 32: Panel for adding finite element models.

As with adding FEM models, default values are provided for most information; the user must only specify the body's position, either by left-clicking in the viewer (similar to Section 3.7), or by entering coordinates in the position field of the Location subpanel. Once a position is specified, a wireframe preview of the rigid body appears in the viewer (Figure 31), showing its geometry and allowing it to be moved or rotated using an attached transformer. The user is then free to continue editing the properties, geometry and inertia information, until the model is in the desired form, at which point it can be added to the MechModel by clicking the Add button.

From top to bottom, the Add RigidBody panel contains:

- An *instruction box* containing directions for the user.
- A *General Properties* subpanel, which allows the user to set properties for the body. For brevity, some of these properties are hidden; the panel can be expanded by clicking the more... button.
- A *Location* subpanel, allowing the position and orientation of the body's coordinate system to be set manually. Position is specified as a three-vector, while the orientation is given as a rotation in *axis-angle* format (see Section 13.3).
- A *Geometry And Inertia* subpanel, which allows the user to specify the body's surface mesh geometry and spatial inertia, using the same type of panel as described in Section 13.5.1.
- An *option* panel, containing the Add button, a Clear button which resets the displayed fields to default values, and a Cancel button which closes the panel without adding a rigid body.

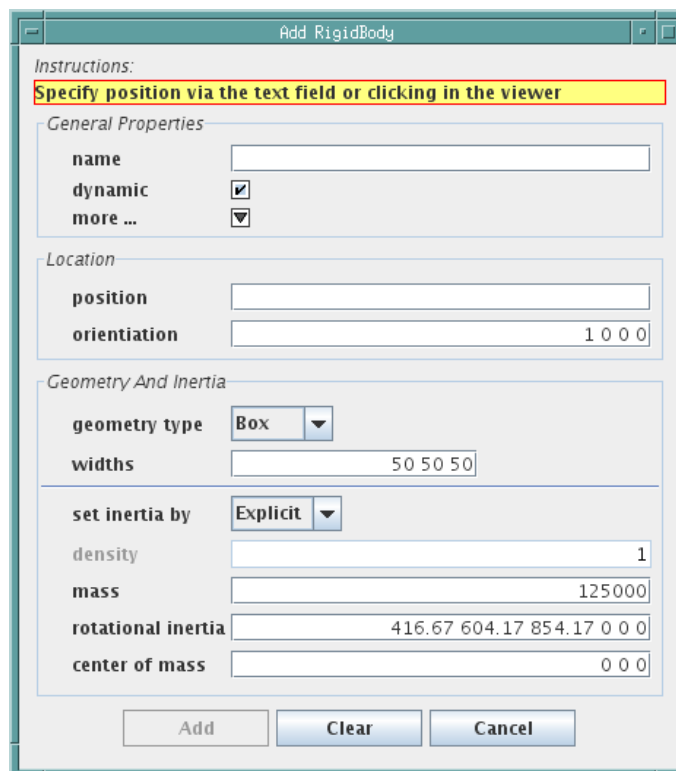
### 13.4.3 Adding frame markers

A **FrameMarker** is a massless **Point** attached to a **RigidBody**. It can be used for tracing motions of that body, or as an anchor point for attaching axial springs or other components.

To add one or more frame markers to the rigid bodies in a MechModel, you can select either the MechModel, or one of its rigid bodies, and then choose "Add FrameMarkers ..." in the context menu. This will open a FrameMarker editing panel, as shown in Figure 34. While this panel is open, frame markers can be added by using the viewer and left-clicking the mouse over the surface mesh of the rigid body at the location where you want the marker to be placed (see Section 3.7). The rigid body in question must belong to the MechModel that was originally selected; no marker will be added to bodies that belong to another MechModel or a MechModel which is a submodel of the current one.

From top to bottom, the FrameMarker editing panel contains





The 'Add RigidBody' dialog box is titled 'Add RigidBody'. It contains an 'Instructions' section with a yellow highlight: 'Specify position via the text field or clicking in the viewer'. The dialog is divided into three sections: 'General Properties', 'Location', and 'Geometry And Inertia'. 'General Properties' includes a 'name' text field, a 'dynamic' checkbox (checked), and a 'more ...' dropdown. 'Location' includes a 'position' text field and an 'orientation' text field with the value '1 0 0 0'. 'Geometry And Inertia' includes a 'geometry type' dropdown (set to 'Box'), a 'widths' text field with the value '50 50 50', a 'set inertia by' dropdown (set to 'Explicit'), a 'density' text field with the value '1', a 'mass' text field with the value '125000', a 'rotational inertia' text field with the value '416.67 604.17 854.17 0 0 0', and a 'center of mass' text field with the value '0 0 0'. At the bottom are 'Add', 'Clear', and 'Cancel' buttons.

Instructions:  
Specify position via the text field or clicking in the viewer

General Properties

name

dynamic ☒

more ...

Location

position

orientation 1 0 0 0

Geometry And Inertia

geometry type Box

widths 50 50 50

set inertia by Explicit

density 1

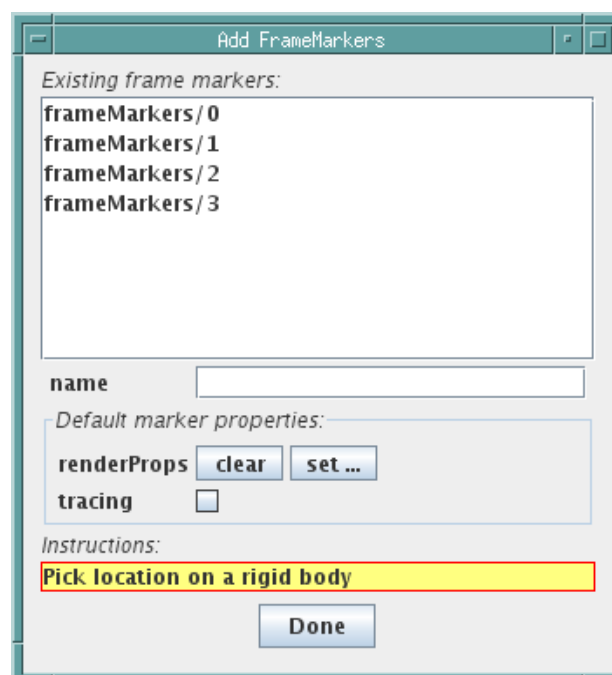
mass 125000

rotational inertia 416.67 604.17 854.17 0 0 0

center of mass 0 0 0

Add Clear Cancel

Figure 33: Panel for adding RigidBodies.



The 'Add FrameMarkers' dialog box is titled 'Add FrameMarkers'. It contains an 'Existing frame markers:' section with a list of markers: 'frameMarkers/0', 'frameMarkers/1', 'frameMarkers/2', and 'frameMarkers/3'. Below this is a 'name' text field. The 'Default marker properties:' section includes a 'renderProps' section with 'clear' and 'set ...' buttons, and a 'tracing' checkbox. The 'Instructions' section has a yellow highlight: 'Pick location on a rigid body'. At the bottom is a 'Done' button.

Existing frame markers:

frameMarkers/0  
frameMarkers/1  
frameMarkers/2  
frameMarkers/3

name

Default marker properties:

renderProps clear set ...

tracing ☐

Instructions:  
Pick location on a rigid body

Done

Figure 34: Panel for adding frame markers.

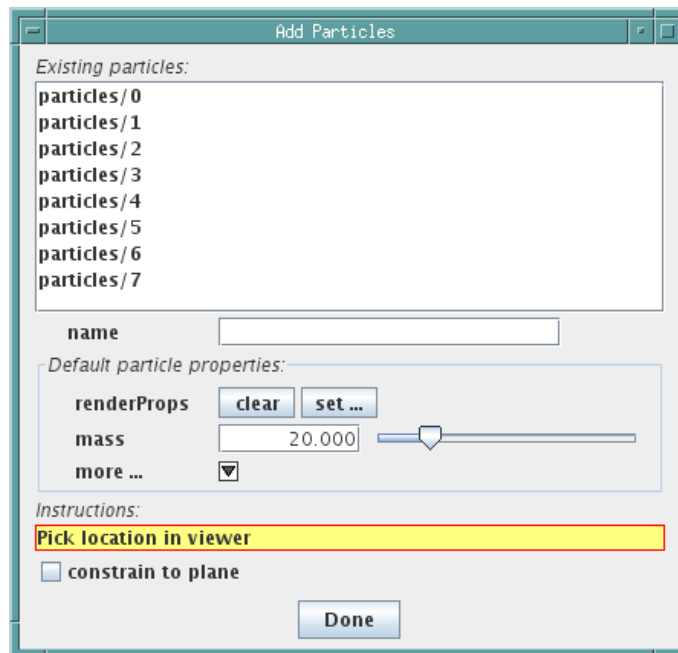


Figure 35: Panel for adding particles to a MechModel.

- An *Existing frame markers* list, showing all the MechModel's frame markers (expressed by their path names with respect to the MechModel). This list is connected to the selection manager and can be used to select one or more markers.
- A *name* field that allows a name to be specified for the marker.
- A *Default marker properties* panel, which allows the user to set properties for subsequent FrameMarkers that are added.
- An *instruction box* containing directions for the user.
- An *option* panel, which in this case contains a Done button which the user should click when finished.

#### 13.4.4 Adding particles

A [Particle](#) is a dynamic component, with mass, derived from [Point](#). It is usually connected to other components in a model with either axial springs (Section [13.4.5](#)) or point-to-point attachments (Section [13.4.7](#)).

To add one or more particles to a MechModel, select the MechModel in question and choose "Add Particles ..." in the context menu. This will open a Particle editing panel, as shown in Figure [35](#). While this panel is open, a particle can be added by left-clicking the mouse in the viewer at the location where you want the particle to be placed, using the constrain to plane option if necessary (see Section [3.7](#)).

From top to bottom, the Particle editing panel contains

- An *Existing particles* list, showing all the MechModel's particles (expressed by their path names with respect to the MechModel). This list is connected to the selection manager and can be used to select one or more particles.
- A *name* field that allows a name to be specified for the particle.
- A *Default particle properties* panel, which allows the user to set properties for subsequent particles that are added. For brevity, some of these properties are hidden; the panel can be expanded by clicking the more... button.
- An *instruction box* containing directions for the user.
- A constrain to plane option.
- An *option* panel, which in this case contains a Done button which the user should click when finished.

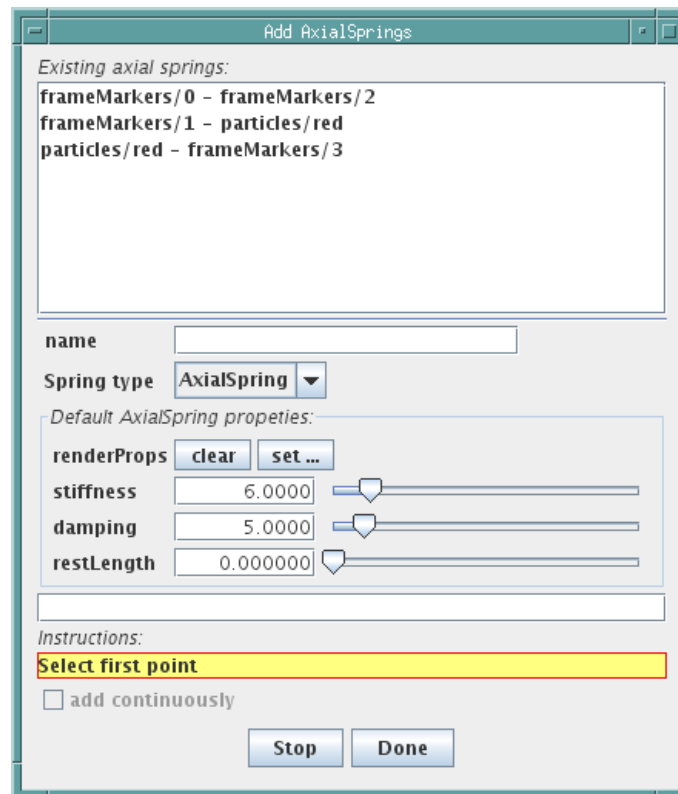


Figure 36: Panel for adding axial springs and muscles.

### 13.4.5 Adding axial springs and muscles

An **AxialSpring** is a point-to-point force effector that connects two **Points** and effects a force between them based on their separating distance. AxialSprings and its subclasses can be used to implement linear or nonlinear springs, as well as the subclass **Muscle** used to implement two-point muscles.

To add one or more axial springs to a MechModel, select the MechModel in question and choose "Add AxialSprings ..." in the context menu. This will open an AxialSpring editing panel, as shown in Figure 36. While this panel is open, axial springs can be added by selecting (using the viewer or any other selection mechanism) the two points to which the spring is attached. Points may include frame markers, particles, or FEM nodes. However, the points must be contained within the MechModel or one of its submodels.

By default, two points must be selected, in succession, for each axial spring added. Alternatively, by selecting add continuously at the bottom of the panel, a continuous sequence of springs will be created whereby the second point selected for a given spring becomes the first point for the spring following it.

From top to bottom, the AxialSpring editing panel contains

- An *Existing axial springs* list, showing all the MechModel's springs (expressed by the path names, with respect to the MechModel, of their points). This list is connected to the selection manager and can be used to select one or more springs.
- A *name* field that allows a name to be specified for the spring.
- A *Spring type* field that allows a specific subclass of AxialSpring to be selected.
- A *Default properties* panel, which allows the user to set properties for subsequent springs that are added. The properties in question vary depending on the type selected in the Spring type field. For brevity, some properties may be hidden, in which case the panel can be expanded by clicking the more... button.
- A *progress* field displaying the path names of the points as they are selected.

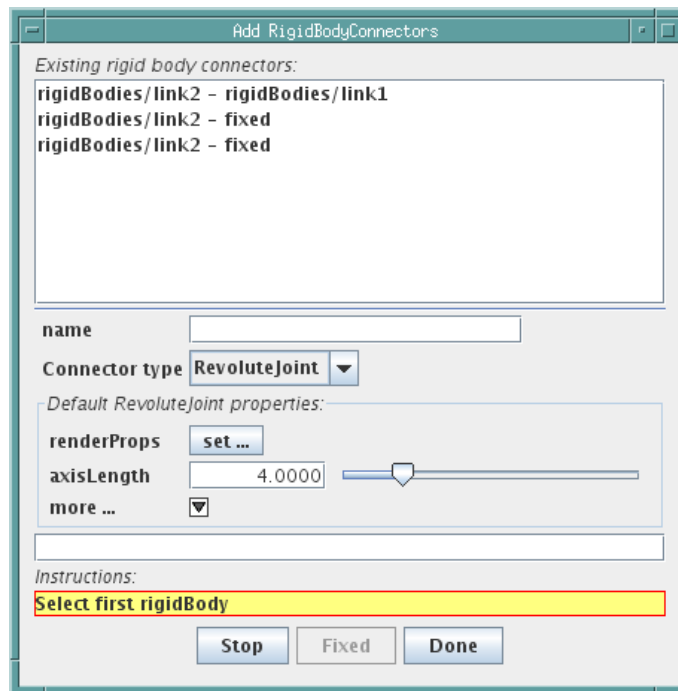


Figure 37: Panel for adding rigid body connectors.

- An *instruction box* containing directions for the user.
- An add continuously option as described above.
- An *option* panel, containing an Add/Stop button which is used to initiate or stop the addition of springs, and a Done button which the user should click when finished.

#### 13.4.6 Adding rigid body connectors

A [RigidBodyConnector](#) is a component that implements constraint-based joints between either two rigid bodies, or between one rigid body and ground. The GUI currently allows two types of joints to be added: *spherical* and *revolute*.

To add one or more rigid body connectors to a MechModel, select the MechModel in question and choose "Add RigidBodyConnectors ..." in the context menu. This will open a RigidBodyConnector editing panel, as shown in Figure 37. While this panel is open, a connector can be added by selecting in succession (using the viewer or any other selection mechanism) the rigid bodies associated with it. For the case of a single rigid body connected to ground, the user clicks the Fixed button instead of selecting a second body.

After the bodies have been selected, the connector location must then be specified by left-clicking in the viewer (Section 3.7). By default, the orientation of the connector is aligned with the world axes. This can be adjusted later using the dragger fixtures (Section 5.1).

From top to bottom, the RigidBodyConnector editing panel contains

- An *Existing rigid body connectors* list, showing all the MechModel's connectors (expressed by the path names, with respect to the MechModel, of their rigid bodies). This list is connected to the selection manager and can be used to select one or more connectors.
- A *name* field that allows a name to be specified for the connector.
- A *Connector type* field that allows a specific connector type to be selected.

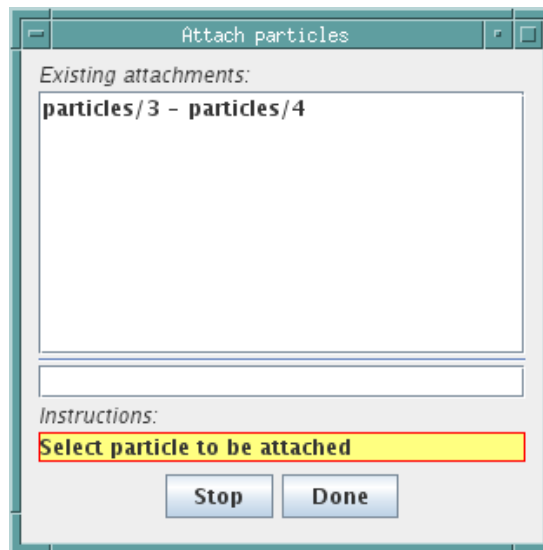


Figure 38: Panel for attaching particles together.

- A *Default properties* panel, which allows the user to set properties for subsequent connectors that are added. The properties in question vary depending on the type selected in the Connector type field. For brevity, some properties may be hidden, in which case the panel can be expanded by clicking the more... button.
- A *progress* field displaying the path names of the rigid bodies as they are selected.
- An *instruction box* containing directions for the user.
- An *option* panel, containing an Add/Stop button which can be used to initiate or stop the addition of connectors, a Fixed button used to indicate when a rigid body is to be connected to ground, and a Done button which the user should click when finished.

#### 13.4.7 Attaching particles to particles

Within a MechModel, two particles or FEM nodes can be attached together, resulting in what is essentially a single particle that combines the dynamics of both original particles. In particular, these *particle attachments* are a convenient way to connect FEM models to other FEM models or to particles within a MechModel.

To attach particles contained within a MechModel, select the MechModel in question and choose "Attach particles ..." in the context menu. This will open a ParticleAttachment panel, as shown in Figure 38. While this panel is open, pairs of particles can be attached by selecting in succession (using the viewer or any other selection mechanism) the two particles to be connected.

From top to bottom, the ParticleAttachment panel contains

- An *Existing attachments* list, showing all the MechModel's attachments (expressed by the path names, with respect to the MechModel, of their particles). This list is connected to the selection manager and can be used to select one or more attachments.
- A *progress* field displaying the path names of the particles as they are selected.
- An *instruction box* containing directions for the user.
- An *option* panel, containing an Attach/Stop button which can be used to initiate or stop the attachment process, and a Done button which the user should click when finished.

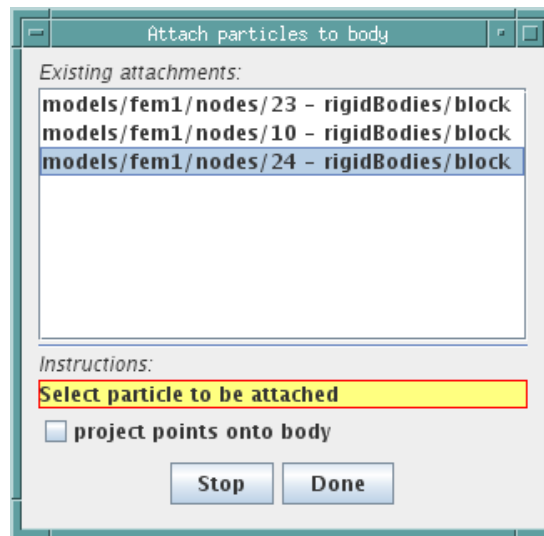


Figure 39: Panel for attaching particles to a rigid body.

#### 13.4.8 Attaching particles to rigid bodies

Within a MechModel, particles and FEM nodes can also be attached to rigid bodies. In particular, this provides a way to connect FEM models to rigid bodies within a MechModel.

To attach particles to a rigid body, select the rigid body in question and choose "Attach particles ..." in the context menu. This will open a ParticleRigidBodyAttachment panel, as shown in Figure 39. While this panel is open, particles can be attached to the body by selecting them in succession. By default, the attached particles remain where they are, so that the attachment point is determined by the current particle location relative to the rigid body's coordinates. However, this will typically not coincide with the body's surface mesh. By selecting project points onto body at the bottom of the panel, attached points will be relocated to the nearest location on the surface mesh as they are selected.

From top to bottom, the ParticleRigidBodyAttachment panel contains

- An *Existing attachments* list, showing all the MechModel's particle to rigid body attachments (expressed by the path names, with respect to the MechModel, of the particles and the bodies). This list is connected to the selection manager and can be used to select one or more attachments.
- A *progress* field displaying the path names of the particles as they are selected.
- A project points onto body field, described above.
- An *instruction box* containing directions for the user.
- An *option* panel, containing an Attach/Stop button which can be used to initiate or stop the attachment process, and a Done button which the user should click when finished.

#### 13.4.9 Collision handling

In ArtiSynth, collision detection and handling can be enabled between any pair of rigid or deformable bodies. Self intersections can also be enabled for deformable bodies. Rigid bodies are of type [RigidBody](#), and deformable bodies currently include [FemModel3d](#).

The collision response between any two pairs of bodies is determined by a *collision behavior*, which contains two properties:

##### enabled

whether or not collisions are enabled;

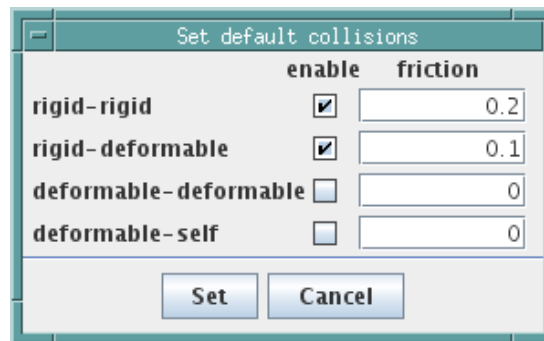


Figure 40: Dialog for setting default collision behavior in a MechModel.

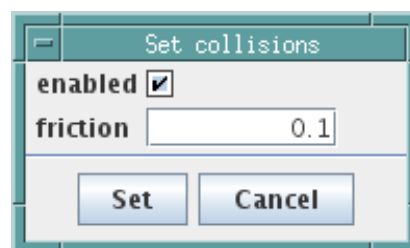


Figure 41: Dialog for setting collision behavior between bodies.

### friction

the friction coefficient if collisions are enabled.

Collisions handling is performed by MechModel. Each MechModel provides four default behaviors that determine the default collision response for (a) rigid body pairs, (b) rigid-deformable body pairs, (c) deformable body pairs, and (d) deformable self-intersection. In addition to these, *override* collision behaviors can be specified for any specific pair of bodies.

The *primary* collision behavior for any given pair of bodies is the behavior that occurs if no override behavior has been specified for that pair. If there are no sub-MechModels located under the MechModel, the primary behavior is simply the default behavior.

If the MechModel contains sub-MechModels, the situation is more complicated. In that case, to determine the primary collision behavior for a pair of bodies, let *M* denote the MechModel and *L* denote the lowest sub-MechModel beneath *M* that contains both bodies. If an override collision behavior for the pair is present in any model between *M* (exclusive) and *L* (inclusive), then the highest such override determines the primary behavior for the pair. Otherwise, the primary behavior is determined by the default behavior in *L*.

There are several ways to edit collision behavior using the GUI.

First, the default collision behaviors for the combinations described above can be edited by selecting the MechModel and then choosing "Set default collisions ..." from the context menu. This will open the dialog shown in Figure 40, allowing the default settings to be adjusted. For the example shown, collisions are enabled between all rigid bodies, with a friction coefficient of 0.2, and between all rigid and deformable bodies, with a coefficient of 0.1. Other collisions are disabled.

Second, if a user selects a particular set of rigid and/or deformable bodies, a specific collision behavior may be established among those bodies by choosing "Set collisions ..." from the context menu. That will open the dialog shown in Figure 41, allowing a specific behavior to be set. If this behavior does not match the default behavior, override behaviors will be added for the pairs of bodies in the set.

Third, if a user selects a single deformable body, a specific self-intersection behavior for that body may be established by selecting "Set self collision ...".

Finally, all override collision behaviors in a specific MechModel may be removed by selecting "Remove collision overrides". This will cause the collision behavior among all bodies to revert to their primary behavior.

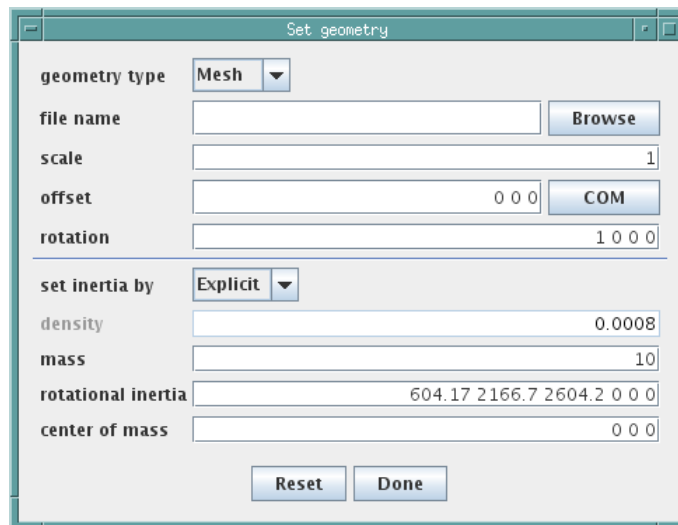


Figure 42: Panel for editing geometry and inertia.

## 13.5 Editing Rigid Bodies

The GUI provides some ability to edit rigid bodies, (type [RigidBody](#)), the most important of which allows the user to edit its mesh geometry and inertia (see Section [13.5.1](#)). If a rigid body is selected, the context menu will provide the following options:

### Add FrameMarkers ...

Allows FrameMarkers to be added to the rigid body (see Section [13.4.3](#)).

### Select markers

Causes all markers attached to the rigid body to be selected.

### Save mesh as ...

Allows the surface mesh to be saved as an Alias Wavefront `.obj` file.

### Edit geometry and inertia ...

Change the mesh geometry and/or inertia (see Section [13.5.1](#), below).

### Attach particles ...

Allows particles to be attached to the rigid body (see Section [13.4.8](#)).

### 13.5.1 Geometry and inertia

Choosing "Edit geometry and inertia ..." in the context menu for a rigid body opens a geometry and inertia panel, as shown in Figure [42](#).

The upper part of the panel allows the user to set the mesh geometry, according to a type specified by the `geometry type` field. Changing the geometry type changes the panel to include fields for setting parameters appropriate to the type. Currently supported types include:

#### Box

An axis-aligned box, centered with respect to body coordinates, with the x, y, and z widths set by three numbers in a `widths` field.

#### Sphere

A sphere, centered with respect to body coordinates, with the radius and the number of vertical mesh slices given by fields `radius` and `slices`.



**Mesh** A mesh read in from an Alias Wavefront `.obj` file, whose name is specified by a file name field. The read mesh can also be scaled, offset, and rotated using information provided by `scale`, `offset`, and `rotation` fields (see Section 13.3). The **COM** button causes the mesh to be offset so that its center of mass (assuming uniform density) is coincident with the origin of the body's coordinate system (also causing the location of the center of mass to become zero).

**Note:**

At present, there appears to be a bug in the code that compute inertia from geometry, producing small errors in the center of mass calculation. That means that hitting the **COM** button will not cause the center of mass to become zero, but instead a small number that will converge to zero if **COM** is hit repeatedly.

The lower part of the panel sets the body's spatial inertia. Spatial inertia for a rigid body can be set in three ways, corresponding to the value of the body's `inertiaMethod` property:

**Density**

The spatial inertia is calculated from the density and the surface mesh geometry, with the assumption that the density is uniform.

**Mass**

The spatial inertia is calculated from the mass and the surface mesh geometry, with the assumption that the density is uniform. The density is computed by dividing the mass by the mesh volume.

**Explicit**

The spatial inertia is explicitly specified by entering values in the mass, inertia, and center of mass fields. The density is set to the average value obtained by dividing the mass by the mesh volume.

The inertia method can be set using the `set inertia by field`. Four other fields describe properties associated with the spatial inertia itself:

**density**

The mass divided by the volume

**mass**

The scale mass of the body

**rotational inertia**

The `xx`, `yy`, `zz`, `xy`, `xz`, and `yz` components of the rotational inertia tensor about the center of mass in body coordinates

**center of mass**

the position of the center of mass with respect to body coordinates.

Depending on the inertia method, the contents of these fields are either set by the user or updated automatically.

## 13.6 Editing FEM Models

The GUI also provides some ability to edit FEM models (type `FemModel3d`). If an FEM model is selected, the context menu will provide the following options:

**Add FemMarkers ...**

Allows the user to add marker points to the FEM, as described in Section 13.6.1.

**Rebuild surface mesh** Rebuilds the surface mesh for the FEM. The surface mesh is computed automatically from the faces of all the elements, with inside faces being removed. Also, any elements which are fully or partly obscured by an active clipping plane are removed from the calculation, making it possible to create "partial" surface meshes that provide a cutaway view of the model.

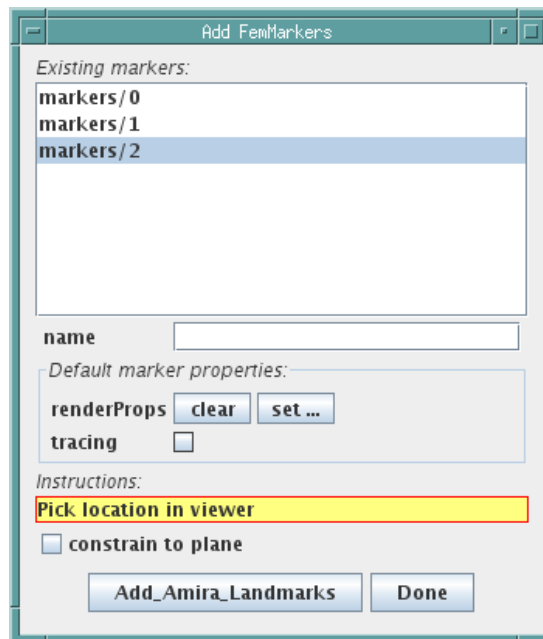


Figure 43: Panel for adding markers to an FEM model.

#### Save surface mesh ...

Allows the current surface mesh to be saved to an Alias Wavefront .obj file.

#### Save mesh as ANSYS file ...

Allows the FEM volumetric mesh to be saved using the ANSYS file format.

### 13.6.1 Adding FEM markers

A **FemMarker** is a massless **Point** attached to a specific **FemElement3d**. It can be used for tracing motions within that element, or as an anchor point for attaching axial springs or other components. It is analogous to a **FrameMarker** for FEM elements.

To add one or more markers to an FEM model, you can select the FEM model in question and then choose "Add FemMarkers ..." in the context menu. This will open a FemMarker editing panel, as shown in Figure 43. While this panel is open, FEM markers can be added by left-clicking the mouse in the viewer over the location where you want the marker placed, using the constrain to plane option if necessary (see Section 3.7). An FEM marker is then created and attached to the nearest element in the FEM. If the marker position is outside the FEM, it is projected onto the closest point on the FEM surface.

In addition, the button Add Amira Landmarks allows a user to add a set of markers based on locations in an Amira landmark file.

From top to bottom, the FemMarker editing panel contains

- An *Existing markers* list, showing all the FEM's frame markers (expressed by their path names with respect to the FEM). This list is connected to the selection manager and can be used to select one or more markers.
- A *name* field that allows a name to be specified for the marker.
- A *Default marker properties* panel, which allows the user to set properties for subsequent markers that are added.
- An *instruction box* containing directions for the user.
- A constrain to plane option.
- An *option* panel, containing an Add Amira Landmarks button, described above, and a Done button which the user should click when finished.

### 13.6.2 Adding muscle bundles

**FemMuscleModel** is a subclass of **FemModel3d** that supports muscle activation. A **FemMuscleModel** may contain muscle bundles (type **MuscleBundle**), each of which is composed of *fibres* and *elements*. The fibres are two-point muscles connecting nodes or markers within the FEM model, with activation provided by forces acting directly on the fibre end points. The elements are a set of references to existing elements within the FEM model, each combined with an activation direction. Each element reference within the bundle provides muscle activation behavior by superimposing a transversely isotropic material behavior on top of the underlying element's material behavior.

Activation of a **MuscleBundle** can be effected by either the fibres *or* the elements, with the latter generally providing a superior simulation result. By default, the fibres are inactive, and are used simply to provide a good visual indication of the activation directions within the model, and a way to automatically compute the referenced elements and their directions (as described below). To make the fibres active, set the bundle's `fibresActive` property to `true`. Conversely, to make the elements inactive, set the bundle's `muscleMaterial` property to `InactiveMuscle`.

To add a **MuscleBundle** to a **FemMuscleModel**, select the model and then choose "Add MuscleBundle ..." from the context menu. This will immediately add a **MuscleBundle** to the model, and then open a **MuscleFibre** editing panel (see Section 13.7.1) to allow the user to add fibres to the model. The panel also contains two extra fields at the top: bundle name, allowing a name to be specified for the bundle, and bundle `renderProps`, allowing its render properties to be adjusted. At present, the panel does not contain a Cancel option. To remove the **MuscleBundle**, either select and delete it, or choose "Undo add MuscleBundle" from the Edit menu.

## 13.7 Editing Muscle Bundles

Existing muscle bundles can be editing to add or remove fibres or element references.

### 13.7.1 Adding fibres

Fibres can be added to a **MuscleBundle** by selecting the bundle and then choosing "Edit fibres ..." from the context menu. This will open a **MuscleFibre** editing panel as shown in Figure 44.

The operation of this panel is essentially identical to the **AxialSpring** editing panel described in Section 13.4.5: fibres are added by successively selecting the points (which in this case must be FEM nodes or markers) which serve as the endpoints for the fibres in question.

The only difference from the **AxialSpring** panel is that the spring type is assumed to be a **Muscle** and there is no option to change this.

### 13.7.2 Adding element references

Elements can be added to a **MuscleBundle** by selecting the bundle and then choosing "Edit elements ..." from the context menu. This will open a **MuscleElement** editing panel as shown in Figure 45.

The operation of this panel is quite simple: one selects the elements that one wishes to add, and then clicks on the Add button to add them to the bundle. Elements which are already contained in the bundle will be excluded. Viewer-based element selection is described in more detail below.

From top to bottom, the **MuscleElement** editing panel contains

- A list of element references already associated with the bundle (expressed by the elements' path names with respect to the FEM muscle model). To remove element references from the bundle, one may select them in this list and then choose "Delete" from the context menu. It should be noted that this deletes the *references* for the elements within the bundle, and not the elements themselves from the FEM model.
- Fields `modelElementSize` and `bundleElementSize` which control the size of the element widgets which are rendered for both the FEM muscle model and the bundle, as described below.
- An *instruction box* containing directions for the user.

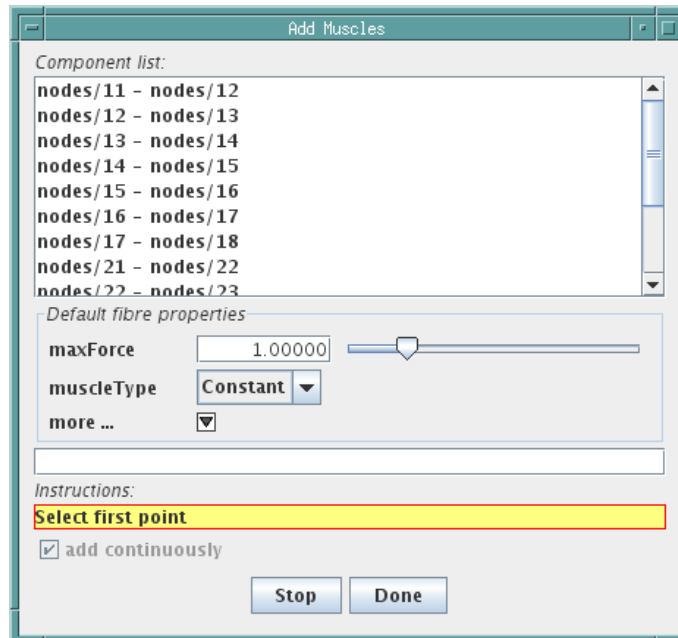


Figure 44: Panel for adding fibres to a muscle bundle.

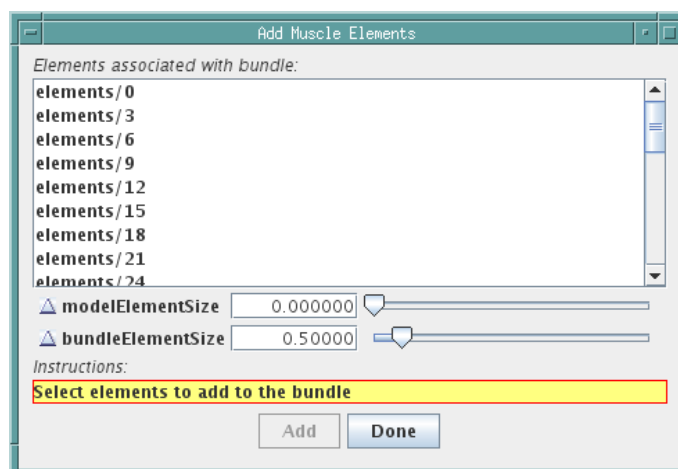


Figure 45: Panel for adding elements to a muscle bundle.

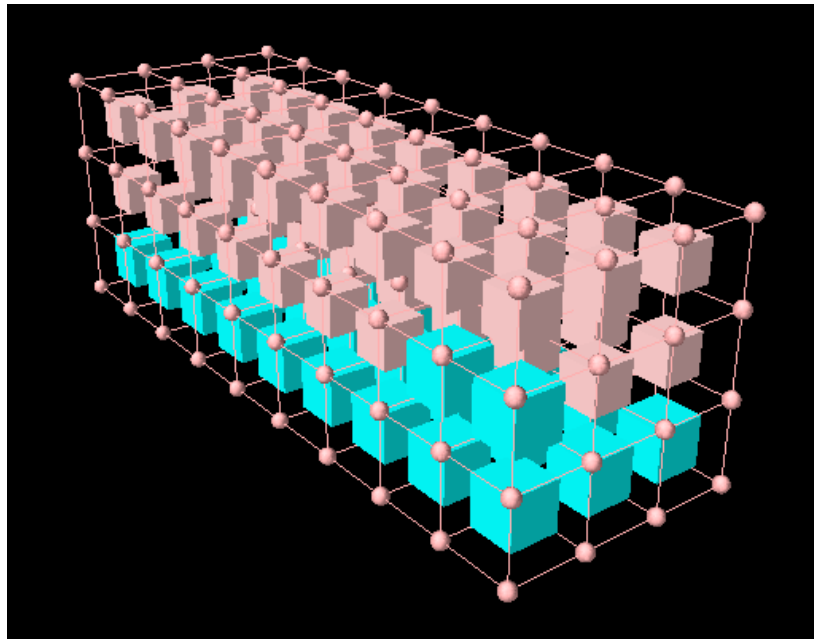


Figure 46: Element widgets rendered for both an FEM model (pink) and a muscle bundle (cyan).

- An *option* panel, containing an Add button which adds selected elements to the bundle, and a Done button which the user should click when finished.

Element selection is often done by clicking on an *element widget* in the viewer. An element widget is a simplified solid rendering of an element's shape, with a size that varies from 0 to 1, with 0 being invisible and 1 being the full size of the element. Element widgets can be rendered for all the elements in an FEM model, with a size controlled by the model's `elementWidgetSize` property. In addition, separate widgets can be rendered for the all the elements referenced by a muscle bundle, with a size controlled by the bundle's `elementWidgetSize` property. In order to be able to see and select both the referenced elements in a bundle, and the other elements in the FEM model, one should set `elementWidgetSize` for the bundle and the model to values greater than zero, with the former larger than the latter. Figure 46 shows a simple example where referenced elements in a bundle are rendered using a widget size of 0.6, while the model elements themselves are rendered using a widget size of 0.5.

To facilitate element selection and visualization, the `MuscleElement` panel temporarily sets `elementWidgetSize` to 0.6 for the bundle and 0.5 for the FEM model. These values can then be adjusted as needed.

### 13.7.3 Automatically Setting Elements and Directions

Since manually selecting elements and specifying their directions for a muscle bundle can be quite tedious, a number of methods exist to help do this automatically, using the easier-to-visualize information supplied by the muscle fibres. From the `MuscleBundle` context menu, one may select:

#### Compute element directions

Automatically computes directions for all referenced elements, using a Delaunay-based interpolation of the directions of the fibres which are closest to them.

#### Add elements near fibres ...

Automatically adds to the set of referenced elements all elements whose centers are within a prescribed distance of one or more of the fibres.

#### Delete elements

Deletes all the element references for the bundle.

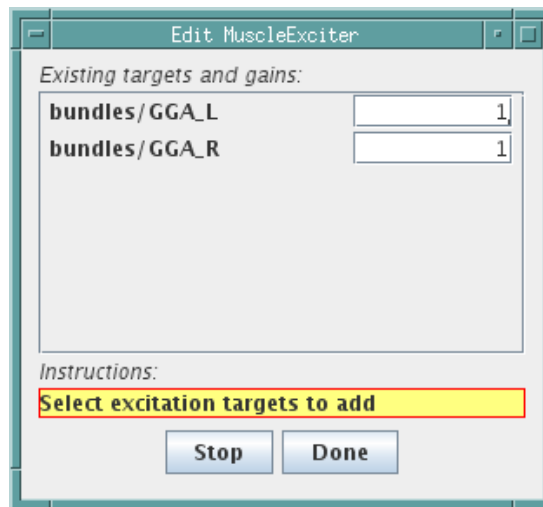


Figure 47: Panel for editing the targets of a muscle exciter.

### 13.7.4 Removing fibres and element references

To remove specific fibres or element references, simply select them (using any of the selection mechanisms), and then choose "Delete" from the context menu.

## 13.8 Editing Muscle Exciters

A **MuscleExciter** is a component that allows muscle excitation signals to be distributed to a set of target **ExcitationComponents**. Excitation components include anything that can receive a muscle excitation, including point-to-point muscles, muscle bundles, and other muscle exciters. The purpose of a muscle exciter is to facilitate grouping so that one excitation signal can drive a number of underlying components. They can be optionally added to both **MechModels** and **FemMuscleModels**, where they are stored in a component list called `exciters`.

The GUI provides the ability to edit the targets associated with a given exciter. To do this, select the exciter in question, and then choose "Edit targets ..." in the context menu. This will open an **ExcitationTarget** panel, as shown in Figure 47.

To add a new excitation target, select the desired excitation component (using any of the selection mechanisms), and it will be added to the list of existing targets. Each target is also associated with a gain, by which the excitation signal is multiplied as it is passed on to the target. Gains can be edited using the numeric field in the list of targets. Finally, to remove a target, simply select it in the list of targets, and choose "remove targets" from the context menu.

From top to bottom, the **ExcitationTarget** panel contains

- An *Existing targets* list, showing all the current targets, allowing them to be selected for removal or their gains to be edited.
- An *instruction box* containing directions for the user.
- An *option* panel, containing an Add/Stop button which can be used to initiate or stop the adding of targets, and a Done button which the user should click when finished.

## 13.9 Editing Root Models

Some very limited graphical editing is available for **RootModels**. It is possible to add a **MechModel** to the **RootModel**, by selecting the **RootModel** and then choosing "Add MechModel ..." in the context menu. This brings up a **MechModel** editing panel as shown in Figure 48.

The panel is quite simple: you edit the **MechModel** properties to the appropriate settings, click the Add button, and a new **MechModel** is added. However, this is of limited use, since normally only one **MechModel** is placed directly under the **RootModel**, as multiple **MechModels** cannot be advanced using the same integrator and must therefore be completely decoupled.

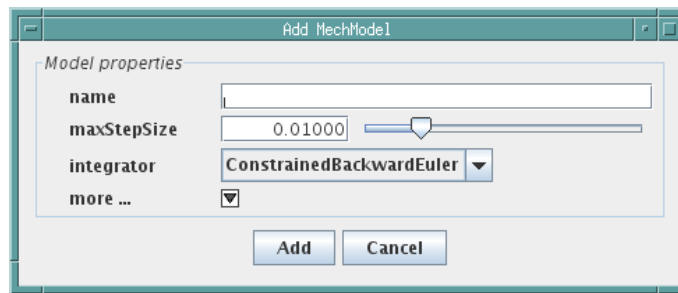


Figure 48: Panel for adding a MechModel to a RootModel.

## 14 Customizing the Models Menu

The Models menu is automatically created at run-time. By default, it has the format described in Section 2.1. However, it is possible to supply an alternative Models menu either of the following command-line parameters:

**-demosFile <filename>** Specifies a flat list of models to be loaded, using a plaintext format.

**-demosMenu <filename>** Specifies a menu that may contain hierarchies, separators, and icons, using an XML format.

A description of both file formats are provided in the following sections.

### 14.1 Plaintext Format

In the plaintext format, entries are listed as title-class pairs, separated by whitespace. Lines beginning with a hash (#) are ignored. Titles containing spaces must be surrounded by quotation marks. The following is an example:

```
# Inverse Demos
HydrostatInvDemo artisynth.models.inversedemos.HydrostatInvDemo
"Tongue tracking" artisynth.models.inversedemos.TongueTip
```

### 14.2 XML Format

The XML format was designed to give users more control over the appearance of the menu. An XML schema is provided that describes and enforces the required document structure (`src/artisynth/core/modelmenu/modelmenu.xsd`). The following XML elements are defined:

<code>ModelMenu:</code>	the root element of the document
<code>model:</code>	specifies a model that can be loaded
<code>separator:</code>	inserts a horizontal line that separates entries
<code>label:</code>	inserts an inactive text entry
<code>menu:</code>	creates a sub-menu
<code>package:</code>	finds and lists all models from a specified Java package
<code>demosFile:</code>	imports all models from a file in plaintext format
<code>include:</code>	imports a menu from another XML file
<code>hidden:</code>	convenience element for hiding menu entries (i.e. commenting them out)

A detailed description of each of the element types and their supported attributes is provided in the next sections. Attributes marked by an asterisk are required in the element definition. Some attributes, such as `icon`, refer to an external file location. The parser tries to find included files by searching directories in the following order:

- The root directory (i.e. absolute path)

- The local directory, relative to the XML file
- All directories listed in ARTISYNTH\_PATH

The first readable file found is used.

### 14.2.1 The root element

The root element encapsulates the entire menu description. It must make reference to the schema for validation purposes. The following code snippet can be used as a template for creating a new menu file.

```
<?xml version="1.0" encoding="UTF-8"?>
<ModelMenu xmlns="http://www.artisynth.org"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.artisynth.org src/artisynth/core/modelmenu/modelmenu.xsd"
  >
  #... contents of menu ...#
</ModelMenu>
```

**Note:**

The second value of `schemaLocation` is the location of the schema file, which may need to be modified depending on its path relative to the current XML file.

### 14.2.2 Models

Individual models are inserted into the menu using a `model` element. These specify a class to load when the menu entry is selected. The model must be a sub-class of [RootModel](#).

**Attributes:**

<code>class*</code> :	the class to load when the entry is selected
<code>text</code> :	the text to display in the menu (default: the class name)
<code>icon</code> :	filename of an icon (relative or absolute path)
<code>fontname</code> :	font family for the displayed text
<code>fontstyle</code> :	font style, from { "", "bold", "italic", "bold italic" }
<code>fontsize</code> :	font size

The following snippet creates a menu entry titled "Muscle Arm", which will launch the model `FemMuscleArm`.

```
<model class="artisynth.models.femdemos.FemMuscleArm" text="Muscle Arm" />
```

### 14.2.3 Separators

A separator is a horizontal line that visually separates menu entries. It can help distinguish groups of related menu items. The separator element has no attributes. The following snippet adds a separator line between models found in the `artisynth.models.femdemos` package and those in `artisynth.models.inversedemos`.

```
<package source="artisynth.models.femdemos" />
<separator/>
<package source="artisynth.models.inversedemos" />
```



### 14.2.4 Labels

Labels are inactive text entries; they cannot be selected in the menu. They can be used to label a group of entries. To help distinguish a label from an active menu item, it is recommended to set the font style to “italic”.

**Attributes:**

text\*: the text to display in the menu  
icon: filename of an icon (relative or absolute path)  
fontname: font family for the displayed text  
fontstyle: font style, from {“, “bold”, “italic”, “bold italic”}  
fontsize: font size

In the following code snippet, a label is added before the tongue tracking models.

```
<label text="Tongue Tracking Models" fontstyle="italic" />
<model class="artisynt.models.tracker.JawDynamicTongue" />
<model class="artisynt.models.tracker.JawKinematicTongue" />
```

### 14.2.5 Sub-menus

Menu hierarchies can be created using the `menu` element. Apart from the root element, this is the only non-empty element type. It can contain any number of valid elements apart from the root element.

**Attributes:**

text\*: the text to display for the sub-menu  
icon: filename of an icon (absolute or relative path)  
fontname: font family for the displayed text  
fontstyle: font style, from {“, “bold”, “italic”, “bold italic”}  
fontsize: font size

The following code snippet creates a sub-menu "FEM Models" with a specified icon, and lists all models found within the `artisynt.models.femdemos` package.

```
<menu text="FEM Models" icon="resources/icons/FEM.gif">
  <package source="artisynt.models.femdemos" />
</menu>
```

### 14.2.6 Packages

The `package` element can be used to include all models belonging to a particular Java package and its sub-packages. A base class can also be specified so that only models that are instances of that base class are added. For example to include all models that are sub-classes of `HexTongueDemo`, the following line can be used:

```
<package source="artisynt.models" base="artisynt.models.femdemos.HexTongueDemo" />
```

The models can be displayed in either a flat or hierarchical structure. To reduce the number of sub-menus, and to shorten some of the displayed text, a “compactness” level is introduced. Illustrative examples for the options are provided in [Figure 49](#).

**Attributes:**

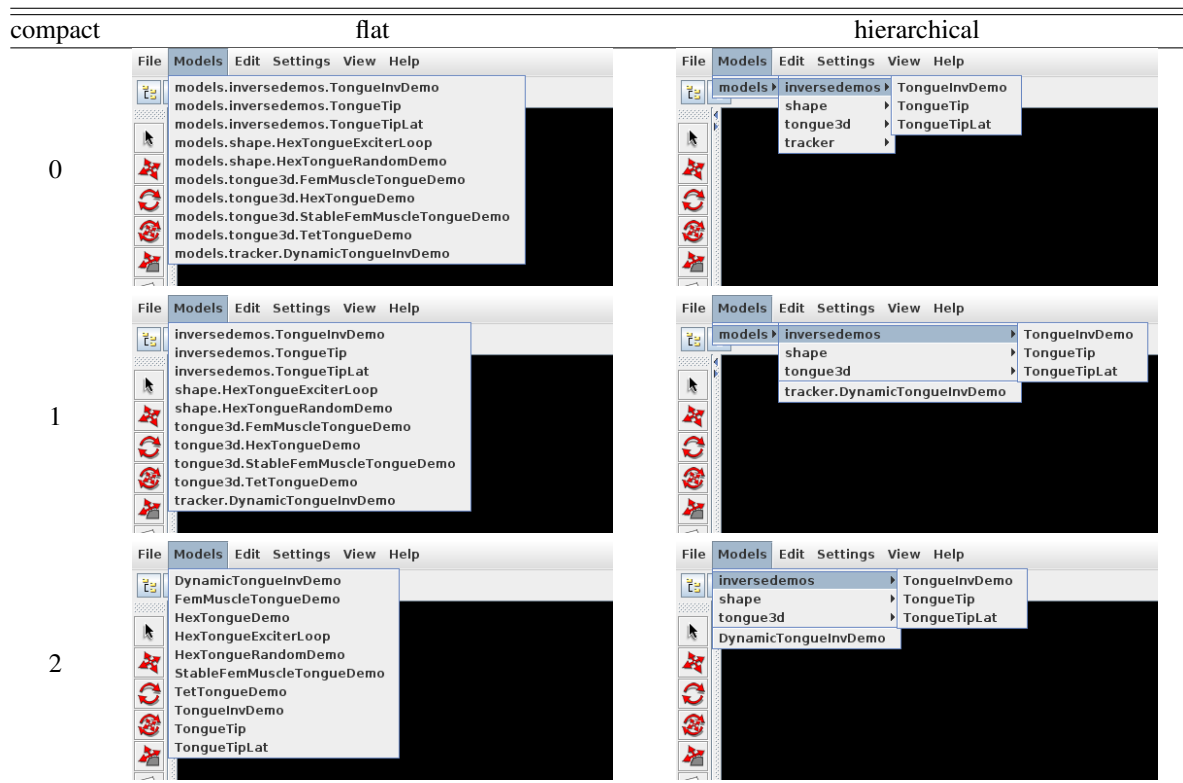


Figure 49: View options for the XML element `<package source="artisynt" base="HexTongueDemo"/>`

`source*`: the package to search for models  
`base`: the base class from which all models must inherit (default: `RootModel`)  
`view`: display format {“flat”, “hierarchicial”} (default: “hierarchicial”)  
`compact`: level of compactness {0, 1, 2} (default: 0)  
     0: A new sub-menu is created for each sub-package (hierarchicial), displayed text refers to full package.class name relative to `source` (flat)  
     1: Sub-packages containing a single entity are merged into the parent menu (hierarchicial), displayed text refers to unique part of the package.class name only (flat)  
     2: Sub-packages containing a single entity are merged into the parent menu (hierarchicial) and displayed text refers to the class name only (hierarchicial/flat)  
`fontname`: font family for the displayed text  
`fontstyle`: font style, from {“”, “bold”, “italic”, “bold italic”}  
`fontsize::` font size

If font information is provided, it is applied to all entries.

```
<package source="" view="flat" compact="2" fontsize="5"/>
```

The previous listing adds every single instance of `RootModel` found in the source tree to the menu. To get the menu to fit on the screen, `compact="2"` was used to strip away all package information from the displayed text, and a tiny font was applied to all entries.

#### Note:

The package element should be used sparingly for two main reasons:

1. Each element adds to the ArtiSynth start-up time.
2. Not all models are functional.

The reason for the start-up delay is that to populate the menu, the parser has to search through the supplied package, create an instance of each class, and test if it is a sub-class of `base`. The parser also has no way of detecting whether or not a model is functional, so all classes matching the criteria are added.

#### 14.2.7 Plaintext files

The XML format supports loading models from a `demosFile` that uses the original plaintext format. Plaintext files have the advantage of being more human-readable, and are easier to edit/comment lines out. Models are listed in the current sub-menu.

**Attributes:**

`file*`: plaintext file to load  
`fontname`: font family for the displayed text  
`fontstyle`: font style, from { "", "bold", "italic", "bold italic" }  
`fontsize`: font size

The following line loads all models from the original default ArtiSynth Models menu.

```
<demosFile file=".demoModels" />
```

If font information is provided, it is applied to all model entries that are created.

#### 14.2.8 Importing other XML files

To facilitate modularity, the `include` element can be used to import all menu content from another XML menu file. All elements contained within the root element of the included file are inserted into the current sub-menu.

**Attributes:**

`file*`: XML file to import

The following code imports the contents from two different XML menu files, and separates them with a separator item.

```
<include file="demos.xml" />
<separator/>
<include file="mymodels.xml" />
```

#### 14.2.9 Hiding Elements

It is often convenient to have the ability to “comment-out” lines in any kind of coding system: the data remains in the file, but has no effect when processed. The typical method for commenting in XML is to use the `<!-- -->` tags. Unfortunately, this can be messy, and comments cannot contain other comments. For this reason, a special `hidden` element was created. Any entries within a `hidden` element are ignored by the parser.

```
<!-- temporarily hide FEM demos -->
<hidden>
  <!-- All FEM demos -->
  <package source="artisynth.models.femdemos" view="flat"/>
</hidden>
```