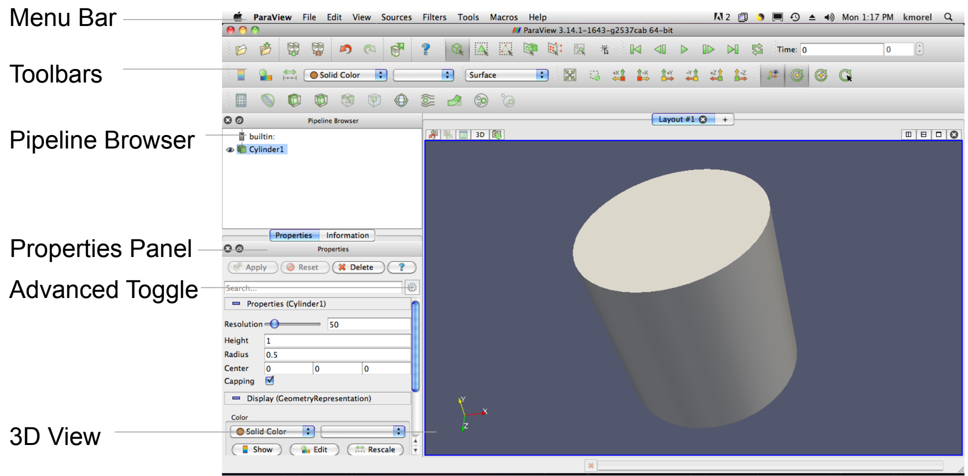
Chapter 2

Basic Usage

Let us get started using ParaView. In order to follow along, you will need your own installation of ParaView. Specifically, this document is based off of ParaView version 4.1. If you do not already have ParaView 4.1, you can download a copy from www.paraview.org (click on the download link). ParaView launches like most other applications. On Windows, the launcher is located in the start menu. On Macintosh, open the application bundle that you installed. On Linux, execute `paraview` from a command prompt (you may need to set your path).

The examples in this tutorial also rely on some data that is available at http://www.paraview.org/Wiki/The_ParaView_Tutorial. You may install this data into any directory that you like, but make sure that you can find that directory easily. Any time the tutorial asks you to load a file it will be from the directory you installed this data in.

2.1 User Interface



The ParaView GUI conforms to the platform on which it is running, but on all platforms it behaves basically the same. The layout shown here is the default layout given when ParaView is first started. The GUI comprises the following components.

Menu Bar As with just about any other program, the menu bar allows you to access the majority of features.

Toolbars The toolbars provide quick access to the most commonly used features within ParaView.

Pipeline Browser ParaView manages the reading and filtering of data with a pipeline. The pipeline browser allows you to view the pipeline structure and select pipeline objects. The pipeline browser provides a convenient list of pipeline objects with an indentation style that shows the pipeline structure.

Properties Panel The properties panel allows you to view and change the parameters of the current pipeline object. On the properties panel is an advanced properties toggle ⚙ that shows and hides advanced controls. The properties are by default coupled with an **Information** tab that shows a basic summary of the data produced by the pipeline object.

3D View The remainder of the GUI is used to present data so that you may view, interact with, and explore your data. This area is initially populated with a 3D view that will provide a geometric representation of the data.

Note that the GUI layout is highly configurable, so that it is easy to change the look of the window. The toolbars can be moved around and even hidden from view. To toggle the use of a toolbar, use the View → Toolbars submenu. The pipeline browser and properties panel are both **dockable** windows. This means that these components can be moved around in the GUI, torn off as their own floating windows, or hidden altogether. These two windows are important to the operation of ParaView, so if you hide them and then need them again, you can get them back with the View menu.

2.2 Sources

There are two ways to get data into ParaView: read data from a file or generate data with a **source** object. All sources are located in the Sources menu. Sources can be used to add annotation to a view, but they are also very handy when exploring ParaView's features.

Exercise 2.1: Creating a Source

Let us start with a simple one. Go to the Sources menu and select Cylinder. Once you select the Cylinder item you will notice that an item named Cylinder1 is added to and selected in the pipeline browser. You will also notice that the properties panel is filled with the properties for the cylinder source. Click the Apply button 

to accept the default parameters.

Once you click Apply, the cylinder object will be displayed in the 3D view window on the right. You can manipulate this 3D view by dragging the mouse over the 3D view. Experiment with dragging different mouse buttons—left, middle, and right—to perform different rotate, pan, and zoom operations. Also try using the buttons in conjunction with the shift and ctrl modifier keys.

ParaView contains a couple of toolbars to help with camera manipulations. The first toolbar, the Camera Controls toolbar, shown here provides quick access to particular camera views. The leftmost button performs a **reset camera** such that it maintains the same view direction but repositions the camera such that the entire object can be seen. The second button performs a **zoom to data**. It behaves very much like reset camera except that instead of positioning the camera to see all data, the camera is placed to look specifically at the data currently selected in the pipeline browser. You currently only have one object in the pipeline browser, so right now reset camera and zoom to data will perform the same operation.

The next button in the camera controls toolbar allows you to select a rectangular region of the screen to zoom to (a **rubber-band zoom**). The following six buttons reposition the camera to view the scene straight down one of the global coordinate's axes in either the positive or negative direction. Try playing with these controls now.

The second toolbar controls the location of the center of rotation and the visibility of the orientation axes. The rightmost button allows you to pick the **center of rotation**. Try clicking that button then clicking somewhere on the cylinder. If you then drag the left button in the 3D view, you will notice that the cylinder now rotates around this new point. The next button to the left replaces the center of rotation to the center of the object. The next button to the left shows or hides and axis drawn at the center of rotation. (You probably will not notice the effects when the center of rotation is at the center of the cylinder because the axes will be hidden by the cylinder. Use the pick center of rotation again and you should be able to see the effects.) The final leftmost button toggles showing the **orientation axes**, the always-viewable axes in the lower left corner of the 3D view.

You surely noticed that ParaView creates not a real cylinder but rather an approximation of a cylinder using polygonal **facets**. The default parameters for the cylinder source provide a very coarse approximation of only six facets. (In fact, this object looks more like a prism than a cylinder.) If we want a better representation of a cylinder, we can create one by increasing the Resolution parameter.

Using either the slider or text edit, increase the resolution to 50 or more. Notice that the Apply button started pulsing blue. This is because changes you make to the object properties are not immediately enacted. The highlighted button is a reminder that the parameters of one or more pipeline objects are "out of sync" with the data that you are viewing. Hitting the Apply button will accept these changes whereas hitting the Reset button will revert the options back to the last time they were applied. Hit the Apply button now. The resolution is changed so that it is virtually indistinguishable from a true cylinder.

If you scroll down to the bottom of the properties panel, you will notice a set of Display properties. Try these options now by clicking on the Edit button to change the color of the cylinder. (This button is also replicated in the toolbar.) You may notice that you do not need to hit Apply for display properties. ♦

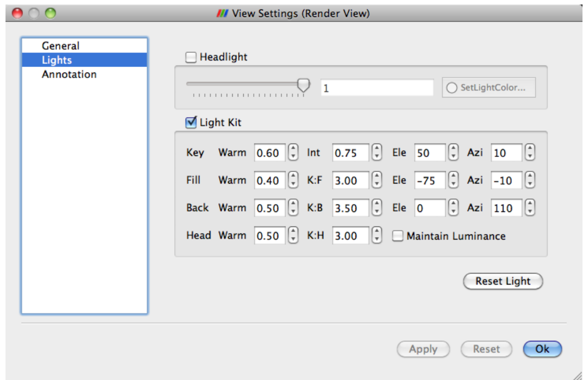
Now is a good time to note the undo and redo buttons in the toolbar. Visualizing your data is often an exploratory process, and it is often helpful to revert back to a previous state. You can even undo back to the point before your data was created and redo again.

Exercise 2.2: Undo and Redo

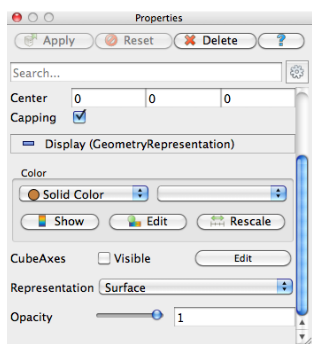
Experiment with the undo and redo buttons. If you have not done so, create and modify a pipeline object like what is done in Exercise 2.1. Watch how parameter changes can be reverted and restored. Also notice how whole pipeline objects can be destroyed and recreated.

There are also undo camera and redo camera buttons. These allow you to go back and forth between camera angles that you have made so that you do not have to worry about errant mouse movements ruining that perfect view. Move the camera around and then use these buttons to revert and restore the camera angle. ♦

There are also many options for selecting how objects are rendered. You will notice over the 3D view a button for changing the rendering options. Clicking this brings up a dialog box that allows you to change things like the background color, the lighting, and annotation.



As discussed in Exercise 2.1, another location for rendering options is the Display section in the properties panel. These properties provide the rendering options that apply specifically for the selected object. It includes the visibility, coloring, and representation. By default many of the lesser used display properties are hidden. The **advanced properties** toggle can be used to show or hide these extra parameters. Be aware that some of the view options and object display options can be repeated elsewhere in the ParaView GUI for convenience.



Exercise 2.3: Modifying Rendering Parameters

Click the button above the 3D view to bring up the Render View Options dialog box. Explore the different panels of options. Try modifying how the view looks in the following ways. (Remember that you will have to hit Apply or OK before the changes take effect.)

- Change the background color. (Notice that you can reset it to the default.)

- Turn the Orientation Axis (the axis in the lower left corner of the view) off and on. (This can also be done using an icon that looks like the Orientation Axis on the right side of the toolbars on top)
- Move the Orientation Axis in the view. (Hint: Make the axis interactive and then click and drag in the 3D view.)

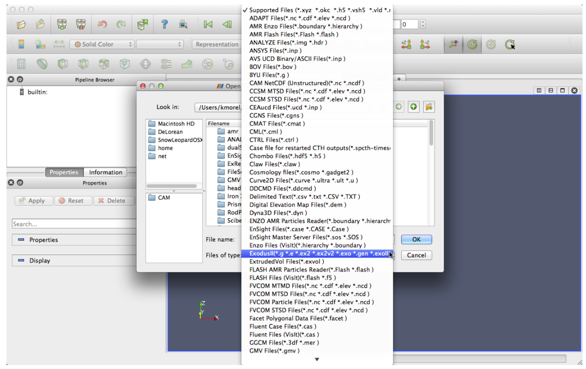
Now change the drawing parameters of the cylinder. (If you do not have a cylinder or another pipeline object, create one as described in Exercise 2.1.) Make sure the cylinder is selected in the pipeline browser. In the properties panel, scroll down to the Display section.

- Set the (solid) color of the cylinder by clicking the Edit button.
- Show 3D axes with tic marks giving spatial position (make Cube Axis visible).
- Make the cylinder shiny. (Hint: Make the Specular Intensity 1.0. This is an advanced parameter, so you will need to toggle .)
- Make the cylinder transparent. (Hint: Lower the Opacity.)

We are done with the cylinder source now. We can delete the pipeline object by selecting the Properties tab and hitting delete Delete in the properties panel. ♦

2.3 Loading Data

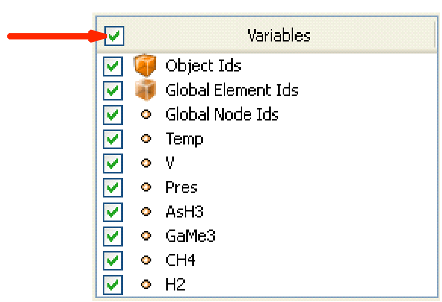
Now that we have had some practice using the ParaView GUI, let us load in some real data. As you would expect, the Open command is the first one off of the File menu, and there is also toolbar button for opening a file. ParaView currently supports over 130 distinct file formats, and the list grows as more types get added. To see the current list of supported files, invoke the Open command and look at the list of files in the Files of type chooser box.



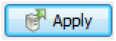
ParaView's modular design allows for easy integration of new VTK readers into ParaView. Thus, check back often for new file formats. If you are looking for a file reader that does not seem to be included with ParaView, check in with the ParaView mailing list (paraview@paraview.org). There are many file readers included with VTK but not exposed within ParaView that could easily be added. There are also many readers created that can plug into the VTK framework but have not been committed back to VTK; someone may have a reader readily available that you can use.

Exercise 2.4: Opening a File

Let us open our first file now. Click the Open toolbar (or menu item) and open the file disk_out_ref.ex2. Note that opening a file is a two step process, so that you do not see any data yet. Instead, you see that the properties panel is populated with several options about how we want to read the data.

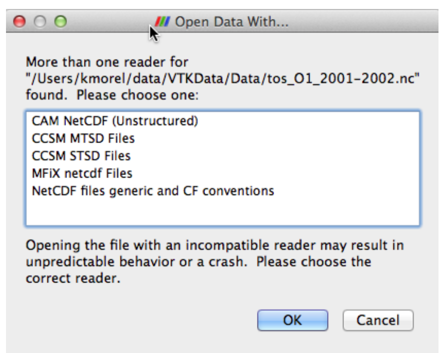


Click the checkbox in the header of the variable list to turn on the loading of all the variables. This is a small data set, so we do not have to worry about loading too much into memory. Once all of the variables are selected, click

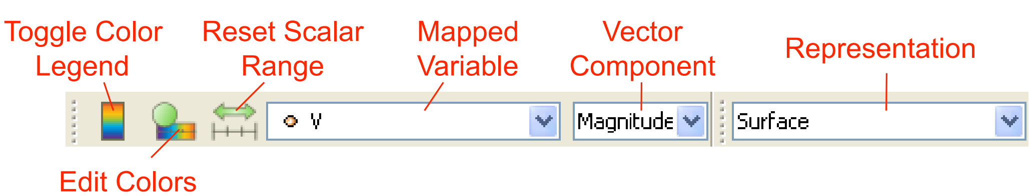


to load all of the data. When the data is loaded you will see that the geometry looks like a cylinder with a hollowed out portion in one end. This data is the output of a simulation for the flow of air around a heated and spinning disk. The mesh you are seeing is the air around the disk (with the cylinder shape being the boundary of the simulation). The hollow area in the middle is where the heated disk would be were it meshed for the simulation. ♦

Most of the time ParaView will be able to determine the appropriate method to read your file based on the file extension and underlying data, as was the case in Exercise 2.4. However, with so many file formats supported by ParaView there are some files that cannot be fully determined. In this case, ParaView will present a dialog box asking what type of file is being loaded. The following image is an example from opening a netCDF file, which is a generic file format for which ParaView has many readers for different conventions.

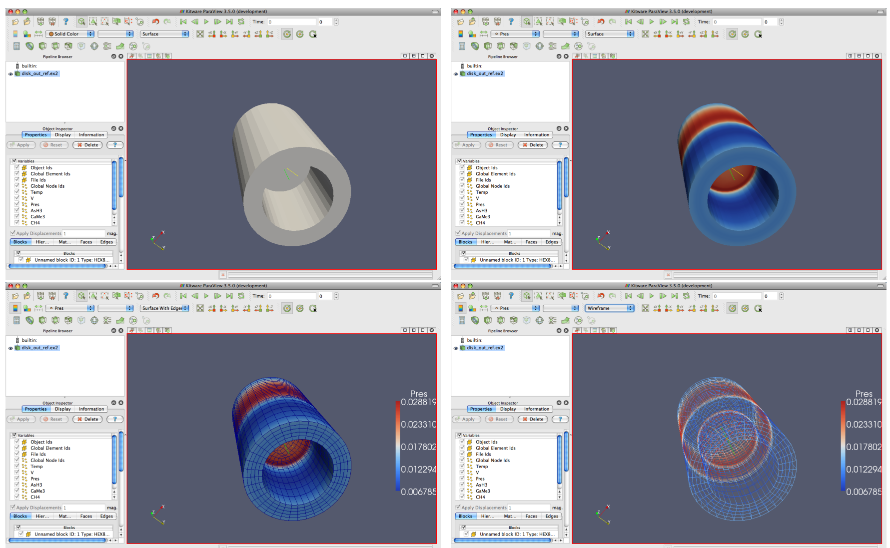


Before we continue on to filtering the data, let us take a quick look at some of the ways to represent the data. The most common parameters for representing data are located in a pair of toolbars. (They can also be found in the Display group of the properties panel.)



Exercise 2.5: Representation and Field Coloring

Play with the data representation a bit. Make sure disk_out_ref.ex2 is selected in the pipeline browser. (If you do not have the data loaded, repeat Exercise 2.4.) Use the variable chooser to color the surface by the Pres variable. Then turn the color legend on to see the actual pressure values. To see the structure of the mesh, change the representation to Surface With Edges. You can view both the cell structure and the interior of the mesh with the Wireframe representation.



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2.4 Filters

We have now successfully read in some data and gleaned some information about it. We can see the basic structure of the mesh and map some data onto the surface of the mesh. However, as we will soon see, there are many interesting features about this data that we cannot determine by simply looking at the surface of this data. There are many variables associated with the mesh of different types (scalars and vectors). And remember that the mesh is a solid model. Most of the interesting information is on the inside.

We can discover much more about our data by applying **filters**. Filters are functional units that process the data to generate, extract, or derive features from the data. Filters are attached to readers, sources, or other filters to modify its data in some way. These filter connections form a **visualization pipeline**. There are a great many filters available in ParaView. Here are the most common, which are all available by clicking on the respective icon in the filters toolbar.

Calculator Evaluates a user-defined expression on a per-point or per-cell basis.

Contour Extracts the points, curves, or surfaces where a scalar field is equal to a user-defined value. This surface is often also called an **isosurface**.

Clip Intersects the geometry with a half space. The effect is to remove all the geometry on one side of a user-defined plane.

Slice Intersects the geometry with a plane. The effect is similar to clipping except that all that remains is the geometry where the plane is located.

Threshold Extracts cells that lie within a specified range of a scalar field.

Extract Subset Extracts a subset of a grid by defining either a volume of interest or a sampling rate.

Glyph Places a **glyph**, a simple shape, on each point in a mesh. The glyphs may be oriented by a vector and scaled by a vector or scalar.

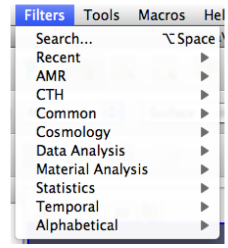
Stream Tracer Seeds a vector field with points and then traces those seed points through the (steady state) vector field.

Warp (vector) Displaces each point in a mesh by a given vector field.

Group Datasets Combines the output of several pipeline objects into a single multi block data set.

Extract Level Extract one or more items from a multi block data set.

These eleven filters are a small sampling of what is available in ParaView. In the Filters menu are a great many more filters that you can use to process your data. ParaView currently exposes more than one hundred filters, so to make them easier to find the Filters menu is organized into submenus. These submenus are organized as follows.



Recent The list of most recently used filters sorted with the most recently used filters on top.

AMR A set of filters designed specifically for data in an adaptive mesh refinement (AMR) structure.

CTH Filters used to process results from a CTH simulation.

Common The most common filters. This is the same list of filters available in the filters toolbar and listed previously.

Cosmology This contains filters developed at LANL for cosmology research.

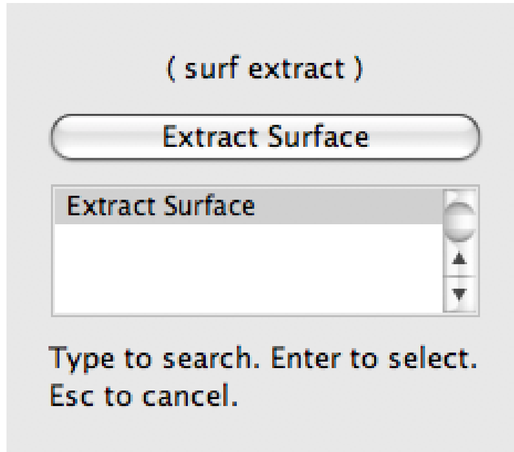
Data Analysis The filters designed to retrieve quantitative values from the data. These filters compute data on the mesh, extract elements from the mesh, or plot data.

Material Analysis Filters for processing data from volume fractions of materials.

Statistics This contains filters that provide descriptive statistics of data, primarily in tabular form.

Temporal Filters that analyze or modify data that changes over time. All filters can work on data that changes over time because they are executed on each time snapshot. However, filters in this category will introspect the available time extents and examine how data changes over time.

Alphabetical An alphabetical listing of all the filters available. If you are not sure where to find a particular filter, this list is guaranteed to have it. There are also many filters that are not listed anywhere but in this list.



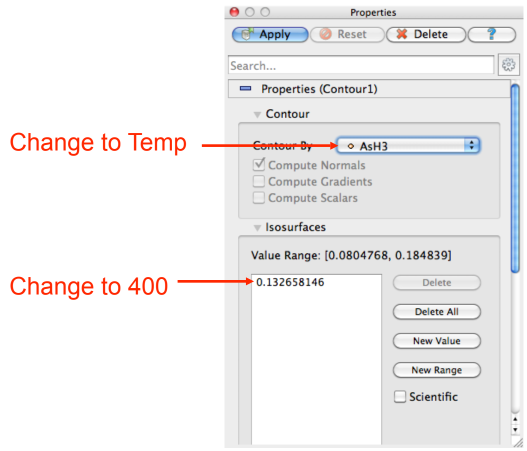
Searching through these lists of filters, particularly the full alphabetical list, can be cumbersome. To speed up the selection of filters, you should use the **quick launch** dialog. Pressing the ctrl and space keys together on Windows or Linux or the alt and space keys together on Macintosh, ParaView brings up a small, lightweight dialog box like the one shown here. Type in words or word fragments that are contained in the filter name, and the box will list only those sources and filters that match the terms. Hit enter to add the object to the pipeline browser. Press Esc a couple of times to cancel the dialog.

You have probably noticed that some of the filters are grayed out. Many filters only work on a specific types of data and therefore cannot always be used. ParaView disables these filters from the menu and toolbars to indicate (and enforce) that you cannot use these filters.

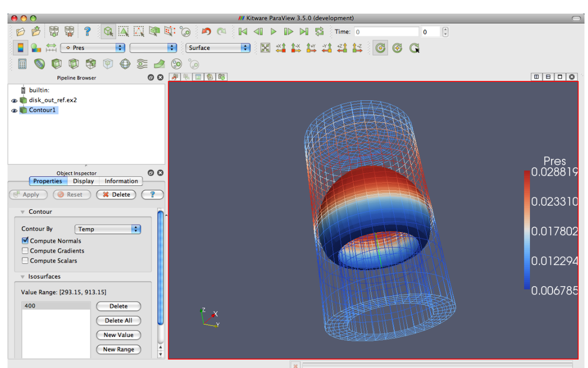
Throughout this tutorial we will explore many filters. However, we cannot explore all the filters in this forum. Consult the Filters Menu chapter of ParaView's on-line or in-built help for more information on each filter.

Exercise 2.6: Apply a Filter

Let us apply our first filter. If you do not have the disk_out_ref.ex2 data loaded, do so know (Exercise 2.4). Make sure that disk_out_ref.ex2 is selected in the pipeline browser and then select the contour filter from the filter toolbar or Filters menu. Notice that a new item is added to the pipeline filter underneath the reader and that the properties panel updates to the parameters of the new filter. As with reading a file, applying a filter is a two step process. After creating the filter you get a chance to modify the parameters (which you will almost always do) before applying the filter.



We will use the contour filter to create an isosurface where the temperature is equal to 400 K. First, change the Contour By parameter to the Temp variable. Then, change the isosurface value to 400. Finally, hit Apply. You will see the isosurface appear inside of the volume. If disk_out_ref.ex2 was still colored by pressure from Exercise 2.5, then the surface is colored by pressure to match.



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In the preceding exercise, we applied a filter that processed the data and gave us the results we needed. For most common operations, a single filter operation is sufficient to get the information we need. However, filters are of the same class as readers. That is, the general operations we apply to readers can also be applied to filters. Thus, you can apply one filter to the data that is generated by another filter. These readers and filters connected together form what we call a **visualization pipeline**. The ability to form visualization pipelines provides a powerful mechanism for customizing the visualization to your needs.

Let us play with some more filters. Rather than show the mesh surface in wireframe, which often interferes with the view of what is inside it, we will replace it with a cutaway of the surface. We need two filters to perform this task. The first filter will extract the surface, and the second filter will cut some away.

Exercise 2.7: Creating a Visualization Pipeline

The images and some of the discussion in this exercise assume you are starting with the state right after finishing Exercise 2.6. If you have had to restart ParaView since or your state does not match up well enough, it is sufficient to simply have disk_out_ref.ex2 loaded.

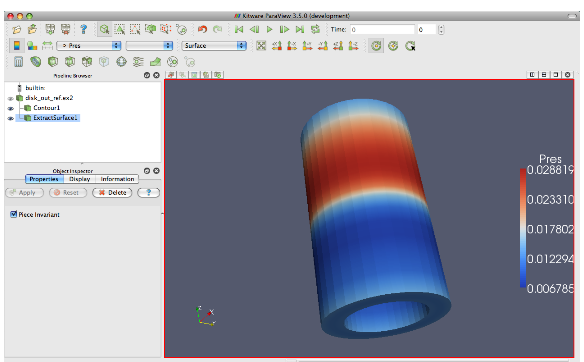
Start by adding a filter that will extract the surfaces. We do that with the following steps.

1. Select disk_out_ref.ex2 in the pipeline browser.

2. From the menu bar, select Filters → Alphabetical → Extract Surface. Or bring up the quick launch (ctrl+space Win/Linux, alt+space Mac), type extract surface, and select that filter.

3. Hit the 

button.



When you apply the Extract Surface filter, you will once again see the surface of the mesh. Although it looks like the original mesh, it is different in that this data is hollow whereas the original data was solid throughout.

If you were showing the results of the contour filter, you cannot see the contour anymore, but do not worry. It is still in there hidden by the surface. If you are showing the contour but you did not see any effect after applying the filter, you may have forgotten step one and applied the filter to the wrong object. If the ExtractSurface1 object is not connected directly to the disk_out_ref.ex2, then this is what went wrong. If so, you can delete the filter and try again.

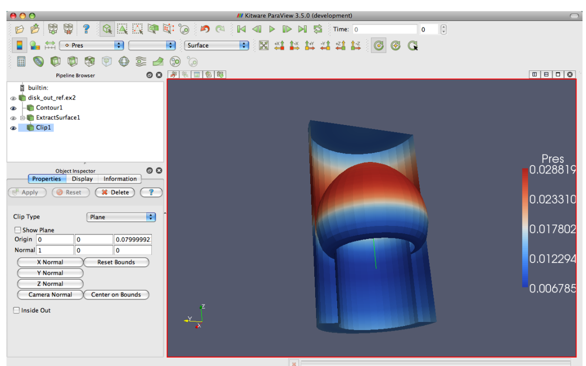
Now we will cut away the external surface to expose the internal structure and isosurface underneath (if you have one).

4. Verify that ExtractSurface1 is selected in the pipeline browser.

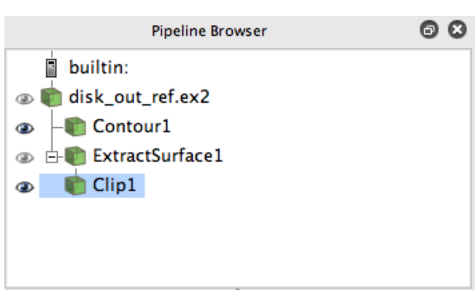
5. Create a clip filter  from the toolbar or Filters menu.

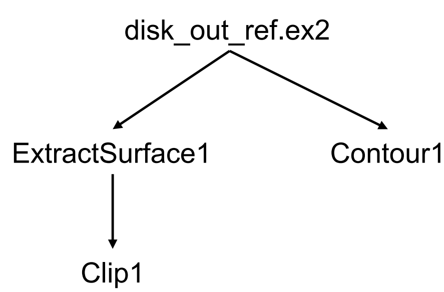
6. Uncheck the Show Plane checkbox ☑ Show Plane in the properties panel.

7. Click the Apply button.



If you have a contour, you should now see the isosurface contour within a cutaway of the mesh surface. You will probably have to rotate the mesh to see the contour clearly. ♦





Now that we have added several filters to our pipeline, let us take a look at the layout of these filters in the pipeline browser. The pipeline browser provides a convenient list of pipeline objects that we have created make it easy to select pipeline objects and change their **visibility** by clicking on the eyeball icons next to them. But also notice the indentation of the entries in the list and the connecting lines toward the right. These features reveal the **connectivity** of the pipeline. It shows the same information as the traditional graph layout on the right, but in a much more compact space. The trouble with the traditional layout of pipeline objects is that it takes a lot of space, and even moderately sized pipelines require a significant portion of the GUI to see fully. The pipeline browser, however, is complete and compact.

2.5 Multiview

Occasionally in the pursuit of science we can narrow our focus down to one variable. However, most interesting physical phenomena rely on not one but many variables interacting in certain ways. It can be very challenging to present many variables in the same view. To help you explore complicated visualization data, ParaView contains the ability to present multiple views of data and correlate them together.

So far in our visualization we are looking at two variables: We are coloring with pressure and have extracted an isosurface with temperature. Although we are starting to get the feel for the layout of these variables, it is still difficult to make correlations between them. To make this correlation easier, we can use multiple views. Each view can show an independent aspect of the data and together they may yield a more complete understanding.

On top of each view is a small toolbar, and the buttons controlling the creating and deletion of views are located on the right side of this tool bar. There are four buttons in all. You can create a new view by splitting an existing view horizontally or vertically with the and buttons, respectively. The button deletes a view, whose space is consumed by an adjacent view. The temporarily fills view space with the selected view until is pressed.

Exercise 2.8: Using Multiple Views

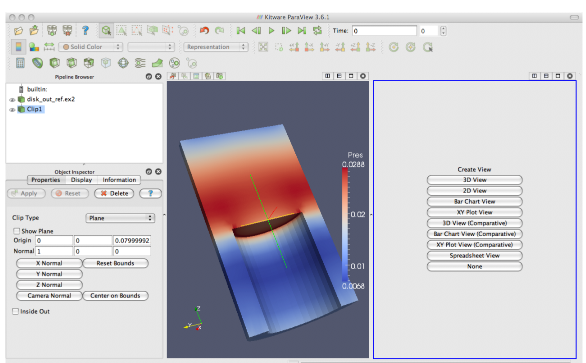
We are going to start a fresh visualization, so if you have been following along with the exercises so far, now is a good time to reset ParaView. The easiest way to do this is to press the button. We will discuss what this does later in more detail in Chapter 3, but for now just know that it is roughly the equivalent of restarting ParaView.

First, we will look at one variable. We need to see the variable through the middle of the mesh, so we are going to clip the mesh in half.

1. Open the file disk_out_ref.ex2, load all variables, Apply (see Exercise 2.4).
2. Add the Clip filter to disk_out_ref.ex2.
3. Uncheck the Show Plane checkbox Show Plane in the properties panel.
4. Click the Apply button.
5. Color the surface by pressure by changing the variable chooser (in the toolbar) from Solid Color to Pres.

Now we can see the pressure in a plane through the middle of the mesh. We want to compare that to the temperature on the same plane. To do that, we create a new view to build another visualization.

6. Press the button.

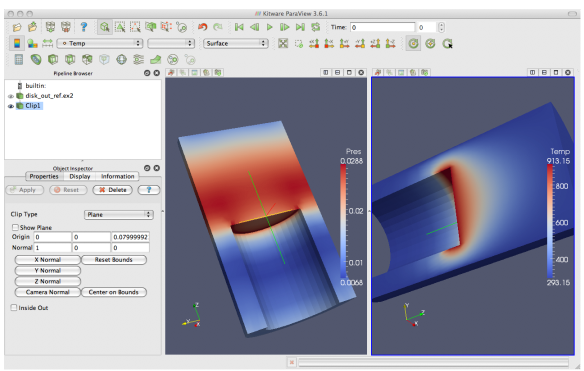


The current view is split in half and the right side is blank, ready to be filled with a new visualization. Notice that the view in the right has a blue border around it. This means that it is the **active view**. Widgets that give information about and controls for a single view, including the pipeline browser and properties panel, follow the active view. In this new view we will visualize the temperature of the mesh.

1. Make sure the blue border is still around the new, blank view (to the right). You can make any view the active view by simply clicking on it.

2. Turn on the visibility of the clipped data by clicking the eyeball  next to Clip1 in the pipeline browser.

3. Color the surface by temperature by selecting Clip1 in the pipeline browser and changing the variable chooser (in the toolbar) from Solid Color to Temp (you may want to turn on the color bar at this point as well).



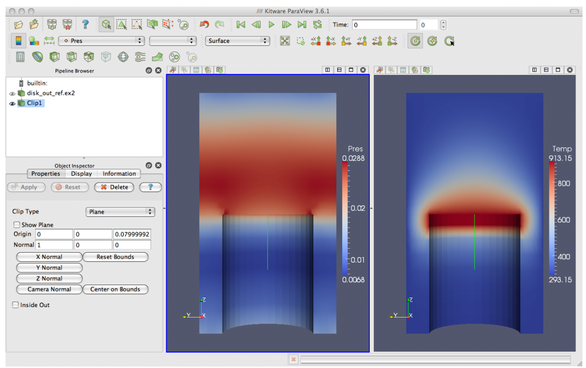
We now have two views: one showing information about pressure and the other information about temperature. We would like to compare these, but it is difficult to do because the orientations are different. How are we to know how a location in one correlates to a location in the other? We can solve this problem by adding a **camera link** so that the two views will always be drawn from the same viewpoint. Linking cameras is easy.

4. Right click on one of the views over the background and select Link Camera... from the pop up menu. (If Link Camera... is not in the pop up menu, make sure you click over the background of the image, not on the object. If you are on a Mac with no right mouse button, you can perform the same operation with the menu option Tools → Add Camera Link....)

5. Click in a second view.

6. Try moving the camera in each view.

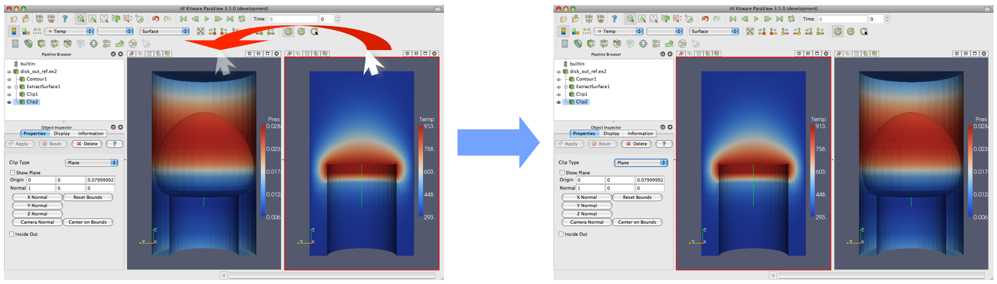
Voilà! The two cameras are linked; each will follow the other. With the cameras linked, we can make some comparisons between the two views. Click the button to get a straight-on view of the cross section.



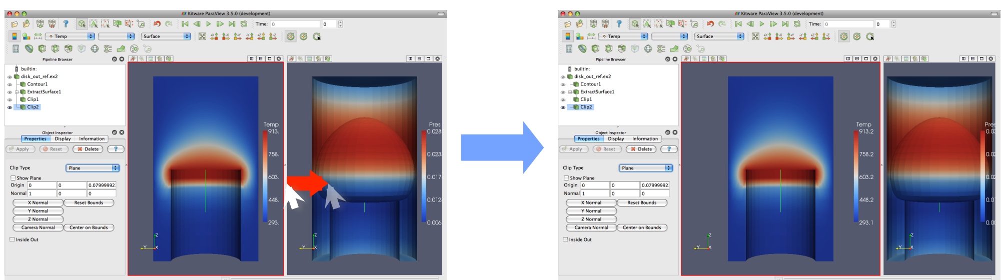
Notice that the temperature is highest at the interface with the heated disk. That alone is not surprising. We expect the air temperature to be greatest near the heat source and drop off away from it. But notice that at the same position the pressure is not maximal. The air pressure is maximal at a position above the disk. Based on this information we can draw some interesting hypotheses about the physical phenomenon. We can expect that there are two forces contributing to air pressure. The first force is that of gravity causing the upper air to press down on the lower air. The second force is that of the heated air becoming less dense and therefore rising. We can see based on the maximal pressure where these two forces are equal. Such an observation cannot be drawn without looking at both the temperature and pressure in this way. ♦

Multiview in ParaView is of course not limited to simply two windows. Note that each of the views has its own set of multiview buttons. You can create more views by using the split view buttons to arbitrarily divide up the working space. And you can delete views at any time.

The location of each view is also not fixed. You are also able to swap two views by clicking on one of the view toolbars (somewhere outside of where the buttons are), holding down the mouse button, and dragging onto one of the other view toolbars. This will immediately swap the two views.



You can also change the size of the views by clicking on the space in between views, holding down the mouse button, and dragging in the direction of either one of the views. The divider will follow the mouse and adjust the size of the views as it moves.



2.6 Vector Visualization

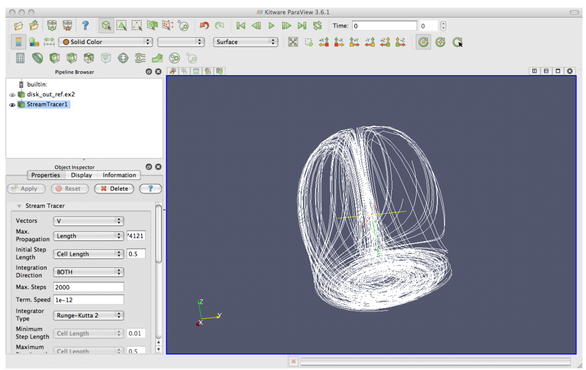
Let us see what else we can learn about this simulation. The simulation has also outputted a velocity field describing the movement of the air over the heated rotating disk. We will use ParaView to determine the currents in the air.

A common and effective way to characterize a vector field is with **streamlines**. A streamline is a curve through space that at every point is tangent to the vector field. It represents the path a weightless particle will take through the vector field (assuming steady-state flow). Streamlines are generated by providing a set of **seed points**.

Exercise 2.9: Streamlines

We are going to start a fresh visualization, so if you have been following along with the exercises so far, now is a good time to reset ParaView. The easiest way to do this is to press the button.

1. Open the file disk_out_ref.ex2, load all variables, Apply (see Exercise 2.4).
2. Add the stream tracer filter to disk_out_ref.ex2.
3. Click the Apply button to accept the default parameters.



The surface of the mesh is replaced with some swirling lines. These lines represent the flow through the volume. Notice that there is a spinning motion around the center line of the cylinder. There is also a vertical motion in the center and near the edges.

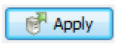
The new geometry is off-center from the previous geometry. We can quickly center the view on the new geometry with the **reset camera** command. This command centers and fits the visible geometry within the current view and also resets the center of rotation to the middle of the visible geometry. ♦

One issue with the streamlines as they stand now is that the lines are difficult to distinguish because there are many close together and they have no shading. Lines are a 1D structure and shading requires a 2D surface. Another issue with the streamlines is that we cannot be sure in which direction the flow is.

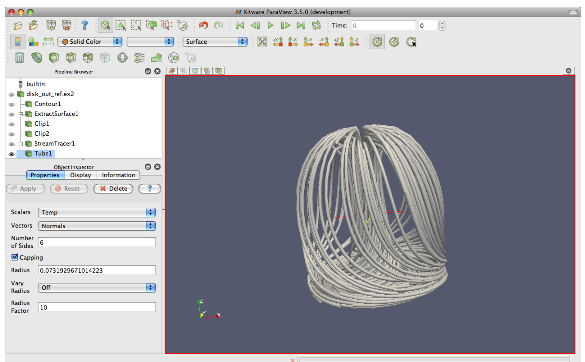
In the next exercise, we will modify the streamlines we created in Exercise 2.9 to correct these problems. We can create a 2D surface around our stream traces with the tube filter. This surface adds shading and depth cues to the lines. We can also add glyphs to the lines that point in the direction of the flow.

Exercise 2.10: Making Streamlines Fancy

1. Use the quick launch (ctrl+space Win/Linux, alt+space Mac) to apply the Tube filter.

2. Hit the 

button.



You can now see the streamlines much more clearly. As you look at the streamlines from the side, you should be able to see circular convection as air heats, rises, cools, and falls. If you rotate the streams to look down the Z axis at the bottom near where the heated plate should be, you will also see that the air is moving in a circular pattern due to the friction of the rotating disk.

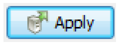
Now we can get a little fancier. We can add glyphs to the streamlines to show the orientation and magnitude.

3. Select StreamTracer1 in the pipeline browser.

4. Add the glyph filter  to StreamTracer1.

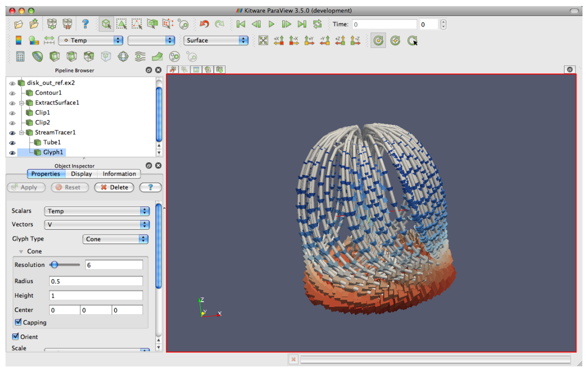
5. In the properties panel, change the Vectors option (second option from the top) to V.

6. In the properties panel, change the Glyph Type option (third option from the top) to Cone.

7. Hit the 

button.

8. Color the glyphs with the Temp variable.



Now the streamlines are augmented with little pointers. The pointers face in the direction of the velocity, and their size is proportional to the magnitude of the velocity. Try using this new information to answer the following questions.

- Where is the air moving the fastest? Near the disk or away from it? At the center of the disk or near its edges?
- Which way is the plate spinning?
- At the surface of the disk, is air moving toward the center or away from it?

♦

2.7 Plotting

ParaView's plotting capabilities provide a mechanism to drill down into your data to allow quantitative analysis. Plots are usually created with filters, and all of the plotting filters can be found in the Data Analysis submenu of Filters. There is also a data analysis toolbar containing the most common data analysis filters, some of which are used to generate plots.

Extract Selection Extracts any data selected into its own object. Selections are described in Section 2.11.

Plot Global Variables Over Time Data sets sometimes capture information in “global” variables that apply to an entire dataset rather than a single point or cell. This filter plots the global informaiton over time. ParaView’s handling of time is described in Section 2.9.

Plot Over Line Allows you to define a line in segment in 3D space and then plot field information over this line.

Plot Selection Over Time Takes the fields in selected points or cells and plots their values over time. Selections are described in Section 2.11 and time is described in Section 2.9.

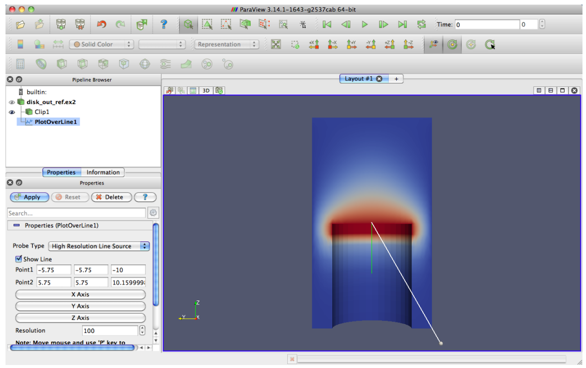
Probe Provides the field values in a particular location in space.

In the next exercise, we create a filter that will plot the values of the mesh’s fields over a line in space.

Exercise 2.11: Plot Over a Line in Space

We are going to start a fresh visualization, so if you have been following along with the exercises so far, now is a good time to reset ParaView. The easiest way to do this is to press the button.

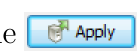
1. Open the file disk_out_ref.ex2, load all variables, Apply (see Exercise 2.4).
2. Add the Clip filter to disk_out_ref.ex2, Uncheck the Show Plane checkbox Show Plane in the properties panel, and click Apply (like in Exercise 2.8). This will make it easier to see and manipulate the line we are plotting over.
3. Click on disk_out_ref.ex2 in the pipeline browser to make that the active object.
4. From the toolbars, select the plot over line filter.



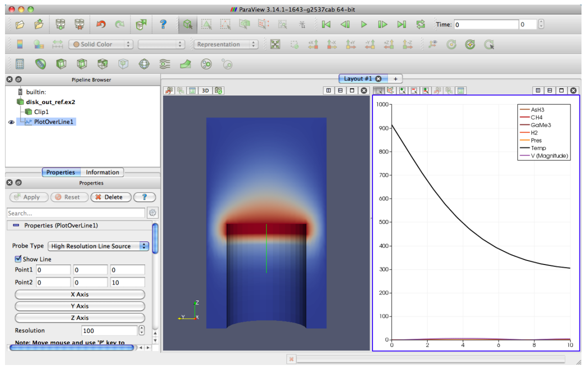
In the active view you will see a line through your data with a ball at each end. If you move your mouse over either of these balls, you can drag the balls through the 3D view to place them. Notice that each time you move the balls some of the fields in the properties panel also change. You can also place the balls by hovering your mouse over the target location and hitting the p key. This will alternatively place each ball at the surface underneath the mouse cursor. This was the purpose of adding the clip filter: It allows us to easily add the endpoints to this plane. Note that placing the endpoints in this manner only works when rendering solid surfaces. It will not work with a volume rendered image.

This representation is called a **3D widget** because it is a GUI component that is manipulated in 3D space. There are many examples of 3D widgets in ParaView. This particular widget, the line widget, allows you to specify a line segment in space. Other widgets allow you to specify points or planes.

5. Adjust the line so that it goes from the base of the disk straight up to the top of the mesh using the 3D widget manipulators, the p key shortcut, or the properties panel parameters.

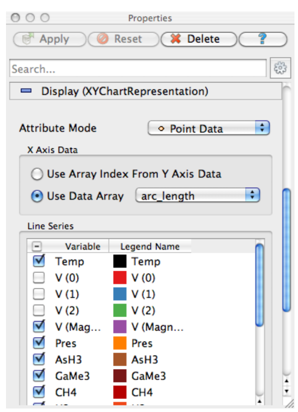
6. Once you have your line satisfactorily located, click the 

button.

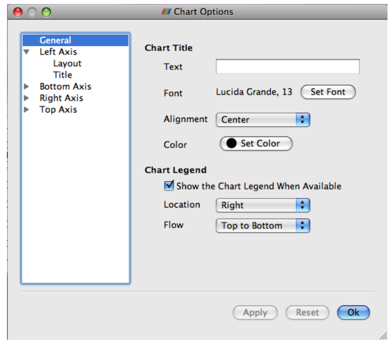


There are several interactions you can do with the plot. Roll the mouse wheel up and down to zoom in and out. Drag with the middle button to do a rubber band zoom. Drag with the left button to scroll the plot around. You can also use the reset camera command to restore the view to the full domain and range of the plot. ♦

Plots, like 3D renderings, are considered views. Both provide a representation for your data; they just do it in different ways. Because plots are views, you interact with them in much the same ways as with a 3D view. If you look in the Display section of the properties panel, you will see many options on the representation for each line of the plot including colors, line styles, vector components, and legend names.



Plots also have a button that brings up a dialog that allows you to change plot-wide options such as labels, legends, and axes ranges.



Like any other views, you can capture the plot with the File → Save Screenshot. We will discuss Save Screenshot later in the tutorial. You can also resize and swap plots in the GUI like you can other views.

In the next exercise, we use these features to get more information out of our plot. Specifically, we use the plot to compare the pressure and temperature variables.

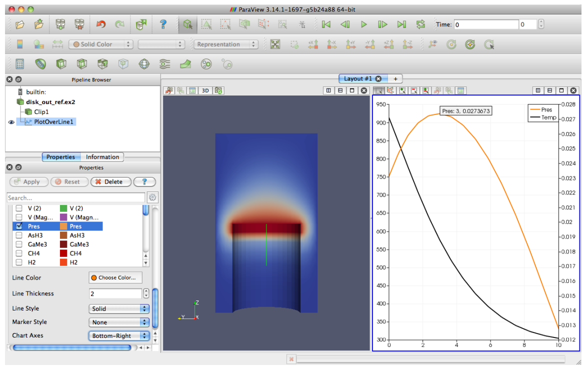
Exercise 2.12: Plot Series Display Options

This exercise is a continuation of Exercise 2.11. You will need to finish that exercise before beginning this one.

1. Choose a place in your GUI that you would like the plot to go and try using the split, delete, resize, and swap view features to move it there.
2. Make the plot view active, go to the Display section of the properties panel, and turn off all variables except Temp and Pres.

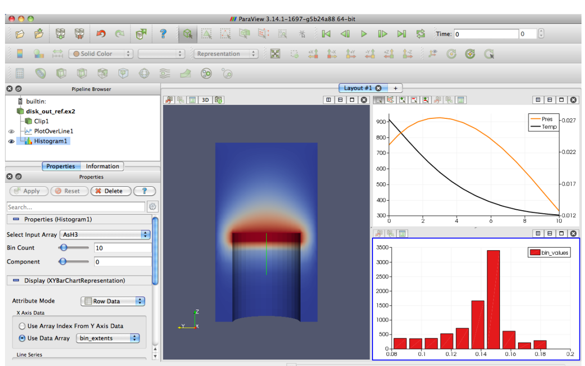
The Temp and Pres variables have different units. Putting them on the same scale is not useful. We can still compare them in the same plot by placing each variable on its own scale. The line plot in ParaView allows for a different scale on the left and right axis, and you can scale each variable individually on each axis.

3. Select the Pres variable in the Display tab.
4. Change the Chart Axis to Bottom - Right



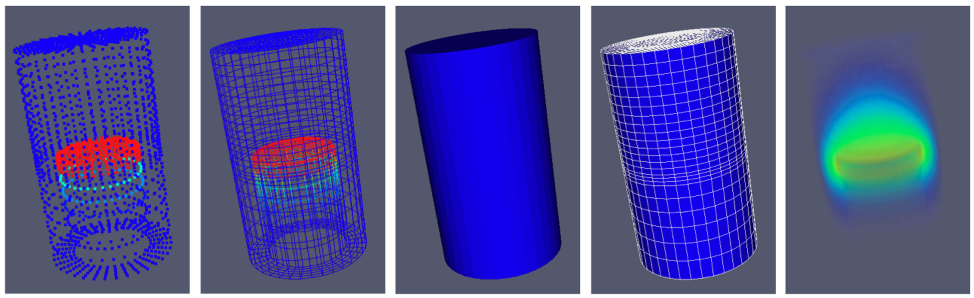
From this plot we can verify some of the observations we made in Section 2.5. We can see that the temperature is maximal at the plate surface and falls as we move away from the plate, but the pressure goes up and then back down. In addition, we can observe that the maximal pressure (and hence the location where the forces on the air are equalized) is 2.74 units away from the disk. ♦

The ParaView framework is designed to accommodate any number of different types of views. This is to provide researchers and developers a way to deliver new ways of looking at data. To see another example of view, select disk_out_ref.ex2 in the pipeline browser, and then select Filters → Data Analysis → Histogram. Make the histogram for the Temp variable, and then hit the Apply button.



2.8 Volume Rendering

ParaView has several ways to represent data. We have already seen some examples: surfaces, wireframe, and a combination of both. ParaView can also render the points on the surface or simply draw a bounding box of the data.



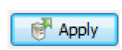
Points Wireframe Surface Surface with Edges Volume

A powerful way that ParaView lets you represent your data is with a technique called **volume rendering**. With volume rendering, a solid mesh is rendered as a translucent cloud with the scalar field determining the color and density at every point in the cloud. Unlike with surface rendering, volume rendering allows you to see features all the way through a volume.

Volume rendering is enabled by simply changing the representation of the object. Let us try an example of that now.

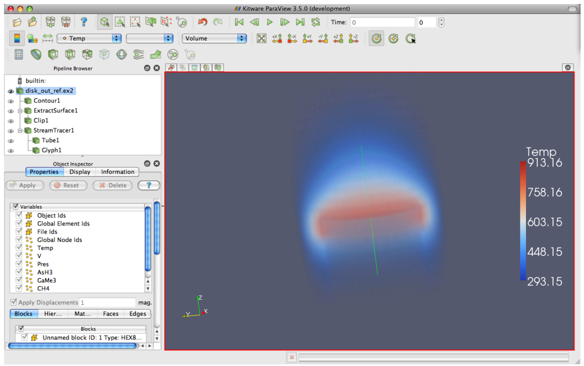
Exercise 2.13: Turning On Volume Rendering

We are going to start a fresh visualization, so if you have been following along with the exercises so far, now is a good time to reset ParaView. The easiest way to do this is to press the  button.

1. Open the file disk_out_ref.ex2, load all variables, 

(see Exercise 2.4).

2. Make sure disk_out_ref.ex2 is selected in the pipeline browser. Change the variable viewed to Temp and change the representation to Volume.



The solid opaque mesh is replaced with a translucent volume. You may notice that when rotating the image is temporarily replaced with a simpler image for performance reasons, which we discuss in more detail later in Chapter 3. ♦

A useful feature of ParaView's volume rendering is that it can be mixed with the surface rendering of other objects. This allows you to add context to the volume rendering or to mix visualizations for a more information-rich view. For example, we can combine this volume rendering with a streamline vector visualization like we did in Exercise 2.9.

Exercise 2.14: Combining Volume Rendering and Surface-Based Visualization

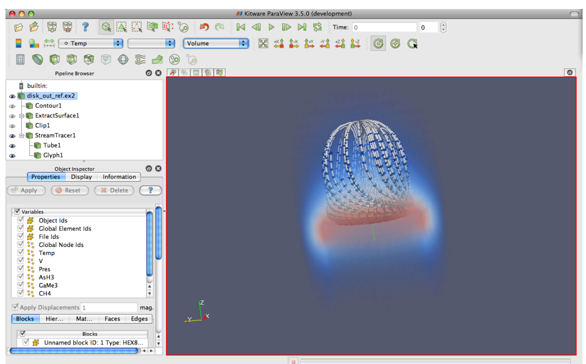
This exercise is a continuation of Exercise 2.13. You will need to finish that exercise before beginning this one.

1. Add the stream tracer filter to disk_out_ref.ex2.
2. Click the Apply button to accept the default parameters.

You should now be seeing the streamlines embedded within the volume rendering. The following additional steps add geometry to make the streamlines easier to see much like in Exercise 2.10. They are optional, so you can skip them if you wish.

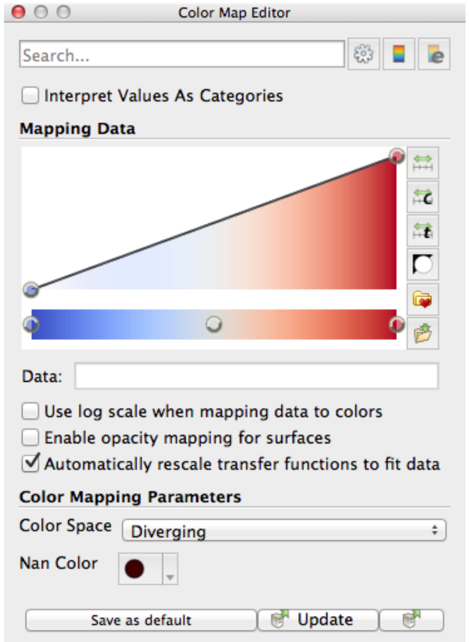
3. Use the quick launch (ctrl+space Win/Linux, alt+space Mac) to apply the Tube filter and hit Apply.

4. If the streamlines are colored by Temp, change that to Solid Color.
5. Select StreamTracer1 in the pipeline browser.
6. Add the glyph filter to StreamTracer1.
7. In the properties panel, change the Vectors option (second option from the top) to V.
8. In the properties panel, change the Glyph Type option (third option from the top) to Cone.
9. Hit the Apply button.
10. Color the glyphs with the Temp variable.



The streamlines are now shown in context with the temperature throughout the volume. ♦

By default, ParaView will render the volume with the same colors as used on the surface with the transparency set to 0 for the low end of the range and 1 for the high end of the range. ParaView also provides an easy way to change the **transfer function**, how scalar values are mapped to color and transparency. You can access the transfer function editor by selecting the volume rendered pipeline object and clicking on the edit color map button.



The first time you bring up the color map editor, it should appear at the right side of the ParaView GUI window. Like most of the panels in ParaView, this is a dockable window that you can move around the GUI or pull off and place elsewhere on your desktop. Like the properties panel, some of the advanced options are hidden to simplify the interface. To access these hidden features, toggle the button in the upper right or type a search string.

The two colorful boxes at the top represent the transfer function. The first box with a function plot with colors underneath represents the transparency whereas the long box at the bottom represents the colors.[1] The dots on the transfer functions represent the **control points**. The control points are the specific color and opacity you set at particular scalar values, and the colors and transparency are interpolated between them. Clicking on a blank spot in either bar will create a new control point. Clicking on an existing control point will select it. The selected control point can be dragged throughout the box to change its scalar value and transparency (if applicable). Double clicking on a color control point will allow you to change the color. The

[1] For surface rendering, the transparency controls have no effect unless “Enable opacity mapping for surfaces” is enabled.

selected control point will be deleted when you hit the backspace or delete key.

Directly below the color and transparency bars is a text entry widget to numerically specify the Data Value of the selected control point. Below this are checkbox options to Use log scale when mapping data to colors, to Enable opacity mapping for surfaces, and to Automatically rescale transfer functions to fit data. (Note that this last option causes the data range to be resized under most operations that change data, but not when the time value changes. See Section 2.9 for more details.)

The following Color Space parameter changes how colors are interpolated. This parameter has no effect on the color at the control points, but can drastically affect the colors between the control points. Finally, the Nan Color allows you to select a color for "invalid" values. A **NaN** is a special floating point value used to represent something that is not a number (such as the result of 0/0).

Setting up a transfer function can be tedious, so you can save it by clicking the Save to preset button. The Choose preset button brings up a dialog that allows you to manage and apply the color maps that you have created as well as many provided by ParaView.

Exercise 2.15: Modifying Volume Rendering Transfer Functions

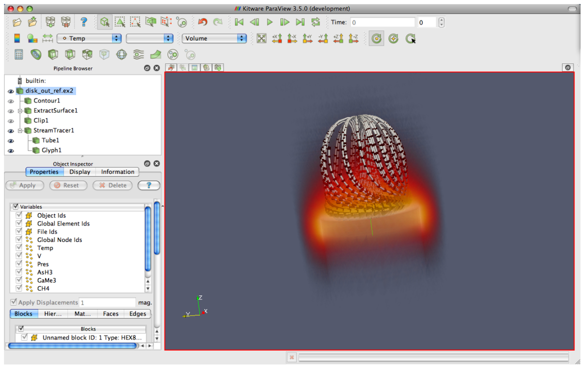
This exercise is a continuation of Exercise 2.14. You will need to finish that exercise (or minimally Exercise 2.13) before beginning this one.

1. Click on disk_out_ref.ex2 in the pipeline browser to make that the active object.

2. Click on the edit color map button.

3. Change the volume rendering to be more representative of heat. Press Choose preset, select Black-Body Radiation in the dialog box, and then click Close.

4. Try adding and changing control points and observe their effect on the volume rendering. Click the Update button or turn on the update automatically toggle to see the effects of your changes.



Notice that not only did the color mapping in the volume rendering change, but all the color mapping for Temp changed. This ensures consistency between the views and avoids any confusion from mapping the same variable with different colors or different ranges. ♦

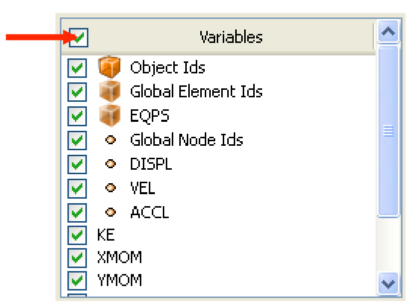
2.9 Time

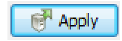
Now that we have thoroughly analyzed the disk_out_ref simulation, we will move to a new simulation to see how ParaView handles time. In this section we will use a new data set from another simple simulation, this time with data that changes over time.

Exercise 2.16: Loading Temporal Data

We are going to start a fresh visualization, so if you have been following along with the exercises so far, now is a good time to reset ParaView. The easiest way to do this is to press the button.

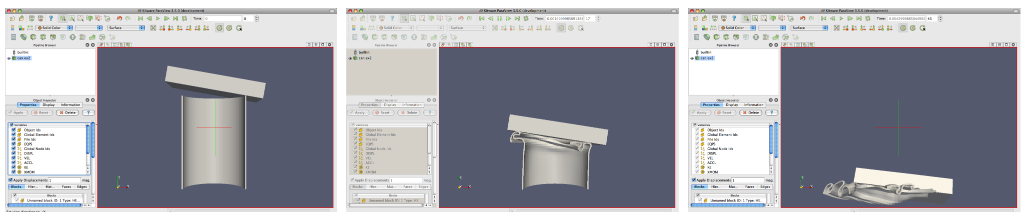
1. Open the file can.ex2.



2. As before, click the checkbox in the header of the variable list to turn on the loading of all the variables and hit the  button.

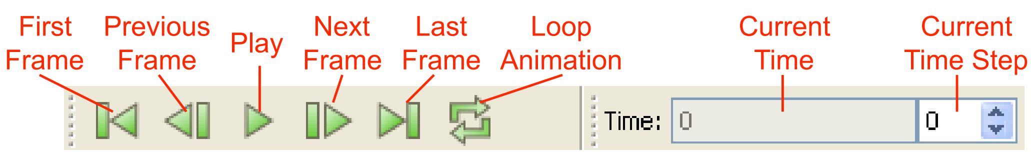
3. Press the  button to orient the camera to the mesh.

4. Press the play button  in the toolbars and watch ParaView animate the mesh to crush the can with the falling brick.



♦

That is really all there is to dealing with data that is defined over time. ParaView has an internal concept of time and automatically links in the time defined by your data. Become familiar with the toolbars that can be used to control time.



Saving an animation is equally as easy. From the menu, select File → Save Animation. ParaView provides dialogs specifying how you want to save the animation, and then automatically iterates and saves the animation.

Exercise 2.17: Temporal Data Pitfall

The biggest pitfall users run into is that with mapping a set of colors whose range changes over time. To demonstrate this, do the following.

1. If you are not continuing from Exercise 2.16, open the file can.ex2, load all variables, .

2. Go to the first time step .

3. Color by the EQPS variable.

4. Turn on the color legend .
5. Play through the animation (or skip to the last time step).

The coloring is not very useful. To quickly fix the problem:

6. While at the last time step, click the Rescale to Data Range button.
7. Play the animation again.

The colors are more useful now. ♦

Although this behavior seems like a bug, it is not. It is the consequence of two unavoidable behaviors. First, when you turn on the visibility of a scalar field, the range of the field is set to the range of values in the current time step. Ideally, the range would be set to the max and min over all time steps in the data.

However, this requires ParaView to load in all of the data on the initial read, and that is prohibitively slow for large data. Second, when you animate over time, it is important to hold the color range fixed even if the range in the data changes. Changing the scale of the data as an animation plays causes a misrepresentation of the data. It is far better to let the scalars go out of the original color map's range than to imply that they have not. There are several workarounds to this problem:

- If for whatever reason your animation gets stuck on a poor color range, simply go to a representative time step and hit . This is what we did in the previous exercise.
- Open the settings dialog box accessed in the menu from Edit → Settings (ParaView → Preferences on the Mac). Under the General tab, change the On File Open setting to Goto last timestep. When this is selected, ParaView will automatically go to the last time step when loading any data set with time. For many data (such as in can), the field ranges are more representative at the last time step than at the beginning. Thus, as long as you color by a field before changing the time, the color range will be adequate.
- Open the edit color map dialog and specify a range for the data using Rescale to custom range . This is a good choice if you cannot

find, or do not know, a "representative" time step or if you already know a good range to use. You should also consider turning off the Automatically rescale transfer functions to fit data to prevent your scale from changing the next time you add a filter.

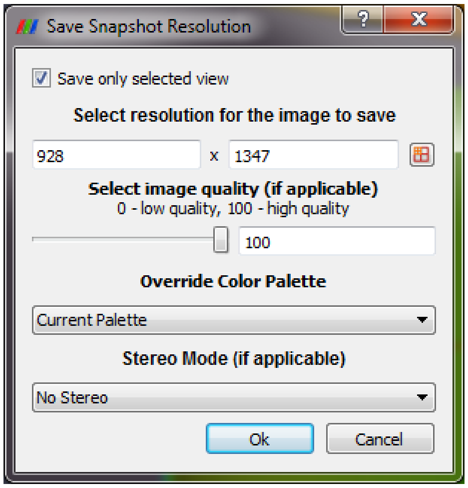
- If you are willing to wait or have small data, you can use the Rescale to data range over all timesteps button on the edit color map dialog and ParaView will compute this overall temporal range automatically. Keep in mind that this option will require ParaView to load your entire data set over all time steps whenever you load a data set. Although ParaView will not hold more than one time step in memory at a time, it will take a long time to pull all that memory off of disk for large data sets.

2.10 Save Screenshot and Save Animation

One of the most important products of any visualization is screenshots and movies that can be used in presentations and reports. In this section we save a screenshot (picture) and animation (movie). Once again, we will use the can.ex2 dataset.

Exercise 2.18: Save Screenshot

1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, and Apply (see Exercise 2.16).
2. Press the button to orient the camera to the mesh.
3. Color by GlobalNodeId. We use GlobalNodeId so that the 3D object has some color.
4. Select the Rescale to color range button.
5. Select File → Save Screenshot .



The Save Screenshot window includes numerous important controls.

In the upper left of this window is the checkbox Save only selected view. If you have multiple views open, clicking on this checkbox will only write the selected one to an image file. Unselecting it will write all views to the image file.

The Select resolution for the image to save entries allow you to create an image that is larger (or smaller) than the current size of the 3d view. The Override Color Palette pulldown menu allows a user to use the default color scheme or one with a white color motif for printing. Finally, the Stereo Mode (if applicable) menu allows you to create stereo screenshots.

6. Press the OK button.

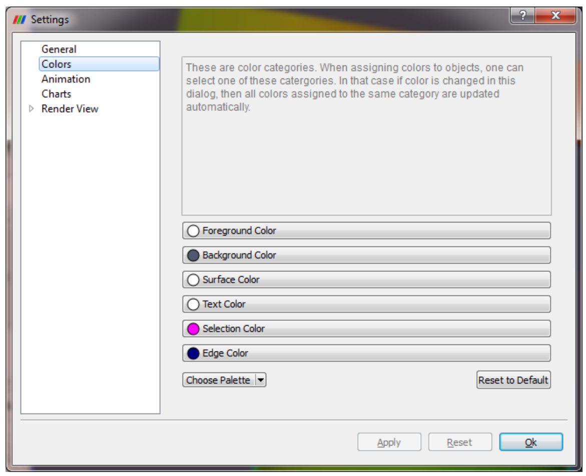
This brings us to the file selection screen. If you pull down the menu Files of type: at the bottom of the dialog box, you will see several file types supported including portable network graphics (PNG), JPEG, and portable document format (PDF).

Select a File name for your file, and place it somewhere you can later find and delete. We usually recommend saving images as PNG files. The lossy compression of JPEG often creates noticeable artifacts in the images generated by ParaView, and the compression of PNG is better than most other raster formats.

7. Press the OK button.

Using your favorite image viewer, find and load the image you created. If you have no image viewer, ParaView itself is capable of loading PNG files. ♦

The colors used for the color palettes (as chosen, for example, with the Override Color Palette in the previous exercise), are part of ParaView's settings. You can see and set all of these colors in the Edit → Settings (ParaView → Preferences on the Mac) under the (Colors) tab.

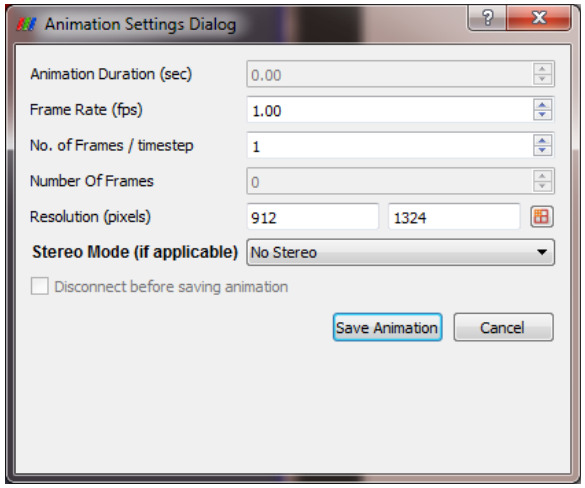


Next, we will save an animation.

Exercise 2.19: Save Animation

1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, and  (see Exercise 2.16).

2. Select File → Save Animation .



The Save Screenshot window includes numerous important controls.

The Resolution (pixels) entries allow you to create an animation that is larger (or smaller) than the current size of the 3d view.

The Stereo Mode (if applicable) menu allows you to create stereo movies.

3. Press the Save Animation button.

This brings us to the file selection screen. If you pull down the menu Files of type: at the bottom of the dialog box, you will see the several file types including Ogg/Theora, AVI, JPEG, and PNG.

Select a File name for your file, and place it somewhere you can later find and delete. AVI will create a movie format that can be used on windows, and with some open source viewers. is used in many open source viewers. Otherwise, you can create a **flipbook**, or series of images. These images can be stitched together to form a movie using numerous open source tools. For now, try creating an AVI.

4. Press the OK button.

Using your favorite movie viewer, find and load the image you created.

♦

2.11 Selection

The goal of visualization is often to find the important details within a large body of information. ParaView's selection abstraction is an important simplification of this process. Selection is the act of identifying a subset of some dataset. There are a variety of ways that this selection can be made, most of which are intuitive to end users, and a variety of ways to display and process the specific qualities of the subset once it is identified.

More specifically the subset identifies particular select points, cells, or blocks within any single data set. There are multiple ways of specifying which elements to include in the selection including id lists of multiple varieties, spatial locations, and scalar values and scalar ranges.

In ParaView, selection can take place at any time, and the program maintains a current selected set that is linked between all views. That is, if you select something in one view, that selection is also shown in all other views that display the same object.

The most direct means to create a selection is via the Find Data dialog. Launch this dialog from the toolbar or the Edit menu. From this dialog you can enter characteristics of the data that you are seraching for. For example, you could look for points whose velocity magnitude is near terminal velocity. Or you could look for cells whose strain exceeds the failure of the material. The following exercise provides a quick example of using the Find Data dialog box.

Exercise 2.20: Performing Query-Based Selections

In this exercise we will find all cells with a large equivalent plastic strain (EQPS).

1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, Apply (see Exercise 2.16).

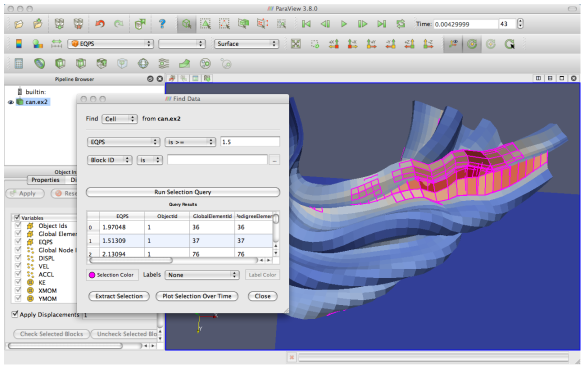
2. Go to the last time step.

3. Open the find data dialog.

4. From the top combo box, choose to find Cells.

5. In the next row of widgets, choose EQPS from the first combo box, is >= from the second combo box, and enter 1.5 in the final text box.

6. Click the Run Selection Query button.



Observe the spreadsheet below the Run Selection Query button that gets populated with the results of your query. Each row represents a cell and each column represents a field value or property (such as an identifier).

You may also notice that several cells are highlighted in the 3D view of the main ParaView window. These highlights represent the selection that your query created. Close the Find Data dialog and note that the selection remains. ♦

One of the easiest ways of creating a selection is to pick elements right inside the 3D view. Most of the 3D view selections are performed with a **rubber-band selection**. That is, by clicking and dragging the mouse in the 3D view, you will create a boxed region that will select elements underneath it. There are also some 3D view selections that allow you to select within a polygonal region drawn on the screen. There are several types of interactive selections that can be performed, and you initiate one by selecting one of the icons in the small toolbar over the 3D view or using one of the shortcut keys. The following 3D selections are possible.

 **Select Cells On (Surface)** Selects cells that are visible in the view under a rubber band. (Shortcut: s)

 **Select Points On (Surface)** Selects points that are visible in the view under a rubber band.

 **Select Cells Through (Frustum)** Selects all cells that exist under a rubber band.

Select Points Through (Frustum) Selects all points that exist under a rubber band.

Select Cells With Polygon Like Select Cells On except that you draw a polygon by dragging the mouse rather than making a rubber-band selection.

Select Points With Polygon Like Select Points On except that you draw a polygon by dragging the mouse rather than making a rubber-band selection.

Select Blocks Selects blocks in a multiblock data set. (Shortcut: b)

The shortcuts s and b allow you to quickly select a cell or block, respectively. Use them by placing the mouse cursor somewhere in the currently selected 3D view and hitting the appropriate key. Then click on the cell or block you want selected (or drag a rubber band over multiple elements).

Feel free to experiment with the selections now.

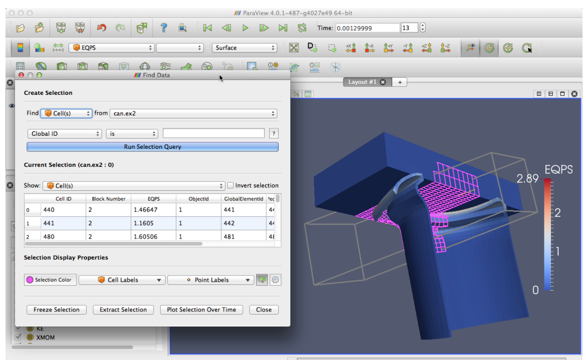
You can manage your selection with the Find Data dialog even if the selection was created with one of these 3D interactions rather than directly with a find data query. The find data dialog allows you to view all the points and cells in the selection as well perform simple operations on the selection. These include inverting the selection (a checkbox just over the spreadsheet), adding labels (Exercise 2.23), freezing selections (Exercise 2.21), and shortcuts for the Extract Selection and Plot Selection Over Time filters (Exercises 2.25 and 2.24, respectively).

Experiment with selections in Find Data a bit. Open the Find Data dialog box. Then make selections using the rubber-band selection and see the results in the Find Data dialog box. Also experiment with altering the selection by inverting selections with the Invert selection checkbox.

It should be noted that selections can be internally represented in different ways. Some are recorded as a list of data element ids. Others are specified as a region in space or by query parameters. Although the selections all look the same, they can be have differently, especially with respect to changes in time. The following exercise demonstrates how these different selection mechanisms can behave differently.

Exercise 2.21: Data Element Selections vs. Spatial Selections

1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, Apply (see Exercise 2.16).
2. Make a selection using the Select Cells Through tool.
3. If it is not already visible, show the Find Data dialog box.
4. Click on the Show Frustum checkbox in the Find Data dialog and rotate the 3D view. (Yes, the Show Frustum button has the same icon as the Select Cells Through button.)



5. Play the animation a bit. Notice that the region remains fixed and the selection changes based on what cells move in or out of the region.
6. Go to a timestep where some data is selected. In the Find Data dialog box, click the Freeze Selection button.
7. Play again. Notice that the cells selected are fixed regardless of position.

In summary, a spatial selection (created with one of the select through tools) will re-perform the selection at each time step as elements move in and out of the selected region. Likewise, other queries such as field range queries will also re-execute as the data changes. However, when you select the Freeze

Selection button, ParaView captures the identifiers of the currently selected elements so that they will remain the same throughout the animation. ♦

The **spreadsheet view** is an important tool to use for quantitative drill down. The spreadsheet view allows you to read the actual values of scalar fields throughout the data and the selection mechanism will help you identify the values of interest.

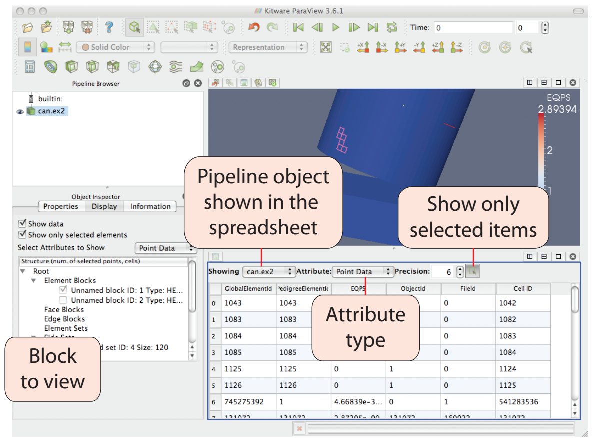
Exercise 2.22: The Spreadsheet View and Selection

1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, Apply (see Exercise 2.16).
2. Split the view vertically ⊟.
3. In the new view, click the Spreadsheet View button.
4. Make can.ex2 visible (by clicking the appropriate 👁) if not already visible.

As you can see, the spreadsheet view is fairly simple. It shows the field data in tabular form for one field type (e.g. point or cell data) of one block of one data set. This constraint is enforced to ensure that every row has the same column data.

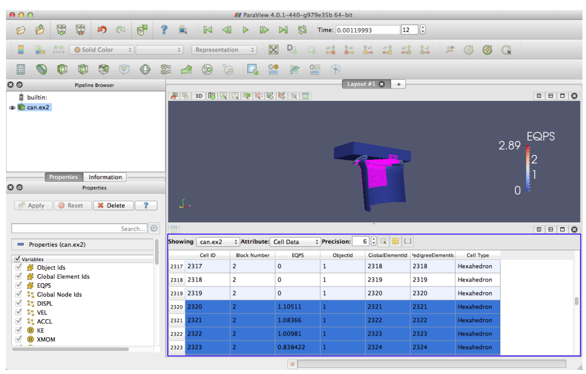
You can sort the rows of the spreadsheet by clicking on a variable name at the top of each column. The spreadsheet will sort the spreadsheet even if the data is spread across multiple remote ParaView servers.

Note the widgets at the top of the spreadsheet view. These let you quickly select the pipeline object, choose the type of field to show, choose the precision shown for floating point numbers, and hide everything but the selection. As with any view, the spreadsheet view has its own Display panels.



5. In the Attribute combo box, select Cell Data.

6. Scroll around the spreadsheet view and find some highlighted rows. (You may have to select a different block in the Display panel.)



Those highlighted rows are the ones that are part of the current selection. This coordination of selection between views is an important mechanism to link views. In this example, it can be difficult to identify the selected items in the spreadsheet view. Often, you just want to see the data in the selection.

7. Click on the Show only selected elements button at the top of the spreadsheet view.

We have now seen a selection made in the 3D view show up in the spreadsheet view. The linking works in reverse as well. We can make selections in the spreadsheet and they will be displayed in the 3D view.

1. Uncheck Show only selected elements.

2. Select a few rows in the spreadsheet view.

3. Find the resulting selection in the 3D view.

♦

The spreadsheet provides the most readable way to inspect field data. However, sometimes it is helpful to place the field data directly in the 3D view. The next exercise describes how we can do that.

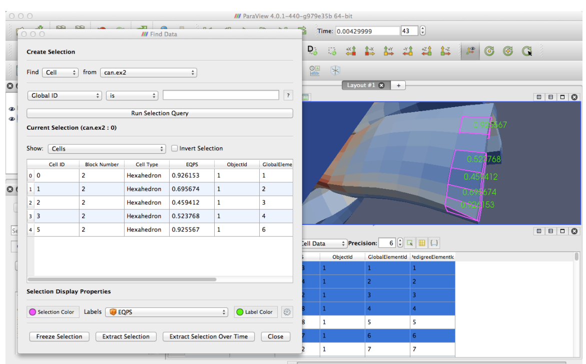
Exercise 2.23: Labeling Selections

1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, Apply (see Exercise 2.16).

2. If you do not have a few cells selected from the previous exercise, select a few now. (For this exercise it is not a good idea to select a large amount of cells.)

3. If it is not already visible, show the Find Data dialog box.

4. In the Labels chooser, select EQPS.

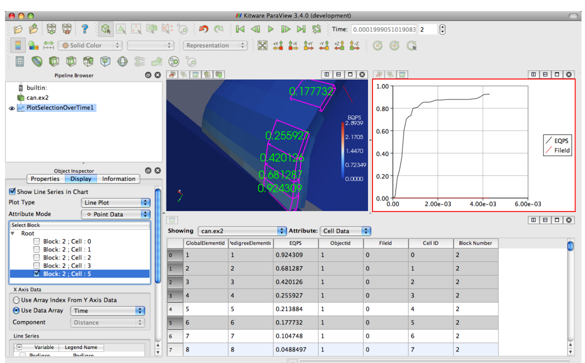


ParaView places the values for the EQPS field near the selected cell that contains that value. It is also possible to change the look of the font with respect to type, size, and color with the Find Data dialog box. ♦

ParaView provides the ability to plot field data over time. Because you seldom want to plot everything over all time, these plots work against a selection.

Exercise 2.24: Plot Over Time

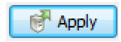
1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, Apply (see Exercise 2.16).
2. If you do not have a few cells selected from the previous exercise, select a few now. (For this exercise it is not a good idea to select a large amount of cells.)
3. With the selection still active, add the Plot Selection Over Time filter.
4. Apply.
5. Go to the Display panel and select different blocks to plot (which correspond to each of the selected elements).

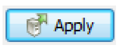


Note that the selection you had was automatically added as the selection to use in the Properties panel. If you want to change the selection, simply make a new one and click Copy Active Selection in the Properties panel. ♦

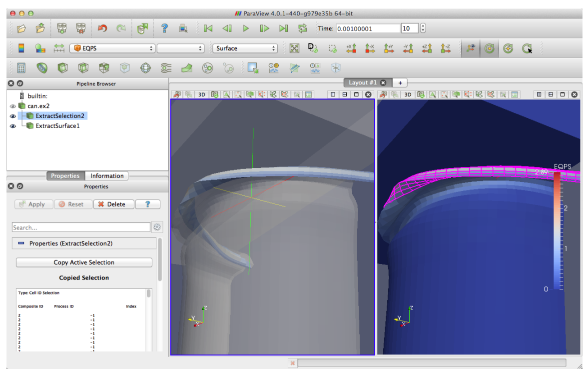
You can also extract a selection in order to view the selected points or cells separately or perform some independent processing on them. This is done through the Extract Selection filter.

Exercise 2.25: Extracting a Selection

1. If you do not already have it loaded from the previous exercise, open the file can.ex2, load all variables, 

(see Exercise 2.16).
2. Turn off cell labels if they are still showing (check the Find Data dialog).
3. Make a sizable cell selection for example, with Select Cells Through .
4. Create an Extract Selection  filter (available on the toolbar).
5. 

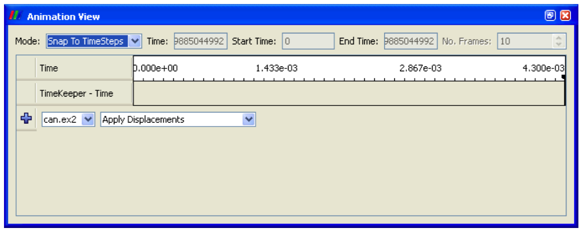
.



The object in the view is replaced with the cells that you just selected. (Note that in this image I added a translucent surface and a second view with the original selection to show the extracted cells in relation to the full data.) You can perform computations on the extracted cells by simply adding filters to the extract selection pipeline object. ♦

2.12 Controlling Time

ParaView has many powerful options for controlling time and animation. The majority of these are accessed through the **animation view**. From the menu, click on View → Animation View.



For now we will examine the controls at the top of the animation view. The **animation mode** parameter determines how ParaView will step through time during playback. There are three modes available.

Sequence Given a start and end time, break the animation into a specified number of frames spaced equally apart.

Real Time ParaView will play back the animation such that it lasts the specified number of seconds. The actual number of frames created depends on the update time between frames.

Snap To TimeSteps ParaView will play back exactly those time steps that are defined by your data.

Whenever you load a file that contains time, ParaView will automatically change the animation mode to Snap To TimeSteps. Thus, by default you can load in your data, hit play ▷, and see each time step as defined in your data. This is by far the most common use case.

A counter use case can occur when a simulation writes data at variable time intervals. Perhaps you would like the animation to play back relative to the simulation time rather than the time index. No problem. We can switch to one of the other two animation modes. Another use case is the desire to change the playback rate. Perhaps you would like to speed up or slow down the animation. The other two animation modes allow us to do that.

Exercise 2.26: Slowing Down an Animation with the Animation Mode

We are going to start a fresh visualization, so if you have been following along with the exercises so far, now is a good time to reset ParaView. The easiest way to do this is to press the button.

1. Open the file can.ex2, load all variables, Apply (see Exercise 2.16).

2. Press the button to orient the camera to the mesh.
3. Press the play button in the toolbars.

During this animation, ParaView is visiting each time step in the original data file exactly once. Note the speed at which the animation plays.

4. If you have not done so yet, make the animation view visible: View → Animation View.
5. Change the animation mode to Real Time. By default the animation is set up with the time range specified by the data and a duration of 10 seconds.
6. Play the animation again.

The result looks similar to the previous Snap To TimeSteps animation, but the animation is now a linear scaling of the simulation time and will complete in 10 seconds.

7. Change the Duration to 60 seconds.
8. Play the animation again.

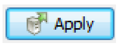
The animation is clearly playing back more slowly. Unless your computer is updating slowly, you will also notice that the animation appears jerkier than before. This is because we have exceeded the temporal resolution of the data set. ♦

Often showing the jerky time steps from the original data is the desired behavior; it is showing you exactly what is present in the data. However, if you wanted to make an animation for a presentation, you may want a smoother animation.

There is a filter in ParaView designed for this purpose. It is called the **temporal interpolator**. This filter will interpolate the positional and field data in between the time steps defined in the original data set.

Exercise 2.27: Temporal Interpolation

This exercise is a continuation of Exercise 2.13. You will need to finish that exercise before beginning this one.

1. Make sure can.ex2 is highlighted in the pipeline browser.
2. Select Filters → Temporal → Temporal Interpolator or apply the Temporal Interpolator filter using the quick launch (ctrl+space Win/Linux, alt+space Mac).
3. 
.
4. Change back to Real Time mode in the Animation View if necessary.
5. Split the view , show the TemporalInterpolator1 in one, show can.ex2 in the other, and link the cameras.
6. Play  the animation.

You should notice that the output from the temporal interpolator animates much more smoothly than the original data. ♦

It is worth noting that the temporal interpolator can (and often does) introduce artifacts in the data. It is because of this that ParaView will never apply this type of interpolation automatically; you will have to explicitly add the Temporal Interpolator. In general, mesh deformations often interpolate well but moving fields through a static mesh do not. Also be aware that the Temporal Interpolator only works if the topology remains constant. If you have an adaptive mesh that changes from one time step to the next, the Temporal Interpolator will give errors.

2.13 Text Annotation

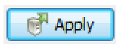
When using ParaView as a communication tool it is often helpful to annotate the images you create with text. With ParaView it is very easy to create text annotation wherever you want in a 3D view. There is a special **text source** that simply places some text in the view.

Exercise 2.28: Adding Text Annotation

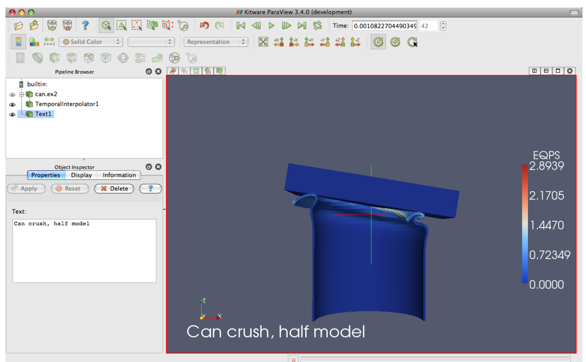
If you are continuing this exercise after finishing Exercise 2.27, feel free to simply continue. If you have had to restart ParaView since or your state does not match up well enough, it is also fine to start with a fresh state.

1. From the menu bar, select Sources → Text.

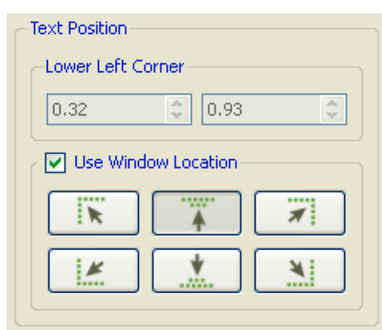
2. In the text edit box of the properties panel, type a message.

3. Hit the 

button.



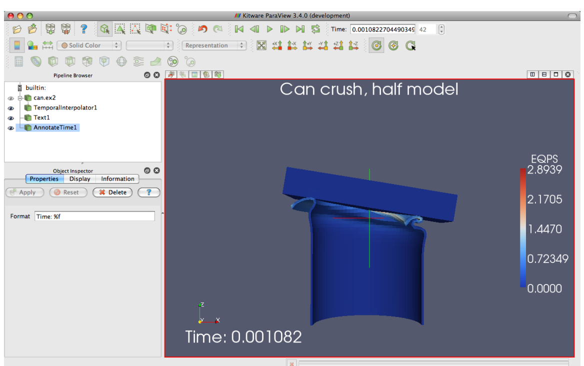
The text you entered appears in the 3D view. You can place this text wherever you want by simply dragging it with the mouse. The Display group in the properties panel provides additional options for the size, font, and color of the text. It also has additional controls for placing the text in the most common locations.



Often times you will need to put the current time value into the text annotation. Typing the correct time value can be tedious and error prone with the standard text source and impossible when making an animation. Therefore, there is a special **annotate time source** that will insert the current animation time into the string.

Exercise 2.29: Adding Time Annotation

1. If you do not already have it loaded from a previous exercise, open the file can.ex2, Apply.
2. Add an Annotate Time source (Sources → Annotate Time or use the quick launch: ctrl+space Win/Linux, alt+space Mac), Apply.
3. Move the annotation around as necessary.
4. Play ▷ and observe how the time annotation changes.



There are instances when the current animation time is not the same as the time step read from a data file. Often it is important to know what the time stored in the data file is, and there is a special version of annotate time that acts as a filter.

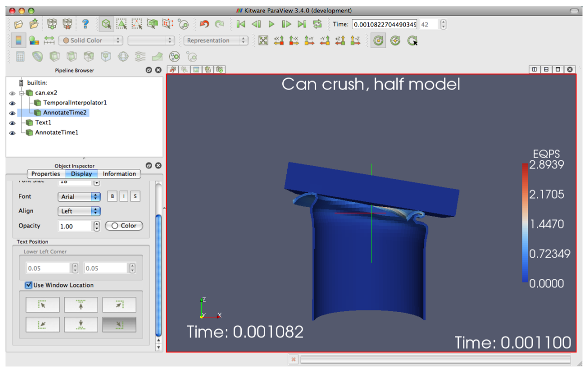
5. Select can.ex2.
6. Use the quick launch (ctrl+space Win/Linux, alt+space Mac) to apply the Annotate Time Filter.

7. Apply.

8. Move the annotation around as necessary.

9. Check the animation mode in the Animation View. If it is set to Snap to TimeSteps, change it to Real Time.

10. Play and observe how the time annotation changes.



♦

2.14 Animations

We have already seen how to animate a data set with time in it (hit). However, ParaView's animation capabilities go far beyond that. With ParaView you can animate nearly any property of any pipeline object.

Exercise 2.30: Animating Properties

We are going to start a fresh visualization, so if you have been following along with the exercises so far, now is a good time to reset ParaView. The easiest way to do this is to press the button.

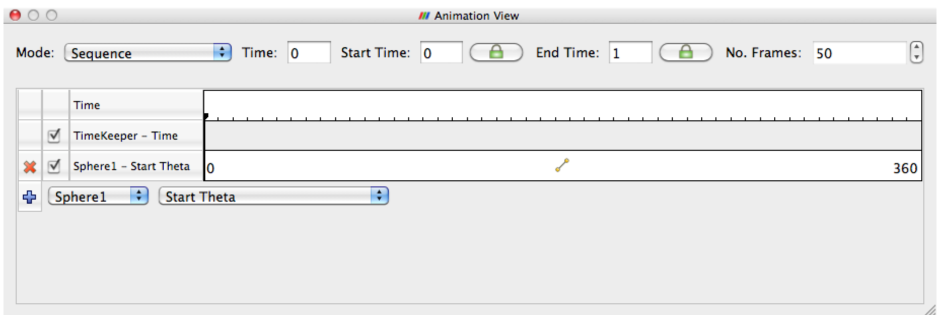
1. Create a sphere source (Sources → Sphere) and Apply it.

2. Now make sure the animation view panel is visible (View → Animation View if it is not).

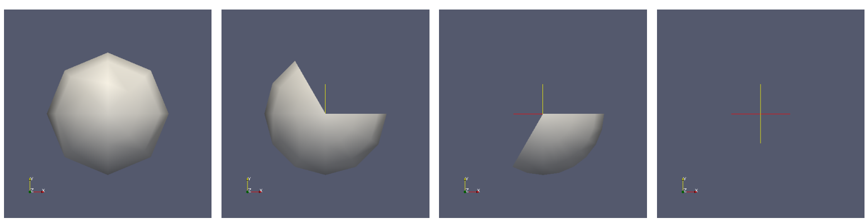
3. Change the No. Frames option to 50 (10 will go far too quickly).

4. Find the property selection widgets at the bottom of the animation view and select Sphere1 in the first box and Start Theta in the second box.

Hit the button.



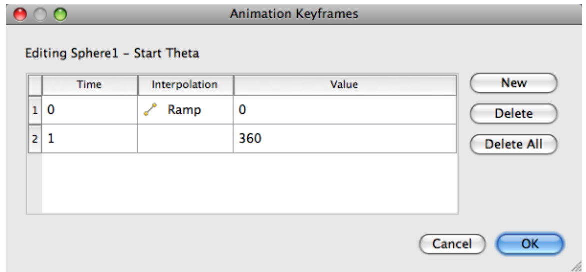
If you play the animation, you will see the sphere open up then eventually wrap around itself and disappear.



♦

What you have done is created a **track** for the Start Theta property of the Sphere1 object. A track is represented as horizontal bars in the animation view. They hold **key frames** that specify values for the property at a specific time instance. The value for the property is interpolated between the key frames. When you created a track two key frames were created automatically: a key frame at the start time with the minimal value and a key frame at the end time with the maximal value. The property you set here defines the start range of the sphere.

You can modify a track by double clicking on it. That will bring up a dialog box that you can use to add, delete, and modify key frames.

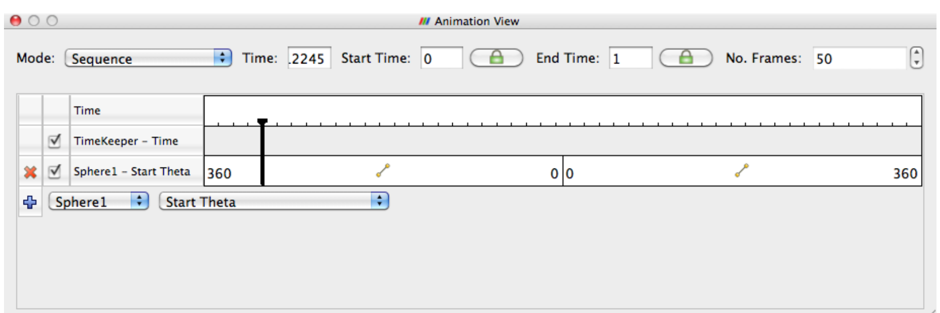


We use this feature to create a new key frame in the animation in the next exercise.

Exercise 2.31: Modifying Animation Track Keyframes

This exercise is a continuation of Exercise 2.30. You will need to finish that exercise before beginning this one.

1. Double-click on the Sphere1 – Start Theta track.
2. In the Animation Keyframes dialog, click the New button. This will create a new key frame.
3. Modify the first key frame value to be 360.
4. Modify the second key frame time to be 0.5 and value to be 0.
5. Click OK.



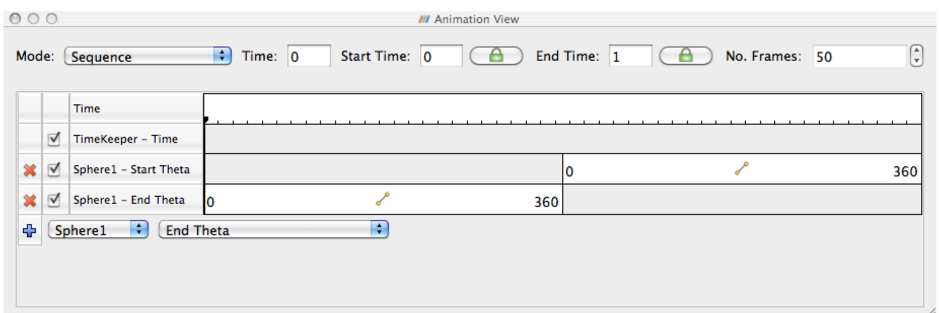
When you play the animation, the sphere will first get bigger and then get smaller again. ♦

You are not limited to animating just one property. You can animate any number of properties you wish. Now we will create an animation that depends on modifying two properties.

Exercise 2.32: Multiple Animation Tracks

This exercise is a continuation of Exercises 2.30 and 2.31. You will need to finish those exercises before beginning this one.

1. Double-click on the Sphere1 – Start Theta track.
2. In the Animation Keyframes dialog, Delete the first track (at time step 0).
3. Click OK.
4. In the animation view, create a track for the Sphere1 object, End Theta property.
5. Double-click on the Sphere1 – End Theta track.
6. Change the time for the second key frame to be 0.5.



The animation will show the sphere creating and destroying itself, but this time the range front rotates in the same direction. It makes for a very satisfying animation when you loop the animation. ♦

In addition to animating properties for pipeline objects, you can animate the camera. ParaView provides methods for animating the camera along curves that you specify. The most common animation is to rotate the camera around an object, always facing the object, and ParaView provides a means to automatically generate such an animation.

Exercise 2.33: Camera Orbit Animations

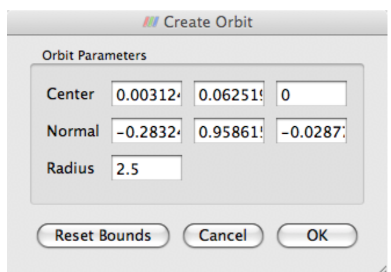
For this exercise, we will orbit the camera around whatever data you have loaded. If you are continuing from the previous exercise, you are set up. If not, simply load or create some data. To see the effects, it is best to have asymmetry in the geometry you load. can.ex2 is a good data set to load for this exercise.

1. Place the camera where you want the orbit to start. The camera will move to the right around the viewpoint.

2. Now make sure the animation view panel is visible (View → Animation View if it is not).

3. In the property selection widgets, select Camera in the first box and Orbit in the second box.

Hit the  button.



Before the new track is created, you will be presented with a dialog box that specifies the parameters of the orbit. The default values come from the current camera position, which is usually what you want.

4. Click OK.

5. Play .

The camera will now animate around the object. ♦