Mayavi User Guide

Release 3.3.1

Prabhu Ramachandran, Gael Varoquaux

December 02, 2009

CONTENTS

Welcome. This is the User Guide for Mayavi (version 3.3.1), the scientific data visualization and 3D plotting tool in Python.

Getting started

- To quick tour the functionalities of Mayavi, read the *Tutorial examples to learn Mayavi* section as a start.
- To learn how to use the interactive Mayavi2 application, see the *Using the Mayavi application* section, although *Tutorial examples to learn Mayavi* is also an excellent introduction.
- To use Mayavi as a Matlab or pylab replacement for scripting 3D plots with *numpy*, get started with the *mlab: Python scripting for 3D plotting*.
- Sources of inspiration may be found in the *Example gallery*, with example code.

CHAPTER

ONE

AN OVERVIEW OF MAYAVI

Section summary

This section gives a quick summary of what is Mayavi, and should help you understand where, in this manual, find relevent information to your use case.

1.1 Introduction

Mayavi2 seeks to provide easy and interactive visualization of 3D data, or 3D plotting. It does this by the following:

- an (optional) rich user interface with dialogs to interact with all data and objects in the visualization.
- a simple and clean scripting interface in Python, including ready to use 3D visualization functionality similar to matlab or matplotlib (using *mlab*), or an object-oriented programming interface.
- harnesses the power of VTK without forcing you to learn it.

Additionally, Mayavi2 strives to be a reusable tool that can be embedded in your libraries and applications in different ways or be combined with the Envisage application-building framework to assemble domain-specific tools.

1.1.1 What is Mayavi2?

Mayavi2 is a general purpose, cross-platform tool for 3-D scientific data visualization. Its features include:

- Visualization of scalar, vector and tensor data in 2 and 3 dimensions.
- Easy scriptability using Python.
- Easy extendability via custom sources, modules, and data filters.
- Reading several file formats: VTK (legacy and XML), PLOT3D, etc.
- Saving of visualizations.
- Saving rendered visualization in a variety of image formats.
- Convenient functionality for rapid scientific plotting via mlab (see *mlab: Python scripting for 3D plotting*).

Unlike its predecessor Mayavi1, Mayavi2 has been designed with scriptability and extensibility in mind from the ground up. Mayavi2 provides a `mayavi2` application which is usable by itself. However, Mayavi2 may also be used as a plotting engine, in scripts, like with matplotlib or gnuplot, as well as a library for interactive visualizations in any other application. It may also be used as an Envisage plugin which allows it to be embedded in other Envisage based applications natively.

1.1.2 Technical details

Mayavi2 provides a general purpose visualization engine based on a pipeline architecture similar to that used in VTK. Mayavi2 also provides an Envisage plug-in for 2D/3D scientific data visualization. Mayavi2 uses the Enthought Tool Suite (ETS) in the form of Traits, TVTK and Envisage. Here are some of its features:

- Pythonic API which takes full advantage of Traits.
- Mayavi can work natively and transparently with numpy arrays (this is thanks to its use of TVTK).
- Easier to script than Mayavi-1 due to a much cleaner MVC design.
- Easy to extend with added sources, components, modules and data filters.
- Provides an Envisage plugin. This implies that it is:
  - easy to use other Envisage plugins in Mayavi. For example, Mayavi provides an embedded Python shell. This is an Envisage plugin and requires one line of code to include in Mayavi.
  - easy to use Mayavi inside Envisage based applications. Thus, any envisage based application can readily use the mayavi plugin and script it to visualize data.
- wxPython/Qt4 based GUI (thanks entirely to Traits, PyFace and Envisage). It is important to note that there is no wxPython or Qt4 code used directly in the Mayavi source.
- A non-intrusive reusable design. It is possible to use Mayavi without a wxPython or Qt4 based UI.

Note: All the following sections assume you have a working Mayavi, for information on downloading and installing Mayavi, see the next section, *Installation*.

1.2 Using Mayavi as an application, or a library?

As a user there are three primary ways to use Mayavi:

1. Use the `mayavi2` application completely graphically. More information on this is in the *Using the Mayavi application* section.
2. Use Mayavi as a plotting engine from simple Python scripts, for example from Ipython, in combination with numpy. The `mlab` scripting API provides a simple way of using Mayavi in batch-processing scripts, see *mlab: Python scripting for 3D plotting* for more information on this.
3. Script the Mayavi application from Python. The Mayavi application itself features a powerful and general purpose scripting API that can be used to adapt it to your needs.
   (a) You can script Mayavi while using the `mayavi2` application in order to automate tasks and extend Mayavi's behavior.
   (b) You can script Mayavi from your own Python based application.
   (c) You can embed Mayavi into your application in a variety of ways either using Envisage or otherwise.

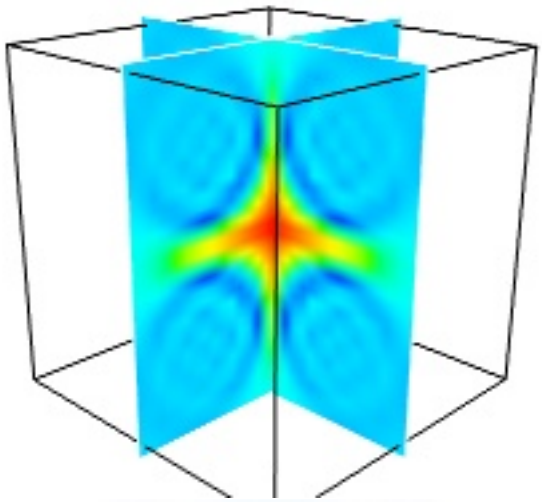
   More details on this are available in the *Advanced Scripting with Mayavi* chapter.

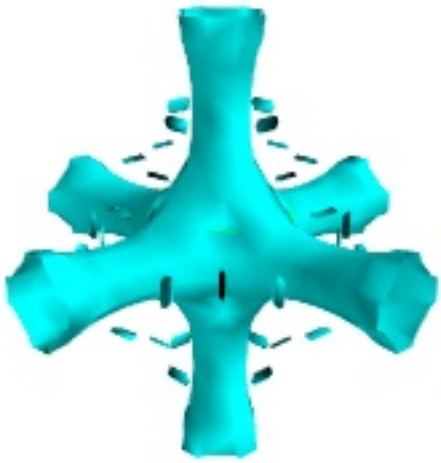
1.3 Scenes, data sources, and visualization modules: the pipeline model

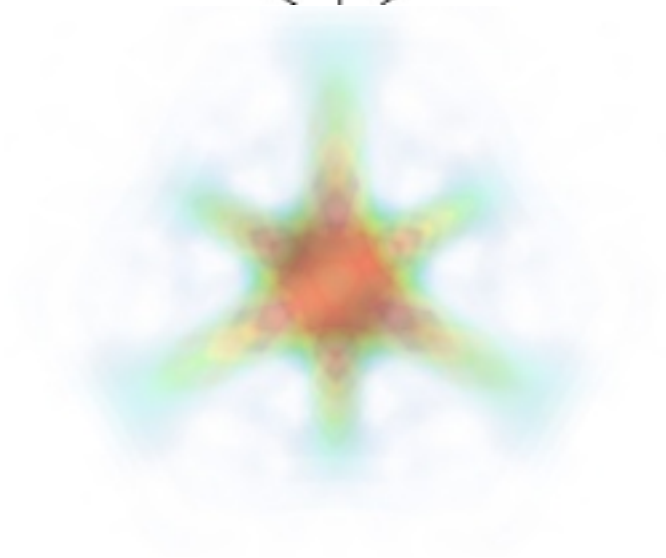
Mayavi uses a pipeline architecture like VTK. As far as a user is concerned this basically boils down to a simple hierarchy.

- Data is loaded into Mayavi and stored in a **data source** (either using a file or created from a script). Any number of data files or data objects may be opened. Data sources are rich objects that describe the data, but not how to visualize it.
- This data is optionally processed using *Filters* that operate on the data and visualized using visualization *Modules*. The filters and **modules** are accessible in the application via the *Visualize* menu on the UI or context menus on the pipeline. They may also be instantiated as Python objects when scripting Mayavi.

  The reasons for separation between *data source*, the data container, and the visualizations tools used to look at it, the *modules*, is that there are many different ways of looking at the same data. For instance the following images are all made by applying different *modules* to the same data source:







- All objects belong to a *Scene* – this is an area where the 3D visualization is performed. In the interactive application, new scenes may be created by using the *File->New->VTK Scene* menu.

1.4 Loading data into Mayavi

Mayavi is a scientific data visualizer. There are two primary ways to make your data available to it:

1. Store your data in a supported file format like VTK legacy or VTK XML files etc. See VTK file formats for more information on the VTK formats. These files can be loaded in the interactive application using the menus.
2. Generate a TVTK dataset via numpy arrays or any other sequence. This is easiest done by using the scripting APIs, for instance *mlab* (see the paragraph on *creating data sources with mlab*, or simply the 3D plotting functions: *3D Plotting functions for numpy arrays*).

Aternatively, if you whish to gain a deeper understanding by creating VTK data structures or files, more information on datasets in general is available in the *Data representation in Mayavi* section.

CHAPTER

TWO

INSTALLATION

Section summary

This section detais the various ways of installing and compiling Mayavi.
If you already have Mayavi up and running, you can skip this section.

2.1 Installing ready-made distributions

Windows Under Window the best way to install Mayavi is to install a full Python distribution, such as EPD or Pythonxy. Note that for Pythonxy, you need to check in 'ETS' in the installer, when selecting components. If you want to reduce the disk used by the Pythonxy, you can uncheck other components.

MacOSX The full Python distribution EPD (that includes Mayavi) is also available for MacOSX. Unless you really enjoy the intricacies of compilation, this is the best solution to install Mayavi.

Ubuntu or Debian Mayavi is packaged in Debian and Ubuntu. In addition, more up to date packages of Mayavi releases for old versions of Ubuntu are available at https://launchpad.net/~gael-varoquaux/+archive . Experimental Debian packages are also available at http://people.debian.org/~varun/ .

RedHat EL3 and EL4 The full Python distribution EPD (that includes Mayavi) is also available for RHEL3 and 4.

2.2 Requirements for manual installs

If you are not using full, ready-made, scientific Python distribution, you need to satistify Mayavi's requirements (for a step-by-step guide on installing all these under windows, see *below*).

Mayavi requires at the very minimum the following packages:

- VTK >= 4.4 (5.x is ideal)
- numpy >= 1.0.1
- setuptools (for installation and egg builds)
- Traits >= 3.0 (*Traits*, *TraitsGUI* and *TraitsBackendWX* or *TraitsBackendQt*, *EnthoughtBase*, *AppTools*) **Note** Depending on your installation procedure, you might not need to instal manually these requirements.

The following requirements are really optional but strongly recommended, especially if you are new to Mayavi:

- wxPython 2.8.x
- configobj
- Envisage == 3.x (*EnvisageCore* and *EnvisagePlugins*) **Note** These last requirements can be automatically installed, see below.

One can install the requirements in several ways.

- Windows and MacOSX: even if you want to build from source, a good way to install the requirements is to install one of the distributions indicated above. Note that under Windows, EPD comes with a compiler (mingw) and facilitates building Mayavi.
- Linux: Most Linux distributions will have installable binaries available for the some of the above. For example, under Debian or Ubuntu you would need `python-vtk`, `python-wxgtk2.6`, `python-setuptools`, `python-numpy`, `python-configobj`. More information on specific distributions and how you can get the requirements for each of these should be available from the list of distributions here:

  https://svn.enthought.com/enthought/wiki/Install

- Mac OS X: The best available instructions for this platform are available on the IntelMacPython25 page.

There are several ways to install TVTK, Traits and Mayavi. These are described in the following.

2.3 Doing it yourself: Python packages: Eggs

2.3.1 Installing with *easy_install*

First make sure you have the prerequisites for Mayavi installed, as indicated in the previous section, i.e. the following packages:

- VTK >= 4.4 (5.x is ideal)
- numpy >= 1.0.1
- wxPython >= 2.8.0
- configobj
- setuptools (for installation and egg builds; later the better)

Mayavi_ is part of the Enthought Tool Suite (ETS). As such, it is distributed as part of ETS and therefore binary packages and source packages of ETS will contain Mayavi. Mayavi releases are almost always made along with an ETS release. You may choose to install all of ETS or just Mayavi alone from a release.

ETS has been organized into several different Python packages. These packages are distributed as Python Eggs. Python eggs are fairly sophisticated and carry information on dependencies with other eggs. As such they are rapidly becoming the standard for distributing Python packages.

The easiest way to install Mayavi with eggs is to use pre-built eggs built for your particular platform and downloaded by *easy_install*. Alternatively *easy_install* can build the eggs from the source tarballs. This is also fairly easy to do if you have a proper build environment.

To install eggs, first make sure the essential requirements are installed, and then build and install the eggs like so:

```
$ easy_install "Mayavi[app]"
```

This one command will download, build and install all the required ETS related modules that Mayavi needs for the latest ETS release, this means that the *Traits* dependencies and the *Envisage* dependencies will be installed automatically. If you run into trouble please check the Enthought Install pages.

One common sources of problems during an install, is the presence of older versions of packages such as Traits, Mayavi, Envisage or TVTK. Make sure that you clean your `site-packages` before installing a new version of Mayavi. Another problem often encountered is running into what is probably a bug of the build system that appears as a "sandbox violation". In this case, it can be useful to try the download and install command a few times.

If you still have problems, given this background, please see the following Enthought Install describes how ETS can be installed with eggs. Check this page first. It contains information on how to install the prebuilt binary eggs for various platforms along with any dependencies.

Note: Automatic downloading of required eggs

If you whish to download all the eggs fetched by *easy_install*, for instance to propagate to an offline PC, you can use virtualenv to create an empty site-packages, and install to it:

```
virtualenv --no-site-packages temp
cd temp
source bin/activate
mkdir temp_subdir
easy_install -zmaxd temp_subdir "Mayavi[app,nonets]"
```

2.3.2 Step-by-step instructions to install with eggs under Windows

If you do not wish to install a ready-made distribution under Windows, these instructions (provided by Guillaume Duclaux) will guide you through the necessary steps to configure a Windows environment in which Mayavi will run.

1. Install Python 2.5. Add 'C:\Python25;' to the PATH environment variables.
2. Install Mingw32, from the Download section of http://www.mingw.org/ , use the MinGW5.1.4 installer. Add 'C:\MinGW\bin;' to the PATH environment variables.
3. Create a 'c:\documents and settings\USERNAME\pydistutils.cfg' file(where USERNAME is the login) with the following contents:

   ```
   [build]
   compiler=mingw32
   ```

4. Create the new environment variable HOME and set it to the value: 'c:\docume~1\USERNAME;' (where USERNAME is the login name)
5. Install Setuptools (0.6c9 binary) from its webpage, and 'C:Python25Scripts;' to the PATH environment variables
6. Install VTK 5.2 (using Dr Charl P. Botha Windows binary http://cpbotha.net/2008/09/23/python-25-enabled-vtk-52-windows-binaries/)
   - Unzip the folder content in 'C:\Program Files\VTK5.2_cpbotha'
   - add 'C:\Program Files\VTK5.2_cpbotha\bin;' to the PATH environment variables
   - create a new environment variable PYTHONPATH and set it to the value 'C:\Program Files\VTK5.2_cpbotha\lib\site-packages;'
   - If you are running an old version of windows (older than XP) download msvcr80.dll and msvcp80.dll from the www.dll-files.com website and copy them into C:\winnt\system32.
7. Install Numpy (binary from http://numpy.scipy.org/)
8. Installing wxPython (2.8 binary from http://www.wxpython.org/)
9. Run in cmd.exe:

```
easy_install Sphinx EnvisageCore EnvisagePlugins configobj
```

10. Finally, run in cmd.exe:

```
easy_install Mayavi[app]
```

2.4 Under Mac OSX Snow Leopard

Under Mac OSX Snow Leopard, you may need to build VTK yourself. Here are instructions specific to Snow Leopard (thanks to Darren Dale for providing the instructions):

1. Download the VTK tarball, unzip it, and make a build directory (vtkbuild) next to the resulting VTK directory
2. Then cd into vtkbuild and run "cmake ../VTK". Next, edit CMakeCache.txt (in vtkbuild) and set:

```
//Build Verdict with shared libraries.
BUILD_SHARED_LIBS:BOOL=ON

//Build architectures for OSX
CMAKE_OSX_ARCHITECTURES:STRING=x86_64

//Minimum OS X version to target for deployment (at runtime); newer
// APIs weak linked. Set to empty string for default value.
CMAKE_OSX_DEPLOYMENT_TARGET:STRING=10.6

//Wrap VTK classes into the Python language.
VTK_WRAP_PYTHON:BOOL=ON

//Arguments passed to "python setup.py install ..." during installation.
VTK_PYTHON_SETUP_ARGS:STRING=
```

3. Run "cmake ../VTK" again.
4. Run "make -j 2" for a single cpu system. "make -j 9" will compile faster on an 8-core system.
5. Run "sudo make install"
6. Edit your ~/.profile and add the following line:

```
export DYLD_LIBRARY_PATH=${DYLD_LIBRARY_PATH}:/usr/local/lib/vtk-5.4
```

7. Run "source ~/.profile" or open a new terminal so the DYLD_LIBRARY_PATH environment variable is available.
8. After that, install Mayavi in the usual way.

2.5 The bleeding edge: SVN

If you want to get the latest development version of Mayavi (e.g. for developing Mayavi or contributing to the documentation), we recommend that you check it out from SVN. Mayavi depends on several packages that are part of ETS. It is highly likely that the in-development mayavi version may depend on some feature of an as yet unreleased component. Therefore, it is very convenient to get all the relevant ETS projects that mayavi recursively depends on in one single checkout. In order to do this easily, Dave Peterson has created a package called ETSProjectTools. This

must first be installed and then any of ETS related repositories may be checked out. Here is how you can get the latest development sources.

1. Make sure there is no other ETS package installed in your pythonpath:

```
$ python
>>> import enthought
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ImportError: No module named enthought
```

   If you *don't* get the ImportError (e.g. importing `enthought` succeeds), then there is no way to install the svn Mayavi version over it (even if you put it first in your PYTHONPATH), because the older (setuptools managed) ETS packages will get picked up too and they will mess up things. This behavior might be surprising if you are new to setuptools.

   So for example if you use Ubuntu or Debian, you need to first remove all ETS packages (in Ubuntu 9.04, you need to remove all of these: `mayavi2 python-apptools python-enthoughtbase python-envisagecore python-envisageplugins python-traits python-traitsbackendwx python-traitsgui`).

2. Install ETSProjectTools like so:

```
$ svn co https://svn.enthought.com/svn/enthought/ETSProjectTools/trunk \
       ETSProjectTools
$ cd ETSProjectTools
$ python setup.py install
```

   This will give you the useful scripts `ets`. For more details on the tool and various options check the ETSProjectTools wiki page.

3. To get just the sources for mayavi and all its dependencies do this:

```
$ ets co "Mayavi[app]"
```

   This will look at the latest available mayavi, parse its ETS dependencies and check out the relevant sources. If you want a particular mayavi release you may do:

```
$ ets co "Mayavi[app]==3.0.1"
```

   If you'd like to get the sources for an entire ETS release do this for example:

```
$ ets co "ets==3.0.2"
```

   This will checkout all the relevant sources from SVN. Be patient, this will take a while. More options for the `ets` tool are available in the ETSProjectTools page.

4. Once the sources are checked out you may enter the checked-out directory, for example:

```
$ cd Mayavi_3.3.1/
```

   and either:

   (a) Install a development version, to track changes to SVN easily (recommended):

```
$ ets develop
```

This will install all the checked out sources via a `setup.py develop` applied to each package.

Note: To install of the packages in a different location than the default one, eg '~/usr/', use the following syntax:

```
ets develop -c"--prefix ~/usr"
```

make sure that the corresponding site-packages folder is in your PYTHONPATH environment variable (for the above example it would be: '~/usr/lib/python2.x/site-packages/'

(b) Or build binary eggs of the sources to install localy:

```
$ cd Mayavi_3.3.1
$ ets bdist
```

This will build all the eggs and put them inside a `dist` subdirectory. Run `ets bdist -h` for more bdist related options. The mayavi development egg and its dependencies may be installed via:

```
$ easy_install -f dist "Mayavi[app]"
```

(c) Alternatively, if you'd like just `Mayavi` installed via `setup.py develop` with the rest as binary eggs you may do:

```
$ cd Mayavi_x.y.z
$ python setup.py develop -f ../dist
```

This will pull in any dependencies from the built eggs.

You should now have the latest version of Mayavi installed and usable.

2.6 Testing your installation

The easiest way to test if your installation is OK is to run the mayavi2 application like so:

```
mayavi2
```

To get more help on the command try this:

```
mayavi2 -h
```

`mayavi2` is the mayavi application. On some platforms like win32 you will need to double click on the `mayavi2.exe` program found in your `Python2X\Scripts` folder. Make sure this directory is in your path.

Note: Mayavi can be used in a variety of other ways but the `mayavi2` application is the easiest to start with.

If you have the source tarball of mayavi or have checked out the sources from the SVN repository, you can run the examples in `enthought.mayavi*/examples`. There are plenty of example scripts illustrating various features. Tests are available in the `enthought.mayavi*/tests` sub-directory.

2.7 Troubleshooting

If you are having trouble with the installation you may want to check the *Getting help* page for more details on how you can search for information or email the mailing list.

CHAPTER

THREE

TUTORIAL EXAMPLES TO LEARN MAYAVI

Section summary

In this section, we give a few detailed examples of how you can use the Mayavi application to tour some of its features.
This section is mainly interested with the Mayavi application, but it is a good introduction to the ideas behind using Mayavi as a library. However, if you are only interested in a quick start to use Mayavi as a simple, Matlab-like, plotting library, you can jump directly to the *mlab: Python scripting for 3D plotting* section, and come back later for a deeper understanding.

To get acquainted with mayavi you may start up the Mayavi2 application, `mayavi2` in the command line, like so:

```
$ mayavi2
```

On Windows you can double click on the installed `mayavi2.exe` executable (usually in the `Python2X\Scripts` directory), or use the start menu entry, if you installed python(x,y) or EPD.

Once Mayavi starts, you may resize the various panes of the user interface to get a comfortable layout. These settings will become the default "perspective" of the mayavi application. More details on the UI are available in the *General layout of UI* section.

Before proceeding on the quick tour, it can be useful to locate some data to experiment with. Two of the examples below make use of data shipped with the mayavi sources ship. These may be found in the `examples/data` directory inside the root of the mayavi source tree. If these are not installed, the sources may be downloaded from here: http://code.enthought.com/enstaller/eggs/source/

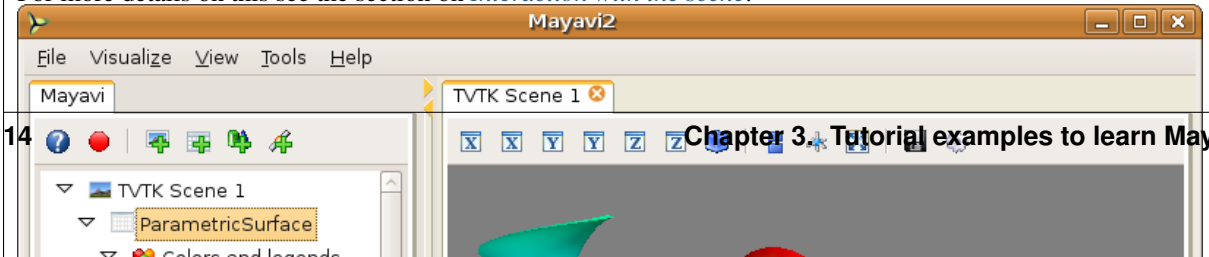
Examples:

3.1 Parametric surfaces: a simple introduction to visualization

Parametric surfaces are particularly handy if you are unable to find any data to play with right away. Parametric surfaces are surfaces parametrized typically by 2 variables, u and v. VTK has a bunch of classes that let users explore Parametric surfaces. This functionality is also available in Mayavi. The data is a 2D surface embedded in 3D. Scalar data is also available on the surface. More details on parametric surfaces in VTK may be obtained from Andrew Maclean's Parametric Surfaces document.

1. After starting mayavi2, create a simple Parametric surface source by selecting *File->Load data->Create Parametric Surface source*. Once you create the data, you will see a new node on the Mayavi tree view on the left that says *ParametricSurface*. Note that you **will not** see anything visualized on the TVTK scene yet.
   You can modify the nature of the parametric surface by clicking on the node for the *ParametricSurface* source object.
2. To see an outline (a box) of the data, navigate to the *Visualize->Modules* menu item and select the *Outline* module. You can also right-click on the *ParametricSurface* node to bring up a context menu and select *Add Module->Surface*. You will immediately see a wireframe cube on the TVTK scene. You should also see two new nodes on the tree view, one called *Colors and legends* and one underneath that called *Outline*.
3. You can change properties of the outline displayed by clicking on the *Outline* node on the left. This will create an object editor window on left bottom of the window (the object editor tab) below the tree view. Play with the settings here and look at the results. For example, to change the color of the outline box modify the value in the color field. If you double-click a node on the left it will pop up an editor dialog rather than show it in the embedded object editor.
4. To navigate the scene look at the section on *Interaction with the scene* section for more details. Experiment with these.
5. To view the actual surface create a *Surface* module by selecting *Visualize->Modules->Surface*. You can show contours of the scalar data on this surface by clicking on the *Surface* node on the left and switching on the *Enable contours* check-box.
6. To view the color legend (used to map scalar values to colors), click on the *Modules* node on the tree view. Then, on the 'Scalar LUT' tab, activate the *Show scalar bar* check-box. This will show you a legend on the TVTK scene. The legend can be moved around on the scene by clicking on it and dragging it. It can also be resized by clicking and dragging on its edges. You can change the nature of the color-mapping by choosing among different lookup tables on the object editor.
7. You can add as many modules as you like. Not all modules make sense for all data. Mayavi does not yet grey out (or disable) menu items and options if they are invalid for the particular data chosen. This will be implemented in the future. However making a mistake should not in general be disastrous, so go ahead and experiment.
8. You may add as many data sources as you like. It is possible to view two different parametric surfaces on the same scene by selecting the scene node and then loading another parametric surface source. Whether this makes sense or not is up to the user. You may also create as many scenes you want to and view anything in those. You can cut/paste/copy sources and modules between any nodes on the tree view using the right click options.
9. To delete the *Outline* module say, right click on the *Outline* node and select the Delete option. You may also want to experiment with the other options.
10. You can save the rendered visualization to a variety of file formats using the *File->Save Scene As* menu.
11. The visualization may itself be saved out to a file via the *File->Save Visualization* menu and reloaded using the *Load visualization* menu.

Shown below is an example visualization made using the parametric source. Note that the positioning of the different surfaces was effected by moving the actors on screen using the actor mode of the scene via the 'a' key. For more details on this see the section on *Interaction with the scene*.



CHAPTER

FOUR

USING THE MAYAVI APPLICATION

Section summary

This section primarily concerns using the `mayavi2` application. Some of the things mentioned here also apply when Mayavi is scripted. We recommend that new users read this chapter to get a better knowledge of the interactive use of the library.

4.1 General layout of UI

When the *mayavi2* application is started it will provide a user interface that looks something like the figure shown below.

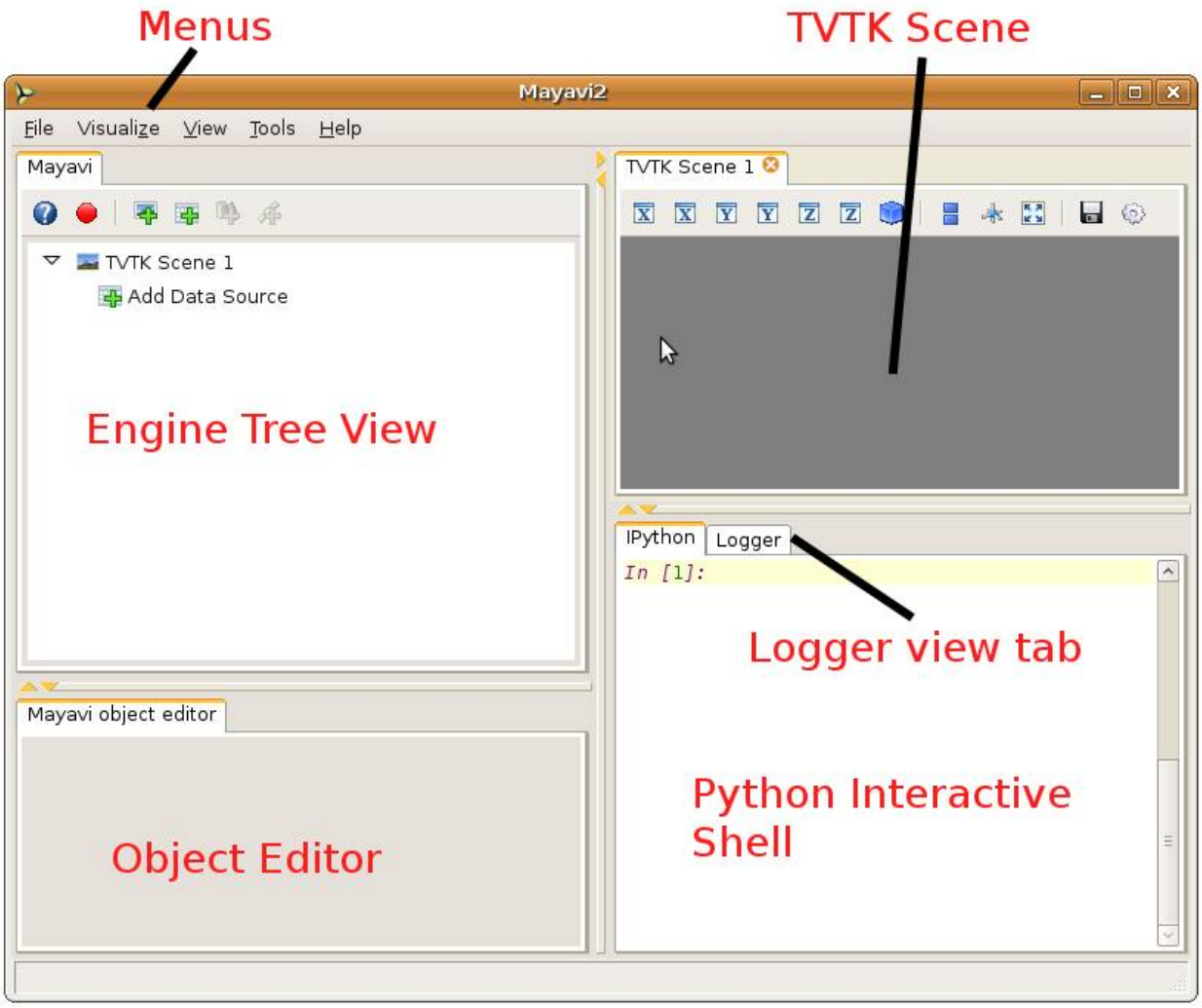


Figure of Mayavi's initial UI window.

The UI features several sections described below.

Menus The menus let you open files, load modules, set preferences etc.

The Mayavi engine tree view

This is a tree view of the Mayavi pipeline.

- Right click a tree node to rename, delete, copy the objects.
- Left click on a node to edit its properties on the object editor below the tree.
- It is possible to drag the nodes around on the tree. For example it is possible to drag and move a module from one set of Modules to another, or to move a visualization from one scene to another.

The object editor This is where the properties of Mayavi pipeline objects can be changed when an object on the engine's pipeline is clicked.

TVTK scenes This is where the visualization of the data happens. One can interact with this scene via the mouse and the keyboard. More details are in the following sections.

Python interpreter The built-in Python interpreter that can be used to script Mayavi and do other things. You can drag nodes from the Mayavi tree and drop them on the interpreter and then script the object

represented by the node!

If you have version of IPython above 0.9.1 installed, this Python interpreter will use IPython.

Logger Application log messages may be seen here.

Mayavi's UI layout is highly configurable:

- the line in-between the sections can be dragged to resize particular views.
- most of the "tabs" on the widgets can be dragged around to move them anywhere in the application.
- Each view area (the Mayavi engine view, object editor, python shell and logger) can be enabled and disabled in the 'View' menu.

Each time you change the appearance of Mayavi it is saved and the next time you start up the application it will have the same configuration. In addition, you can save different layouts into different "perspectives" using the *View->Perspectives* menu item.

Shown below is a specifically configured Mayavi user interface view. In this view the size of the various parts are changed.

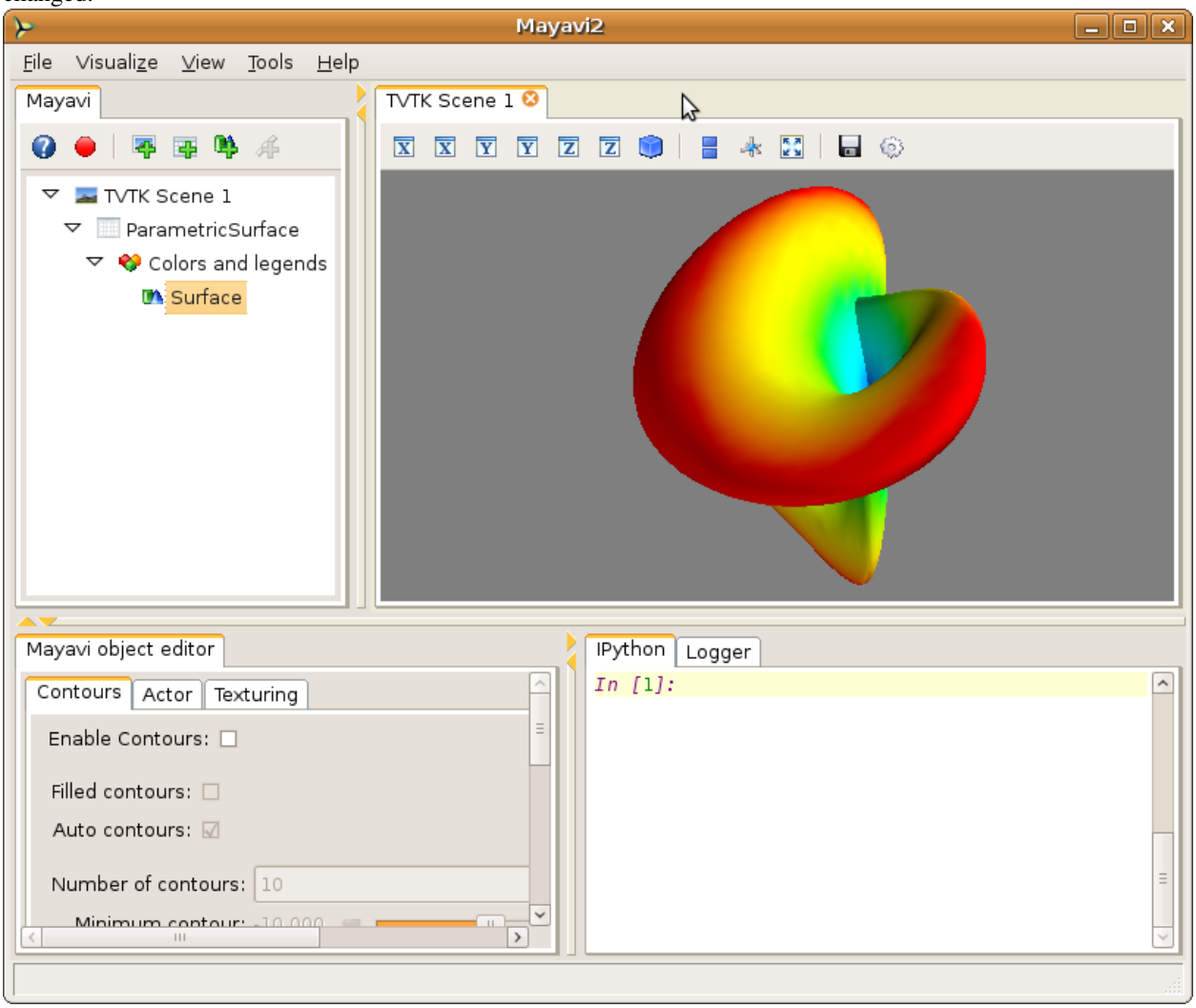


Figure of Mayavi's UI after being configured by a user.

4.2 Visualizing data

Visualization data in Mayavi is performed by loading some data as *data sources*, and applying visualization modules to these sources to visualize the data as described in the *An overview of Mayavi* section and the *Tutorial examples to learn Mayavi* section.

One needs to have some data or the other loaded before a *Module* or *Filter* may be used. Mayavi supports several data file formats most notably VTK data file formats. Alternatively, *mlab* can be used to load data from *numpy* arrays. For advanced information on data structures, refer to the *Data representation in Mayavi* section.

Once data is loaded one can optionally use a variety of *Filters* to filter or modify the data in some way or the other and then visualize the data using several *Modules*.

Here we list all the Mayavi *modules* and *filters*. This list is useful as a reference:

List of modules and filters

4.2.1 Modules

Modules are the objects that perform the visualization itself: they use data to create the visual elements on the scene.
Here is a list of the Mayavi modules along with a brief description.

Axes Draws simple axes.

ContourGridPlane A contour grid plane module. This module lets one take a slice of input grid data and view contours of the data.

CustomGridPlane A custom grid plane with a lot more flexibility than GridPlane module.

Glyph Displays different types of glyphs oriented and colored as per scalar or vector data at the input points.

GridPlane A simple grid plane module.

HyperStreamline A module that integrates through a tensor field to generate a hyperstreamline. The integration is along the maximum eigenvector and the cross section of the hyperstreamline is defined by the two other eigenvectors. Thus the shape of the hyperstreamline is "tube-like", with the cross section being elliptical. Hyperstreamlines are used to visualize tensor fields.

ImageActor A simple module to view image data efficiently.

ImagePlaneWidget A simple module to view image data along a cut.

IsoSurface A module that allows the user to make contours of input volumetric data.

Labels Allows a user to label the current dataset or the current actor of the active module.

OrientationAxes Creates a small axes on the side that indicates the position of the coordinate axes and thereby marks the orientation of the scene. Requires VTK-4.5 and above.

Outline A module that draws an outline for the given data.

ScalarCutPlane Takes a cut plane of any input data set along an implicit plane and plots the data with optional contouring and scalar warping.

SliceUnstructuredGrid This module takes a slice of the unstructured grid data and shows the cells that intersect or touch the slice.

Streamline Allows the user to draw streamlines for given vector data. This supports various types of seed objects (line, sphere, plane and point seeds). It also allows the user to draw ribbons or tubes and further supports different types of interactive modes of calculating the streamlines.

StructuredGridOutline Draws a grid-conforming outline for structured grids.

Surface Draws a surface for any input dataset with optional contouring.

TensorGlyph Displays tensor glyphs oriented and colored as per scalar or vector data at the input points.

Text This module allows the user to place text on the screen.

VectorCutPlane Takes an arbitrary slice of the input data along an implicit cut plane and places glyphs according to the vector field data. The glyphs may be colored using either the vector magnitude or the scalar attributes.

Vectors Displays different types of glyphs oriented and colored as per vector data at the input points. This is merely a convenience module that is entirely based on the Glyph module.

Volume The Volume module visualizes scalar fields using volumetric visualization techniques.

WarpVectorCutPlane Takes an arbitrary slice of the input data using an implicit cut plane and warps it according to the vector field data. The scalars are displayed on the warped surface as colors.

4.2.2 Filters

Filters transform the data, but do not display it. They are used as an intermediate between the data sources and the modules.
Here is a list of the Mayavi Filters.

CellDerivatives Computes derivatives from input point scalar and vector data and pro-

4.3 Interaction with the scene

The TVTK scenes on the UI can be closed by clicking on the little 'x' icon on the tab. Each scene features a toolbar that supports various features:

- Buttons to set the view to view along the positive or negative X, Y and Z axes or obtain an isometric view.
- A button to turn on parallel projection instead of the default perspective projection. This is particularly useful when one is looking at 2D plots.
- A button to turn on an axes to indicate the x, y and z axes.
- A button to turn on full-screen viewing. Note that once full-screen mode is entered one must press 'q' or 'e' to get back a normal window.
- A button to save the scene to a variety of image formats. The image format to use is determined by the extension provided for the file.
- A button that provides a UI to configure the scene properties.

The primary means to interact with the scene is to use the mouse and keyboard.

4.3.1 Mouse interaction

There are two modes of mouse interaction:

- Camera mode: the default, where the camera is operated on with mouse moves. This mode is activated by pressing the 'c' key.
- Actor mode: in this mode the mouse actions operate on the actor the mouse is currently above. This mode is activated by pressing the 'a' key.

The view on the scene can be changed by using various mouse actions. Usually these are accomplished by holding down a mouse button and dragging.

- holding the left mouse button down and dragging will rotate the camera/actor in the direction moved.
  - Holding down "SHIFT" when doing this will pan the scene – just like the middle button.
  - Holding down "CONTROL" will rotate around the camera's axis (roll).
  - Holding down "SHIFT" and "CONTROL" and dragging up will zoom in and dragging down will zoom out. This is like the right button.
- holding the right mouse button down and dragging upwards will zoom in (or increase the actors scale) and dragging downwards will zoom out (or reduce scale).
- holding the middle mouse button down and dragging will pan the scene or translate the object.
- Rotating the mouse wheel upwards will zoom in and downwards will zoom out.

4.3.2 Keyboard interaction

The scene supports several features activated via keystrokes. These are:

- '3': Turn on/off stereo rendering. This may not work if the 'stereo' preference item is not set to True.
- 'a': Use actor mode for mouse interaction instead of camera mode.
- 'c': Use camera mode for mouse interaction instead of actor mode.
- 'e'/'q'/'Esc': Exit full-screen mode.

- 'f': Move camera's focal point to current mouse location. This will move the camera focus to center the view at the current mouse position.
- 'j': Use joystick mode for the mouse interaction. In joystick mode the mouse somewhat mimics a joystick. For example, holding the mouse left button down when away from the center will rotate the scene.
- 'l': Configure the lights that are illumining the scene. This will pop-up a window to change the light configuration.
- 'p': Pick the data at the current mouse point. This will pop-up a window with information on the current pick. The UI will also allow one to change the behavior of the picker to pick cells, points or arbitrary points.
- 'r': Reset the camera focal point and position. This is very handy.
- 's': Save the scene to an image, this will first popup a file selection dialog box so you can choose the filename, the extension of the filename determines the image type.
- 't': Use trackball mode for the mouse interaction. This is the default mode for the mouse interaction.
- '='/'+': Zoom in.
- '-': Zoom out.
- 'left'/'right'/'up'/'down' arrows: Pressing the left, right, up and down arrow let you rotate the camera in those directions. When "SHIFT" modifier is also held down the camera is panned.

4.4 The embedded Python interpreter

The embedded Python interpreter offers extremely powerful possibilities. The interpreter features command completion, automatic documentation, tooltips and some multi-line editing. In addition it supports the following features:

- The name `mayavi` is automatically bound to the `enthought.mayavi.script.Script` instance. This may be used to easily script Mayavi.
- The name `application` is bound to the envisage application.
- If a Python file is opened via the `File->Open File...` menu item one can edit it with a color syntax capable editor. To execute this script in the embedded Python interpreter, the user may type `Control-r` on the editor window. To save the file press `Control-s`. This is a very handy feature when developing simple Mayavi scripts. You can also increase and decrease the font size using `Control-n` and `Control-s`.
- As mentioned earlier, one may drag and drop nodes from the Mayavi engine tree view onto the Python shell. The object may then be scripted as one normally would. A commonly used pattern when this is done is the following:

```
>>> tvtk_scene_1
<enthought.mayavi.core.scene.Scene object at 0x9f4cbe3c>
>>> s = _
```

  In this case the name `s` is bound to the dropped tvtk_scene object. The _ variable stores the last evaluated expression which is the dropped object. Using `tvtk_scene_1` will also work but is a mouthful.

4.5 Automatic script generation

Mayavi features a very handy and powerful script recording facility. This can be used to:

- record all actions performed on the Mayavi UI into a *human readable*, Python script that should be able to recreate your visualization.

- easily learn the Mayavi code base and how to script it.

4.5.1 Recording Mayavi actions to a script

Here is how you can use this feature:

1. When you start the `mayavi2` application, on the Engine View (the tree view) toolbar you will find a red record icon next to the question mark icon. Click it. Note that this will also work from a standalone mlab session, on the toolbar of the `Mayavi pipeline` window.
2. You'll see a window popup with a few lines of boilerplate code so you can run your script standalone/with `mayavi2 -x script.py ``or ``python script.py`. Keep this window open and ignore for now the `Save script` button, that will be used when you are finished.
3. Now do anything you please on the UI. As you perform those actions, the code needed to perform those actions is added to the code listing and displayed in the popup window. For example, create a new source (either via the adder node dialog/view, the file menu or right click, i.e. any normal option), then add a module/filter etc. Modify objects on the tree view.
4. Move the camera on the UI, rotate the camera, zoom, pan. All of these will generate suitable Python code. For the camera only the end position is stored (otherwise you'll see millions of useless lines of code). The major keyboard actions on the scene are recorded (except for the 'c'/'t'/'j'/'a' keys). This implies that it will record any left/right/up/down arrows the '+'/'-' keys etc.

   Since the code is updated as the actions are performed, this is a nice way to learn the Mayavi API.
5. Once you are done, clicking on the record icon again will stop the recording: in the pop-up window, the `Recording` box will be ticked off and no code corresponding to new actions will be displayed any more. If you want to save the recorded script to a Python file, click on the `Save script` button at the bottom of the window. Save the script to some file, say `script.py`. If you are only interested in the code and not saving a file you may click cancel at this point.
6. Close the recorder window and quit Mayavi (if you want to).
7. Now from the shell do:

   ```
   $  mayavi2 -x script.py
   ```

   or even:

   ```
   $ python script.py
   ```

   These should run all the code to get you where you left. You can feel free to edit this generated script – in fact that is the whole point of automatic script generation!

It is important to understand that it is possible to script an existing session of Mayavi too. So, if after starting Mayavi you did a few things or ran a Mayavi script and then want to record any further actions, that is certainly possible. Follow the same procedure as before. The only gotcha you have to remember in this case is that the script recorder will not create the objects you already have setup on the session.

Note: You should also be able to delete/drag drop objects on the Mayavi tree view. However, these probably aren't things you'd want to do in an automatic script.

As noted earlier, script recording will work for an `mlab` session or anywhere else where Mayavi is used. It will not generate any `mlab` specific code but write generic Mayavi code using the OO Mayavi API.

4.5.2 Limitations

The script recorder works for most important actions. At this point it does not support the following actions:

- On the scene, the 'c'/'t'/'j'/'a'/'p' keys are not recorded correctly since this is much more complicated to implement and typically not necessary for basic scripting.
- Arbitrary scripting of the interface is obviously not going to work as you may expect.
- Only trait changes and specific calls are recorded explicitly in the code. So calling arbitrary methods on arbitrary Mayavi objects will not record anything typically. Only the Mayavi engine is specially wired up to record specific methods.

4.6 Command line arguments

The `mayavi2` application features several useful command line arguments that are described in the following section. These options are described in the `mayavi2` man page as well.

A complete pipeline may be built from the command line, so that Mayavi can be integrated in shell scripts to provide useful visualizations.

Mayavi can be run like so:

```
mayavi2 [options] [args]
```

Where `arg1`, `arg2` etc. are optional file names that correspond to saved Mayavi2 visualizations (`filename.mv2`), Mayavi2 scripts (`filename.py`) or any datafile supported by Mayavi. If no options or arguments are provided Mayavi will start up with a default blank scene.

The options are:

-h This prints all the available command line options and exits. Also available through `--help`.

-V This prints the Mayavi version on the command line and exits. Also available through `--version`.

-z file_name This loads a previously saved Mayavi2 visualization. Also available through `--viz file_name` or `--visualization file_name`.

-d data_file Opens any of the supported data file formats or non-file associated data source objects. This includes VTK file formats (`*.vtk`, `*.xml`, `*.vt[i,p,r,s,u]`, `*.pvt[i,p,r,s,u]`), VRML2 (`*.wrl`), 3D Studio (`*.3ds`), PLOT3D (`*.xyz`), STL, BYU, RAW, PLY, PDB, SLC, FACET, OBJ, AVSUCD (`*.inp`), GAMBIT (`*.neu`), Exodus (`*.exii`), PNG, JPEG, BMP, PNM, DCM, DEM, MHA, MHD, MINC, XIMG, TIFF, and various others that are supported.

Note that `data_file` can also be a source object not associated with a file, for example `ParametricSurface` or `PointLoad` will load the corresponding data sources into Mayavi. Also available through `--data`.

-m module-name A module is an object that actually visualizes the data. The given `module-name` is loaded in the current `ModuleManager`. The module name must be a valid one if not you will get an error message.

If a module is specified as `package.sub.module.SomeModule` then the module (`SomeModule`) is imported from `package.sub.module`. Standard modules provided with `mayavi2` do not need the full path specification. For example:

```
mayavi2 -d data.vtk -m Outline -m user_modules.AModule
```

In this example `Outline` is a standard module and `user_modules.AModule` is some user defined module. Also available through `--module`.

-f filter-name A filter is an object that filters out the data in some way or the other. The given `filter-name` is loaded with respect to the current source/filter object. The filter name must be a valid one if not you will get an error message.

If the filter is specified as `package.sub.filter.SomeFilter` then the filter (`SomeFilter`) is imported from `package.sub.filter`. Standard modules provided with `mayavi2` do not need the full path specification. For example:

```
mayavi2 -d data.vtk -f ExtractVectorNorm -f user_filters.AFilter
```

In this example `ExtractVectorNorm` is a standard filter and `user_filters.AFilter` is some user defined filter. Also available through `--filter`.

-M Starts up a new module manager on the Mayavi pipeline. Also available through `--module-mgr`.

-n Creates a new window/scene. Any options passed after this will apply to this newly created scene. Also available through `--new-window`.

-o Run Mayavi in offscreen mode without any graphical user interface. This is most useful for scripts that need to render images offscreen (for an animation say) in the background without an intrusive user interface popping up. Mayavi scripts (run via the `-x` argument) should typically work fine in this mode. Also available through, `--offscreen`.

-x script-file This executes the given script in a namespace where we guarantee that the name 'mayavi' is Mayavi's script instance – just like in the embedded Python interpreter. Also available through `--exec`.

-t Runs the Mayavi test suite and exits. If run as such, this runs both the TVTK and Mayavi2 unittests. If any additional arguments are passed they are passed along to the test runner. So this may be used to run other tests as well. For example:

```
mayavi2 -t enthought.persistence
```

This will run just the tests inside the `enthought.persistence` package. You can also specify a directory with test files to run with this, for example:

```
mayavi2 -t relative_path_to/integrationtests/mayavi
```

will run the integration tests from the Mayavi sources. Also available as `--test`.

-s python-expression Execute the python-expression on the last created object. For example, lets say the previous object was a module. If you want to set the color of that object and save the scene, you may do:

```
$ mayavi2 [...] -m Outline -s"actor.property.color = (1,0,0)" \
 -s "scene.save('test.png', size=(800, 800))"
```

You should use quotes for the expression. This is also available through `--set`.

Warning: Note that `-x` or `--exec` uses *execfile*, so this can be dangerous if the script does something nasty! Similarly, `-s` or `--set` uses *exec*, which can also be dangerous if abused.

It is important to note that Mayavi's **command line arguments are processed sequentially** in the same order they are given. This allows users to do interesting things.

Here are a few examples of the command line arguments:

```
$ mayavi2 -d ParametricSurface -s "function='dini'" -m Surface \
  -s "module_manager.scalar_lut_manager.show_scalar_bar = True" \
  -s "scene.isometric_view()" -s "scene.save('snapshot.png')"

$ mayavi2 -d heart.vtk -m Axes -m Outline -m GridPlane \
  -m ContourGridPlane -m IsoSurface

$ mayavi2 -d fire_ug.vtu -m Axes -m Outline -m VectorCutPlane \
  -f MaskPoints -m Glyph
```

In the above examples, `heart.vtk` and `fire_ug.vtu` VTK files can be found in the `examples/data` directory in the source. They may also be installed on your computer depending on your particular platform.

CHAPTER

FIVE

MLAB: PYTHON SCRIPTING FOR 3D PLOTTING

Section summary

This section describes the *mab* API, for use of Mayavi as a simple plotting in scripts or interactive sessions. This is the main entry point for people interested in doing 3D plotting à la Matlab or IDL in Python. If you are interested in a list of all the functions exposed in mlab, see the *MLab reference*.

The `enthought.mayavi.mlab` module, that we call mlab, provides an easy way to visualize data in a script or from an interactive prompt with one-liners as done in the matplotlib `pylab` interface but with an emphasis on 3D visualization using Mayavi2. This allows users to perform quick 3D visualization while being able to use Mayavi's powerful features.

Mayavi's mlab is designed to be used in a manner well-suited to scripting and does not present a fully object-oriented API. It is can be used interactively with IPython.

Warning: When using IPython with mlab, as in the following examples, IPython must be invoked with the `-wthread` command line option like so:

```
$ ipython -wthread
```

If you are using the Enthought Python Distribution, or the latest Python(x,y) distribution, the Pylab menu entry will start ipython with the right switch. In older release of Python(x,y) you need to start "Interactive Console (wxPython)".
For more details on using mlab and running scripts, read the section *Running mlab scripts*

In this section, we first introduce simple plotting functions, to create 3D objects as representations of *numpy* arrays. Then we explain how properties such as color or glyph size can be modified or used to represent data, we show how the visualization created throught *mlab* can be modified interactively with dialogs, we show how scripts and animations can be ran. Finally, we expose a more advanced use of *mlab* in which full visualization pipeline are built in scripts, and we give some detailled examples of applying these tools to visualizing volumetric scalar and vector data.

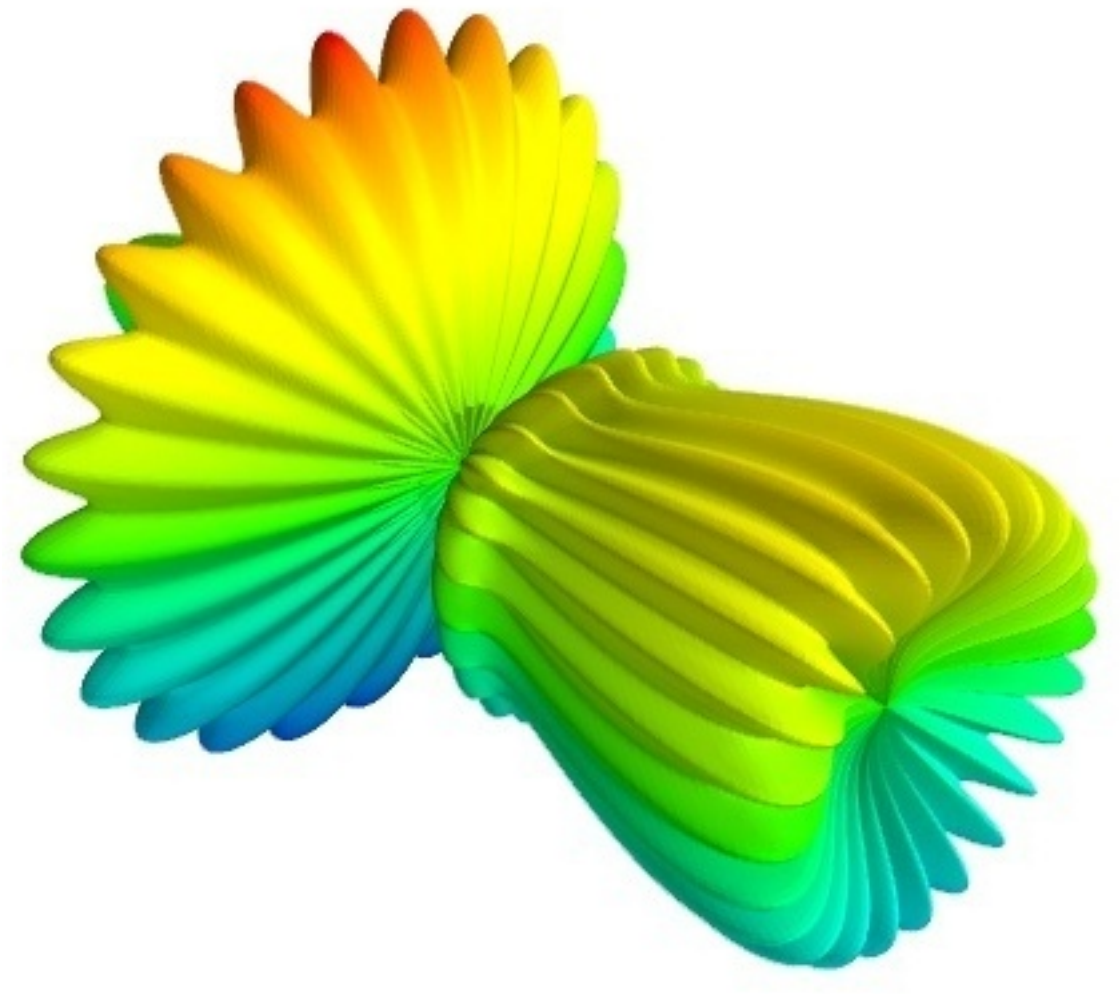
Section contents

5.1 A demo

To get you started, here is a pretty example showing a spherical harmonic as a surface:

```
# Create the data.
from numpy import pi, sin, cos, mgrid
dphi, dtheta = pi/250.0, pi/250.0
[phi,theta] = mgrid[0:pi+dphi*1.5:dphi,0:2*pi+dtheta*1.5:dtheta]
m0 = 4; m1 = 3; m2 = 2; m3 = 3; m4 = 6; m5 = 2; m6 = 6; m7 = 4;
r = sin(m0*phi)**m1 + cos(m2*phi)**m3 + sin(m4*theta)**m5 + cos(m6*theta)**m7
x = r*sin(phi)*cos(theta)
y = r*cos(phi)
z = r*sin(phi)*sin(theta)

# View it.
from enthought.mayavi import mlab
s = mlab.mesh(x, y, z)
mlab.show()
```

Bulk of the code in the above example is to create the data. One line suffices to visualize it. This produces the following visualization:



The visualization is created by the single function `mesh()` in the above.

Several examples of this kind are provided with mlab (see *test_contour3d*, *test_points3d*, *test_plot3d_anim* etc.). The above demo is available as *test_mesh*. Under IPython these may be found by tab completing on *mlab.test*. You can also inspect the source in IPython via the handy *mlab.test_contour3d??*.

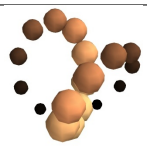
5.2 3D Plotting functions for numpy arrays

Visualization can be created in *mlab* by a set of functions operating on numpy arrays.

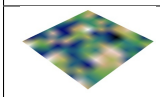
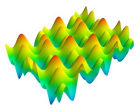
The mlab plotting functions take numpy arrays as input, describing the `x`, `y`, and `z` coordinates of the data. They build full-blown visualizations: they create the data source, filters if necessary, and add the visualization modules. Their behavior, and thus the visualization created, can be fine-tuned through keyword arguments, similarly to pylab. In addition, they all return the visualization module created, thus visualization can also be modified by changing the attributes of this module.

Note: In this section, we only list the different functions. Each function is described in details in the *MLab reference*, at the end of the user guide, with figures and examples. Please follow the links.

5.2.1 0D and 1D data

	`points3d()` Plots glyphs (like points) at the position of the supplied data, described by `x`, `y`, `z` numpy arrays of the same shape.
	`plot3d()` Plots line between the supplied data, described by `x`, `y`, `z` 1D numpy arrays of the same length.

5.2.2 2D data

	`imshow()` View a 2D array as an image.
	`surf()` View a 2D array as a carpet plot, with the z axis representation through elevation the value of the array points.
	`contour_surf()` View a 2D array as line contours, elevated according to the value of the array points.
	`mesh()` Plot a surface described by three 2D arrays, `x`, `y`, `z` giving the coordinnates of the data points as a grid. Unlike `surf()`, the surface is defined by its `x`, `y` and `z` coordinates with no privileged direction. More complex surfaces can be created.
	`barchart()` Plot an array `s`, or a set of points with explicite coordinnates arrays, `x`, `y` and `z`, as a bar chart, eg for histograms. This function is very versatile and will accept 2D or 3D arrays, but also clouds of points, to position the bars.
	`triangular_mesh()` Plot a triangular mesh, fully specified by `x`, `y` and `z` coordinnates of its vertices, and the (n, 3) array of the indices of the triangles.

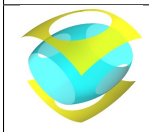
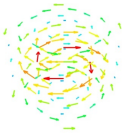
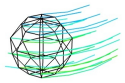
Vertical scale of `surf()` and `contour_surf()`

`surf()` and `contour_surf()` can be used as 3D representation of 2D data. By default the z-axis is supposed to be in the same units as the x and y axis, but it can be auto-scaled to give a 2/3 aspect ratio. This behavior can be controlled by specifying the "warp_scale='auto'".

From data points to surfaces.

Knowing the positions of data points is not enough to define a surface, connectivity information is also required. With the functions `surf()` and `mesh()`, this connectivity information is implicitely extracted from the shape of the input arrays: neighbooring data points in the 2D input arrays are connected, and the data lies on a grid. With the function `triangular_mesh()`, connectivity is explicitely specified. Quite often, the connectivity is not regular, but is not known in advance either. The data points lie on a surface, and we want to plot the surface implicitely defined. The *delaunay2d* filter does the required nearest-neighboor matching, and interpolation, as shown in the (*Surface from irregular data example*).

5.2.3 3D data

	`contour3d()` Plot isosurfaces of volumetric data defined as a 3D array.
	`quiver3d()` Plot arrows to represent vectors at data points. The `x`, `y`, `z` position are specified by numpy arrays, as well as the `u`, `v`, `w` components of the vectors.
	`flow()` Plot trajectories of particles along a vector field described by three 3D arrays giving the `u`, `v`, `w` components on a grid.

Structured or unstructured data

`contour3d()` and `flow()` require ordered data (to be able to interpolate between the points), whereas `quiver3d()` works with any set of points. The required structure is detailed in the functions' documentation.

Note: Many richer visualisations can be created by assembling data sources filters and modules. See the *Assembling pipelines with mlab* and the *Case studies of some visualizations* sections.

5.3 Changing the looks of the visual objects created

5.3.1 Adding color or size variations

Color The color of the objects created by a plotting function can be specified explicitly using the 'color' keyword argument of the function. This color is than applied uniformly to all the objects created.

If you want to vary the color across your visualization, you need to specify scalar information for each data point. Some functions try to guess this information: these scalars default to the norm of the vectors, for functions with vectors, or to the z elevation for functions where is meaningful, such as `surf()` or `barchart()`.

This scalar information is converted into colors using the colormap, or also called LUT, for Look Up Table. The list of possible colormaps is:

```
accent       flag          hot      pubu     set2
autumn       gist_earth    hsv      pubugn   set3
black-white  gist_gray     jet      puor     spectral
blue-red     gist_heat     oranges  purd     spring
blues        gist_ncar     orrd     purples  summer
bone         gist_rainbow  paired   rdbu     winter
brbg         gist_stern    pastel1  rdgy     ylgnbu
bugn         gist_yarg     pastel2  rdpu     ylgn
bupu         gnbu          pink     rdylbu   ylorbr
cool         gray          piyg     rdylgn   ylorrd
copper       greens        prgn     reds
dark2        greys         prism    set1
```

The easiest way to choose the colormap most adapted to your visualization is to use the GUI (as described in the next paragraph). The dialog to set the colormap can be found in the *Colors and legends* node.

Size of the glyph The scalar information can also be displayed in many different ways. For instance it can be used to adjust the size of glyphs positioned at the data points.

A caveat: Clamping: relative or absolute scaling Given six points positionned on a line with interpoint spacing 1:

```
x = [1, 2, 3, 4, 5, 6]
y = [0, 0, 0, 0, 0, 0]
z = y
```

If we represent a scalar varying from 0.5 to 1 on this dataset:

```
s = [.5, .6, .7, .8, .9, 1]
```

We represent the dataset as spheres, using `points3d()`, and the scalar is mapped to diameter of the spheres:

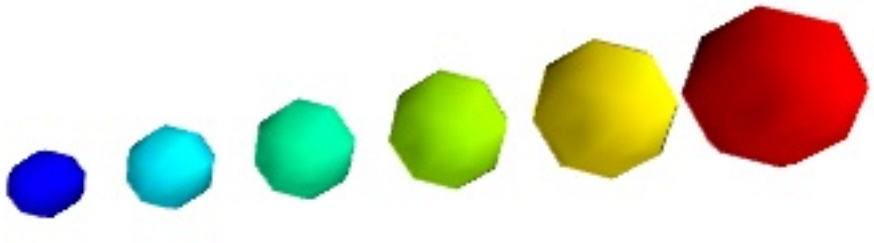
```
from enthought.mayavi import mlab
pts = mlab.points3d(x, y, z, s)
```

By default the diameter of the spheres is not 'clamped', in other words, the smallest value of the scalar data is represented as a null diameter, and the largest is proportional to inter-point distance. The scaling is only relative, as can be seen on the resulting figure:

This behavior gives visible points for all datasets, but may not be desired if the scalar represents the size of the glyphs in the same unit as the positions specified.

In this case, you shoud turn auto-scaling off by specifying the desired scale factor:

```
pts = mlab.points3d(x, y, z, s, scale_factor=1)
```



Warning: In earlier versions of Mayavi (up to 3.1.0 included), the glyphs are not auto-scaled, and as a result the visualization can seem empty due to the glyphs being very small. In addition the minimum diameter of the glyphs is clamped to zero, and thus the glyph are not scaled absolutely, unless you specifie:

```
pts.glyph.glyph.clamping = False
```

More representations of the attached scalars or vectors There are many more ways to represent the scalar or vector information attached to the data. For instance, scalar data can be 'warped' into a displacement, e.g. using a *WarpScalar* filter, or the norm of scalar data can be extract to a scalar component that can be visualized using iso-surfaces with the *ExtractVectorNorm* filter.

Displaying more than one quantity You may want to display color related to one scalar quantity while using a second for the iso-contours, or the elevation. This is possible but requires a bit of work: see *Atomic orbital example*.

If you simply want to display points with a size given by one quantity, and a color by a second, you can use a simple trick: add the size information using the norm of vectors, add the color information using scalars, create a `quiver3d()` plot choosing the glyphs to symetrix glyphs, and use scalars to represent the color:

```
x, y, z, s, c = np.random.random((5, 10))
pts = mlab.quiver3d(x, y, z, s, s, s, scalars=c, mode='sphere')
pts.glyph.color_mode = 'color_by_scalar'
```

5.3.2 Changing the scale and position of objects

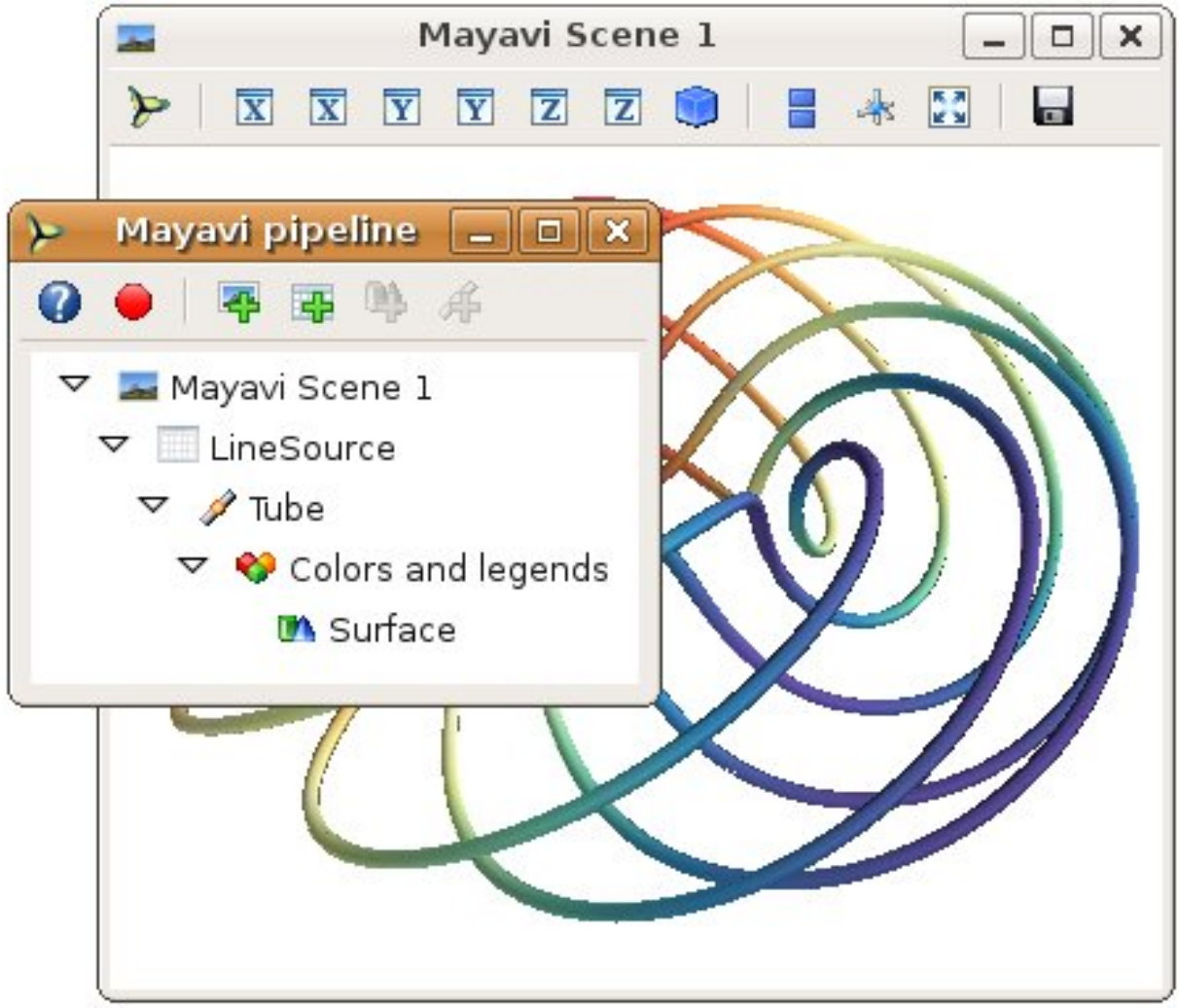
Each mlab function takes an *extent* keyword argument, that allows to set its (x, y, z) extents. This give both control on the scaling in the different directions and the displacement of the center. Beware that when you are using this functionality, it can be useful to pass the same extents to other modules visualizing the same data. If you don't, they will not share the same displacement and scale.

The `surf()`, `contour_surf()`, and `barchart()` functions, which display 2D arrays by converting the values in height, also take a *warp_scale* parameter, to control the vertical scaling.

5.3.3 Changing object properties interactively

Mayavi, and thus mlab, allows you to interactively modify your visualization.

The Mayavi pipeline tree can be displayed by clicking on the mayavi icon in the figure's toolbar, or by using `show_pipeline()` mlab command. One can now change the visualization using this dialog by double-clicking on each object to edit its properties, as described in other parts of this manual, or add new modules or filters by using this icons on the pipeline, or through the right-click menus on the objects in the pipeline.



Note: A very useful feature of this dialog can be found by pressing the red round button of the toolbar. This opens up a recorder that tracks the changes made interactively to the visualization via the dialogs, and generates valid lines of Python code.

In addition, for every object returned by a mlab function, `this_object.edit_traits()` brings up a dialog that can be used to interactively edit the object's properties. If the dialog doesn't show up when you enter this command, please see *Running mlab scripts*.

Using `mlab` with the full Envisage UI

Sometimes it is convenient to write an mlab script but still use the full envisage application so you can click on the menus and use other modules etc. To do this you may do the following before you create an mlab figure:

```
from enthought.mayavi import mlab
mlab.options.backend = 'envisage'
f = mlab.figure()
# ...
```

This will give you the full-fledged UI instead of the default simple window.

5.4 Figures, legends, camera and decorations

5.4.1 Handling several figures

All mlab functions operate on the current scene, that we also call `figure()`, for compatibility with matlab and pylab. The different figures are indexed by key that can be an integer or a string. A call to the `figure()` function giving a key will either return the corresponding figure, if it exists, or create a new one. The current figure can be retrieved with the `gcf()` function. It can be refreshed using the `draw()` function, saved to a picture file using `savefig()` and cleared using `clf()`.

5.4.2 Figure decorations

Axes can be added around a visualization object with the `axes()` function, and the labels can be set using the `xlabel()`, `ylabel()` and `zlabel()` functions. Similarly, `outline()` creates an outline around an object. `title()` adds a title to the figure.

Color bars can be used to reflect the color maps used to display values (LUT, or lookup tables, in VTK parlance). `colorbar()` creates a color bar for the last object created, trying to guess whether to use the vector data or the scalar data color maps. The `scalarbar()` and `vectorbar()` function scan be used to create color bars specifically for scalar or vector data.

A small *xyz* triad can be added to the figure using `orientation_axes()`.

Warning: The `orientation_axes()` was named *orientationaxes* before release 3.2.

5.4.3 Moving the camera

The position and direction of the camera can be set using the `view()` function. They are described in terms of Euler angles and distance to a focal point. The `view()` function tries to guess the right roll angle of the camera for a pleasing view, but it sometimes fails. The `roll()` explicitly sets the roll angle of the camera (this can be achieve intercactively in the scene by pressing down the control key, while dragging the mouse, see *Interaction with the scene*).

The `view()` and `roll()` functions return the current values of the different angles and distances they take as arguments. As a result, the view point obtained interactively can be stored an reset using:

```
# Store the information
view = mlab.view()
roll = mlab.roll()
```

```
# Reposition the camera
mlab.view(*view)
mlab.roll(roll)
```

Rotating the camera around itself

You can also rotate the camera around itself using the *roll*, *yaw* and *pitch* methods of the camera object. This moves the focal point:

```
f = mlab.gcf()
camera = f.scene.camera
camera.yaw(45)
```

Unlike the `view()` and `roll()` function, the angles are incremental, and not absolute.

Modifying zoom and view angle

The camera is entirely defined by its position, its focal point, and its view angle (attributes 'position', 'focal_point', 'view_angle'). The camera method 'zoom' changes the view angle incrementally by the specify ratio, where as the method 'dolly' translates the camera along its axis while keeping the focal point constant. The `move()` function can also be useful in these regards.

5.5 Running mlab scripts

Mlab, like the rest of Mayavi, is an interactive application. If you are not already in an interactive environment (see next paragraph), to interact with the figures or the rest of the drawing elements, you need to use the `show()` function. For instance, if you are writing a script, you need to call `show()` each time you want to display one or more figures and allow the user to interact with them.

5.5.1 Using mlab interactively

Using IPython, mlab instructions can be run interactively, or in scripts using IPython's `%run` command:

```
In [1]: %run my_script
```

You need to start IPython with the *-wthread* option (when installed with EPD, the *pylab* start-menu link does this for you). In this environment, the plotting commands are interactive: they have an immediate effect on the figure, alleviating the need to use the `show()` function.

Mlab can also be used interactively in the Python shell of the mayavi2 application, or in any interactive Python shell of wxPython-based application (such as other Envisage-based applications, or SPE, Stani's Python Editor).

5.5.2 Using together with Matplotlib's pylab

If you want to use Matplotlib's pylab with Mayavi's mlab in IPython you should:

- if your IPython version is greater than 0.8.4: start IPython with the following options:

```
$ ipython -pylab -wthread
```

- elsewhere, start IPython with the *-wthread* option:

```
$ ipython -wthread
```

  and **before** importing pylab, enter the following Python commands:

```
>>> import matplotlib
>>> matplotlib.use('WxAgg')
>>> matplotlib.interactive(True)
```

If you want matplotlib and mlab to work together by default in IPython, you can change you default matplotlib backend, by editing the *~/.matplotlib/matplotlibrc* to add the following line:

```
backend      : WXAgg
```

Capturing mlab plots to integrate in pylab

Starting from Mayavi version 3.4.0, the mlab `screenshot()` can be used to take a screenshot of the current figure, to integrate in a matplotlib plot.

5.5.3 In scripts

Mlab commands can be written to a file, to form a script. This script can be loaded in the Mayavi application using the *File->Open file* menu entry, and executed using the *File->Refresh code* menu entry or by pressing `Control-r`. It can also be executed during the start of the Mayavi application using the `-x` command line switch.

As mentioned above, when running outside of an interactive environment, for instance with *python myscript.py*, you need to call the `show()` function (as shown in the demo above) to pause your script and have the user interact with the figure.

You can also use `show()` to decorate a function, and have it run in the event-loop, which gives you more flexibility:

```
from enthought.mayavi import mlab
from numpy import random

@mlab.show
def image():
    mlab.imshow(random.random((10, 10)))
```

With this decorator, each time the *image* function is called, *mlab* makes sure an interactive environment is running before executing the *image* function. If an interactive environment is not running, *mlab* will start one and the image function will not return until it is closed.

5.6 Animating the data

Often it isn't sufficient to just plot the data. You may also want to change the data of the plot and update the plot without having to recreate the entire visualization, for instance to do animations, or in an interactive application. Indeed, recreating the entire visualization is very inefficient and leads to very jerky looking animations. To do this, mlab provides a very convenient way to change the data of an existing mlab visualization. Consider a very simple example. The *mlab.test_simple_surf_anim* function has this code:

```
x, y = numpy.mgrid[0:3:1,0:3:1]
s = mlab.surf(x, y, numpy.asarray(x*0.1, 'd'))

for i in range(10):
    s.mlab_source.scalars = numpy.asarray(x*0.1*(i+1), 'd')
```

The first two lines define a simple plane and view that. The next three lines animate that data by changing the scalars producing a plane that rotates about the origin. The key here is that the *s* object above has a special attribute called *mlab_source*. This sub-object allows us to manipulate the points and scalars. If we wanted to change the *x* values we could set that too by:

```
s.mlab_source.x = new_x
```

The only thing to keep in mind here is that the shape of *x* should not be changed.

If multiple values have to be changed, you can use the *set* method of the *mlab_source* to set them as shown in the more complicated example below:

```
# Produce some nice data.
n_mer, n_long = 6, 11
pi = numpy.pi
dphi = pi/1000.0
phi = numpy.arange(0.0, 2*pi + 0.5*dphi, dphi, 'd')
mu = phi*n_mer
x = numpy.cos(mu)*(1+numpy.cos(n_long*mu/n_mer)*0.5)
y = numpy.sin(mu)*(1+numpy.cos(n_long*mu/n_mer)*0.5)
z = numpy.sin(n_long*mu/n_mer)*0.5

# View it.
l = plot3d(x, y, z, numpy.sin(mu), tube_radius=0.025, colormap='Spectral')

# Now animate the data.
ms = l.mlab_source
for i in range(10):
    x = numpy.cos(mu)*(1+numpy.cos(n_long*mu/n_mer +
                                   numpy.pi*(i+1)/5.)*0.5)
    scalars = numpy.sin(mu + numpy.pi*(i+1)/5)
    ms.set(x=x, scalars=scalars)
```

Notice the use of the *set* method above. With this method, the visualization is recomputed only once. In this case, the shape of the new arrays has not changed, only their values have. If the shape of the array changes then one should use the *reset* method as shown below:

```
x, y = numpy.mgrid[0:3:1,0:3:1]
s = mlab.surf(x, y, numpy.asarray(x*0.1, 'd'),
              representation='wireframe')
# Animate the data.
fig = mlab.gcf()
ms = s.mlab_source
for i in range(5):
    x, y = numpy.mgrid[0:3:1.0/(i+2),0:3:1.0/(i+2)]
    sc = numpy.asarray(x*x*0.05*(i+1), 'd')
    ms.reset(x=x, y=y, scalars=sc)
    fig.scene.reset_zoom()
```

Many standard examples for animating data are provided with mlab. Try the examples with the name *mlab.test_<name>_anim*, i.e. where the name ends with an *_anim* to see how these work and run.

Note: It is important to remember distinction between *set* and *reset*. Use *set* or directly set the attributes (*x*, *y*, *scalars* etc.) when you are not changing the shape of the data but only the values. Use *reset* when the arrays are changing shape and size. Reset usually regenerates all the data and can be inefficient when compared to *set* or directly setting the traits.

Warning: When creating a Mayavi pipeline, as explained in the following subsection, instead of using ready-made plotting function, the *mlab_source* attribute is created only on sources created via *mlab*. Only pipeline created entirely using *mlab* will present this attribute.

Note: If you are animating several plot objects, each time you modify the data with there *mlab_source* attribute, Mayavi will trigger a refresh of the scene. This operation might take time, and thus slow your animation. In this case, the tip *Accelerating a Mayavi script* may come in handy.

5.7 Assembling pipelines with *mlab*

The plotting functions reviewed above explore only a small fraction of the visualization possibilities of Mayavi. The full power of Mayavi can only be unleashed through the control of the pipeline itself. As described in the *An overview of Mayavi* section, a visualization in Mayavi is created by loading the data in Mayavi with *data source* object, optionally transforming the data through *Filters*, and visualizing it with *Modules*. The mlab functions build complex pipelines for you in one function, making the right choice of sources, filters, and modules, but they cannot explore all the possible combinations.

Mlab provides a submodule *pipeline* which contains functions to populate the pipeline easily from scripts. This module is accessible in *mlab*: *mlab.pipeline*, or can be imported from *enthought.mayavi.tools.pipeline*.

When using an *mlab* plotting function, a pipeline is created: first a source is created from *numpy* arrays, then modules, and possibly filters, are added. The resulting pipeline can be seen for instance with the *mlab.show_pipeline* command. This information can be used to create the very same pipeline using directly the *pipeline* scripting module, as the names of the functions required to create each step of the pipeline are directly linked to the default names of the objects created by *mlab* on the pipeline. As an example, let us create a visualization using `surf()`:

```
import numpy as np
a = np.random.random((4, 4))
from enthought.mayavi import mlab
mlab.surf(a)
mlab.show_pipeline()
```

The following pipeline is created:

```
Array2DSource
    \__ WarpScalar
            \__ PolyDataNormals
                    \__ Colors and legends
                            \__ Surface
```

The same pipeline can be created using the following code:

```
src = mlab.pipeline.array2d_source(a)
warp = mlab.pipeline.warp_scalar(src)
normals = mlab.pipeline.poly_data_normals(warp)
surf = mlab.pipeline.surface(normals)
```

5.7.1 Data sources

The *pipeline* module contains functions for creating various data sources from arrays. They are fully documented in details in the *Mlab pipeline-control reference*. We give a small summary of the possibilities here.

mlab distinguishes sources with scalar data, and sources with vector data, but more important, it has different functions to create sets of unconnected points, with data attached to them, or connected data points describing continuously varying quantities that can be interpolated between data points, often called *fields* in physics or engineering.

Unconnected sources `scalar_scatter()`, `vector_scatter()`

Implicitely-connected sources `scalar_field()`, `vector_field()`, `array2d_source()`

Explicitly-connected sources `line_source()`, `triangular_mesh_source()`

All the *mab* source factories are functions that take numpy arrays and return the Mayavi source object that was added to the pipeline. However, the implicitely-connected sources require well-shaped arrays as arguments: the data is supposed to lie on a regular, orthogonal, grid of the same shape as the shape of the input array, in other words, the array describes an image, possibly 3 dimensional.

5.7.2 Modules and filters

For each Mayavi module or filter (see *Modules* and *Filters*), there is a corresponding *mlab.pipeline* function. The name of this function is created by replacing the alternating capitals in the module or filter name by underscores. Thus *ScalarCutPlane* corresponds to *scalar_cut_plane*.

In general, the *mlab.pipeline* module and filter factory functions simply create and connect the corresponding object. However they can also contain addition logic, exposed as keyword arguments. For instance they allow to set up easily a colormap, or to specify the color of the module, when relevant. In accordance with the goal of the *mlab* interface to make frequent operations simple, they use the keyword arguments to choose the properties of the create object to best suit the requirements. It can be thus easier to use the keyword arguments, when available, than to set the attributes of the objects created. For more information, please check out the docstrings. Full, detailed, usage examples are given in the next subsection.

5.8 Case studies of some visualizations

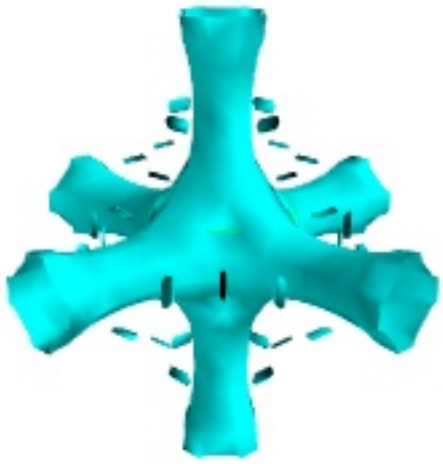
5.8.1 Visualizing volumetric scalar data

There are three main ways of visualizing a 3D scalar field. Given the following field:

```
import numpy as np
x, y, z = np.ogrid[-10:10:20j, -10:10:20j, -10:10:20j]
s = np.sin(x*y*z)/(x*y*z)
```

IsoSurfaces To display iso surfaces of the field, the simplest solution is simply to use the *mlab* `contour3d()` function:

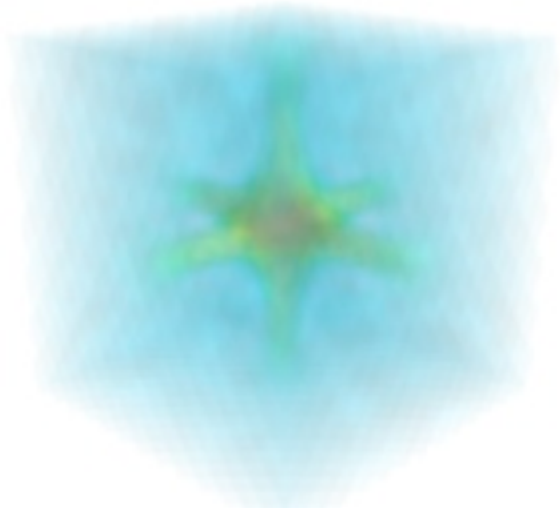
```
mlab.contour3d(s)
```



The problem with this method that outer iso-surfaces tend to hide inner ones. As a result, quite often only one iso-surface can be visible.

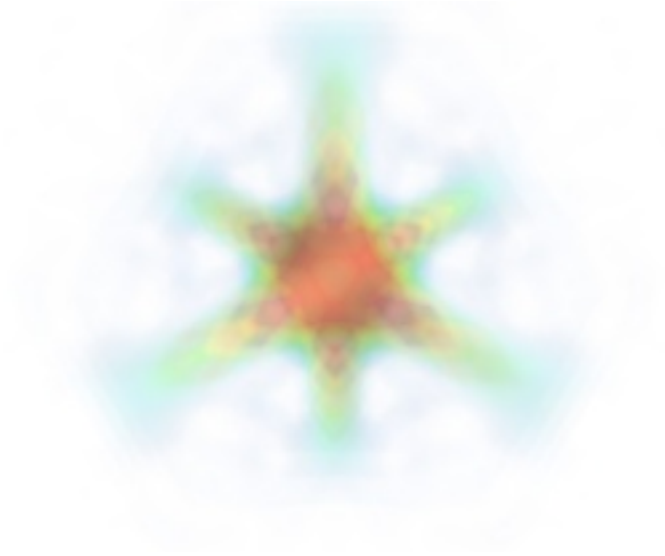
Volume rendering Volume rendering is an advanced technique in which each voxel is given a partly transparent color. This can be achieved with *mlab.pipeline* using the `scalar_field()` source, and the *volume* module:

```
mlab.pipeline.volume(mlab.pipeline.scalar_field(s))
```



For such a visualization, tweaking the opacity transfer function is critical to achieving a good effect. Typically, it can be useful to limit the lower and upper values to the 20 and 80 percentiles of the data, in order to have a reasonnable fraction of the volume transparent:

```
mlab.pipeline.volume(mlab.pipeline.scalar_field(s), vmin=0, vmax=0.8)
```

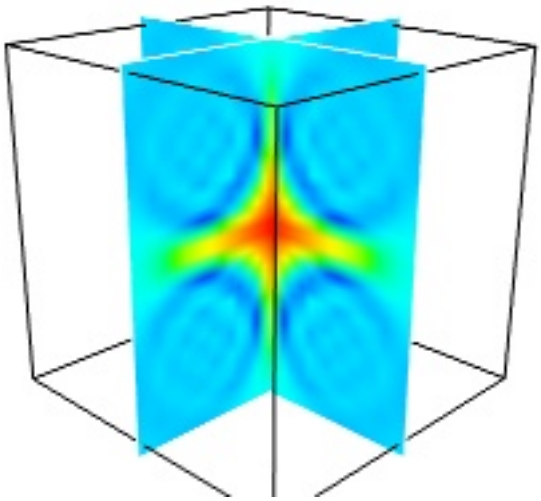


It is useful to open the module's dialog (eg through the pipeline interface, or using it's *edit_traits()* method) and tweak the color transfert function to render transparent the low-intensities regions of the image. **For this module, the LUT as defined in the 'Colors and legends' node are not used**

The limitations of volume rendering is that, while it is often very pretty, it can be difficult to analysis the details of the field with it.

Cut planes While less impressive, cut planes are a very informative way of visualising the details of a scalar field:

```
mlab.pipeline.image_plane_widget(mlab.pipeline.scalar_field(s),
                            plane_orientation='x_axes',
                            slice_index=10,
                        )
mlab.pipeline.image_plane_widget(mlab.pipeline.scalar_field(s),
                            plane_orientation='y_axes',
                            slice_index=10,
                        )
mlab.outline()
```

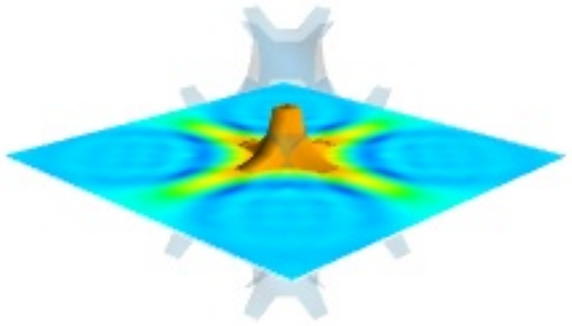


The image plane widget can only be used on regular-spaced data, as created by *mlab.pipeline.scalar_field*, but it is very fast. It should thus be prefered to the scalar cut plane, when possible.

Clicking and dragging the cut plane is an excellent way of exploring the field.

A combination of techniques Finally, it can be interesting to combine cut planes with iso-surfaces and thresholding to give a view of the peak areas using the iso-surfaces, visualize the details of the field with the cut plane, and the global mass with a large iso-surface:

```
src = mlab.pipeline.scalar_field(s)
mlab.pipeline.iso_surface(src, contours=[s.min()+0.1*s.ptp(), ], opacity=0.1)
mlab.pipeline.iso_surface(src, contours=[s.max()-0.1*s.ptp(), ],)
mlab.pipeline.image_plane_widget(src,
                            plane_orientation='z_axes',
                            slice_index=10,
                        )
```



In some cases, thought not in our example, it might be usable to insert a threshold filter before the cut plane, eg to remove area with values below 's.min()+0.1*s.ptp()'. In this case, the cut plane needs to be implemented with *mlab.pipeline.scalar_cut_plane* as the data looses its structure after thresholding.

5.8.2 Visualizing a vector field

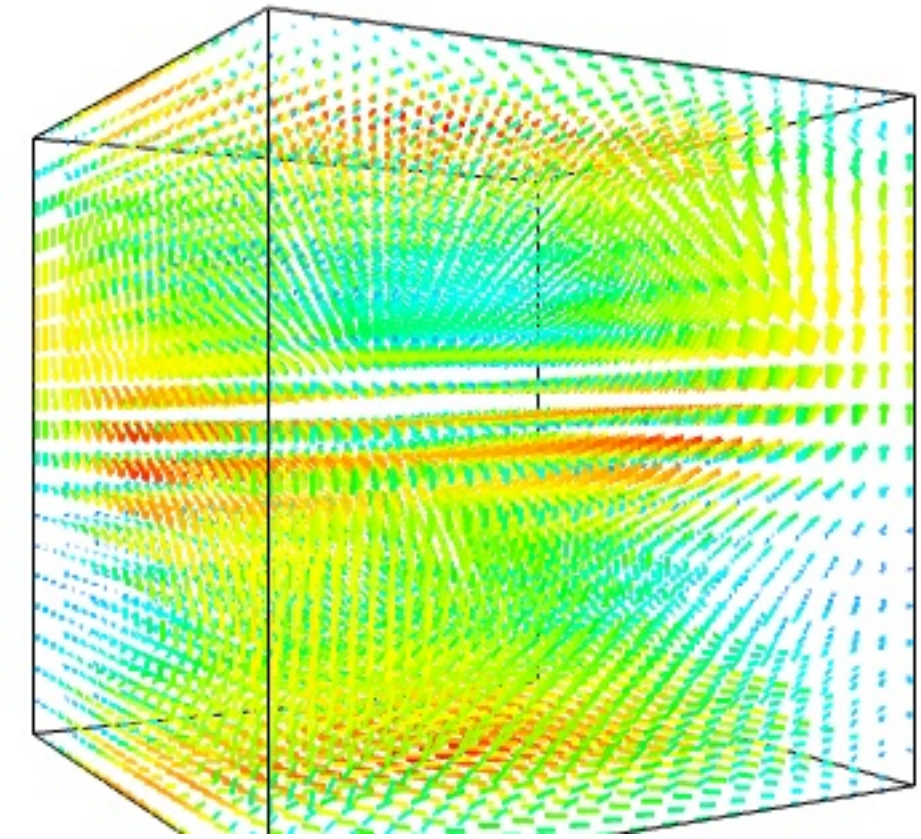
A vector field, ie vectors continuously defined in a volume, can be difficult to visualize, as it contains a lot of information. Let us explore different visualizations for the velocity field of a multi-axis convection cell [1], in hydrodynamics, as defined by its components sampled on a grid, *u*, *v*, *w*:

```
import numpy as np
x, y, z = np.mgrid[0:1:20j, 0:1:20j, 0:1:20j]

u =    np.sin(np.pi*x) * np.cos(np.pi*z)
v = -2*np.sin(np.pi*y) * np.cos(2*np.pi*z)
w = np.cos(np.pi*x)*np.sin(np.pi*z) + np.cos(np.pi*y)*np.sin(2*np.pi*z)
```

[1] Toussaint, V.; Carriere, P. & Raynal, F. A numerical Eulerian approach to mixing by chaotic advection Phys. Fluids, 1995, 7, 2587

Quiver The simplest visualization of a set of vectors, is using the *mlab* function *quiver3d*:

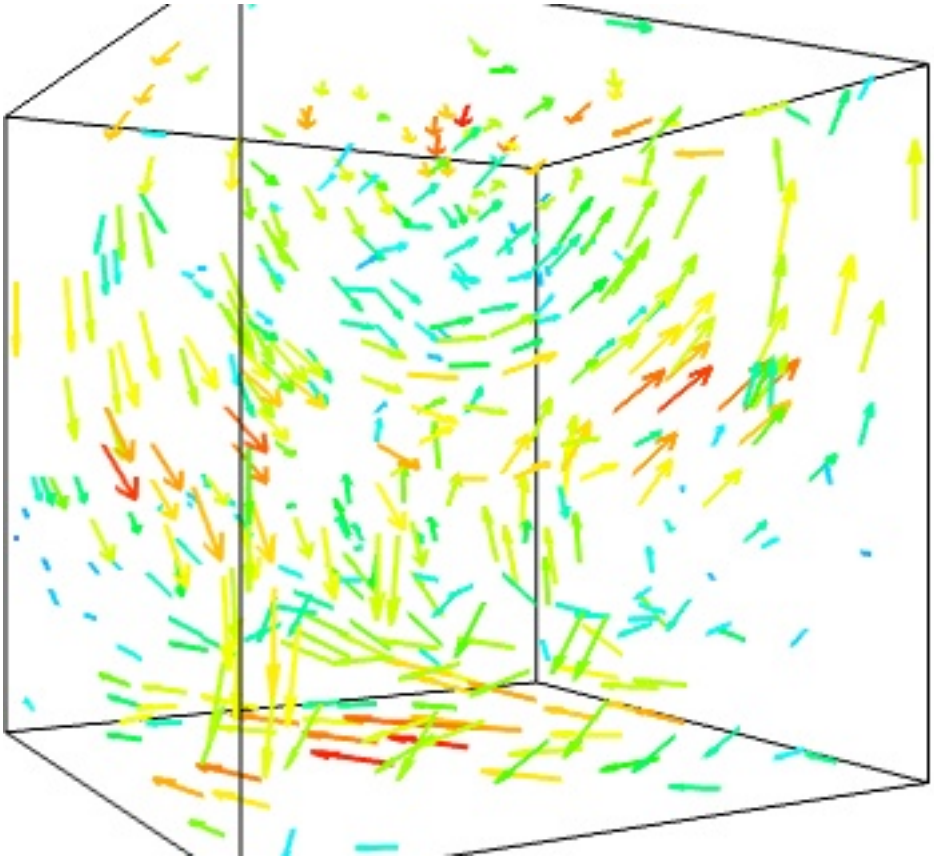
```
mlab.quiver3d(u, v, w)
mlab.outline()
```



The main limitation of this visualization is that it positions an arrow for each sampling point on the grid. As a result the visualization is very busy.

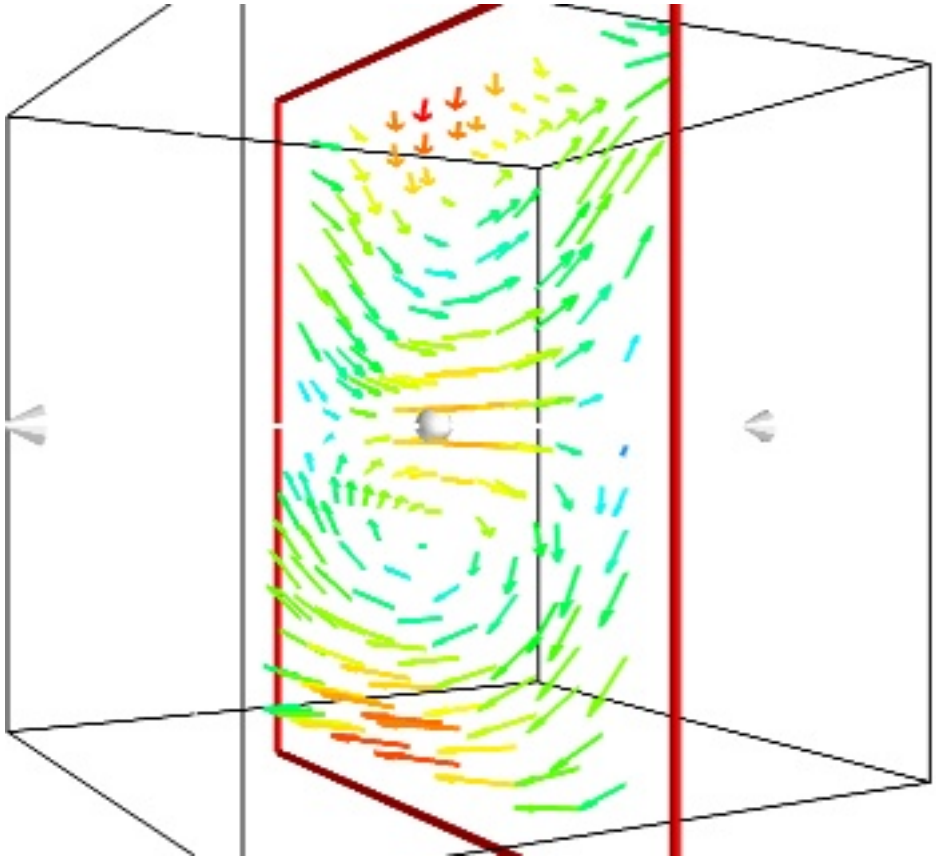
Masking vectors We can use the fact that we are visualizing a vector field, and not just a bunch of vectors, to reduce the amount of arrows displayed. For this we need to build a *vector_field* source, and apply to it the *vectors* module, with some masking parameters (here we keep only one point out of 20):

```
src = mlab.pipeline.vector_field(u, v, w)
mlab.pipeline.vectors(src, mask_points=20, scale_factor=3.)
```



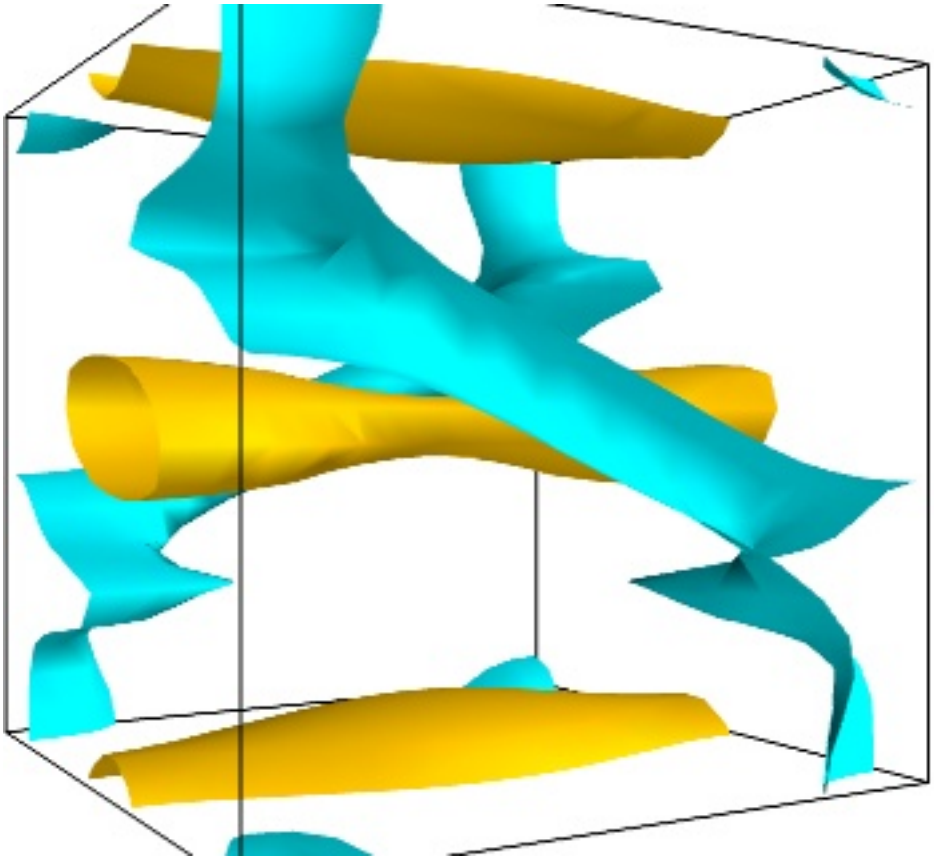
A cut plane If we are interested in displaying the vectors along a cut, we can use a cut plane. In particular, we can inspect interactively the vector field by moving the cut plane along: clicking on it and dragging it can give a very clear understanding of the vector field:

```
mlab.pipeline.vector_cut_plane(src, mask_points=2, scale_factor=3)
```



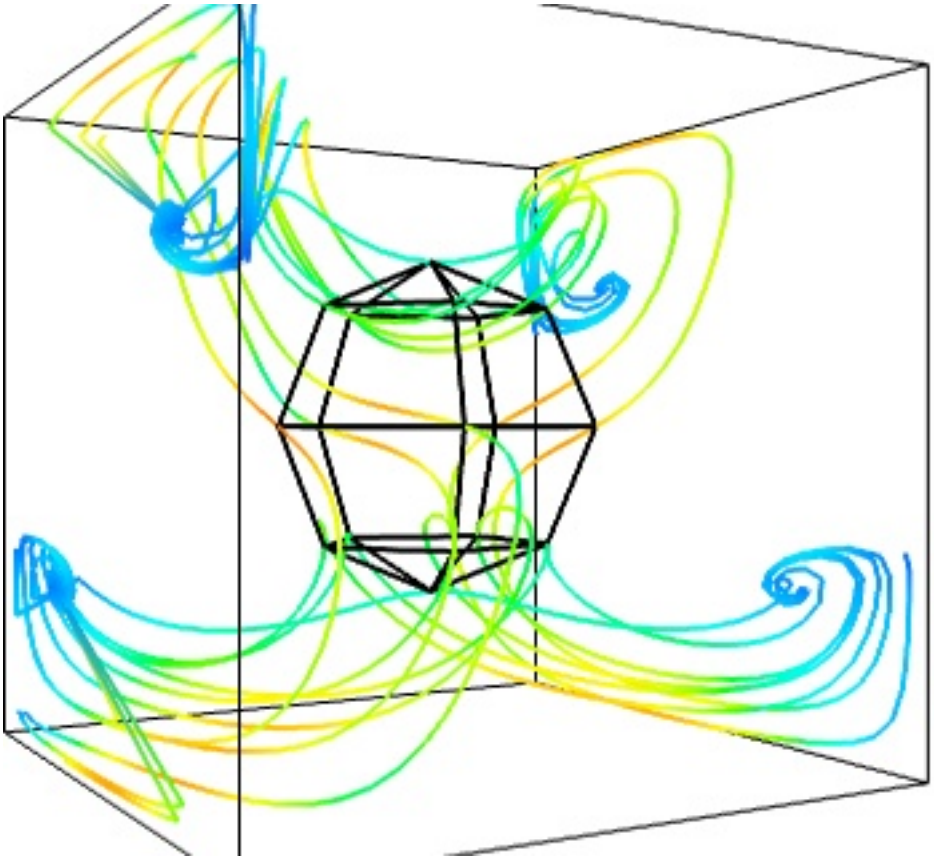
IsoSurfaces of the magnitude An important parameter of the vector field is its magnitude. It can be interesting to display iso-surfaces of the norm of the vectors. For this we can create a scalar field from the vector field using the ExtractVectorNorm filter, and use the IsoSurface module on it. When working interactively, a good understanding of the magnitude of the field can be gained by changing the values of the contours in the object's property dialog.

```
magnitude = mlab.pipeline.extract_vector_norm(src)
mlab.pipeline.iso_surface(magnitude, contours=[1.9, 0.5])
```



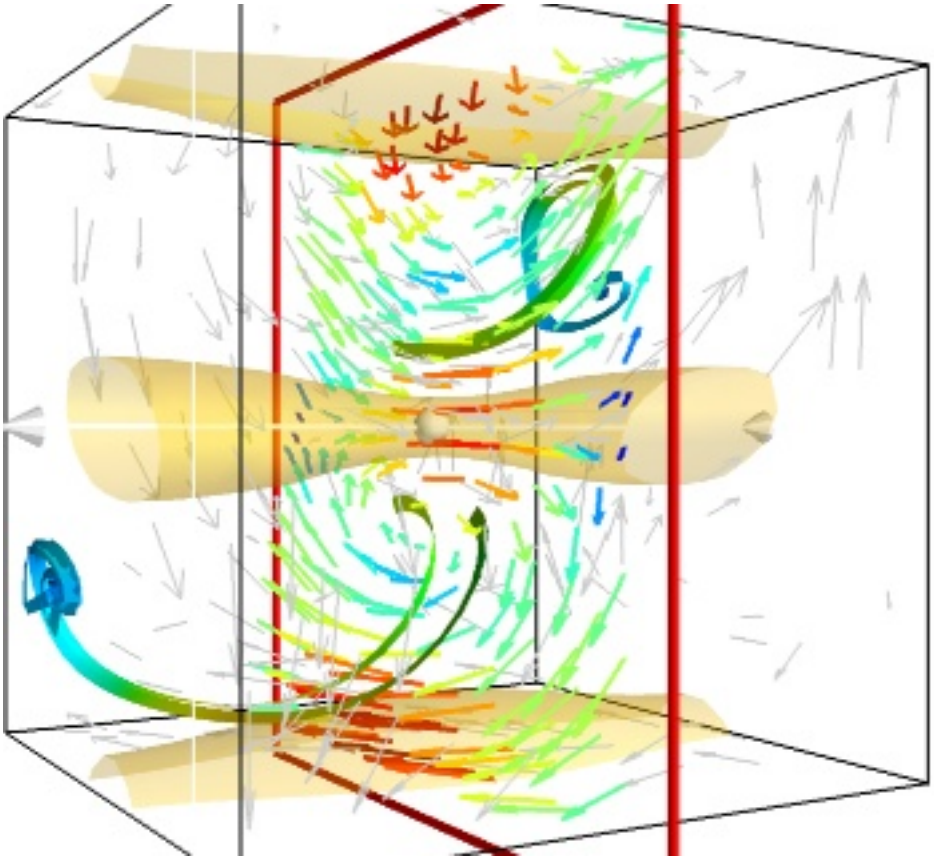
The Flow, or the field lines For certain vector fields, the line of flow of along the field can have an interesting meaning. For instance the can be interpreted as trajectories in hydrodynamics, or field lines in electro-magnetism. We can display the flow lines originating for a certain seed surface using the *streamline* module, or the mlab `flow()` function, which relies on *streamline* internally:

```
flow = mlab.flow(u, v, w, seed_scale=1,
                          seed_resolution=5,
                          integration_direction='both')
```



A combination of techniques Giving a meaningful visualization of a vector field is a hard task, and one must use all the tools at hand to illustrate his purposes. It is important to choose the message conveyed. No one visualization will tell all about a vector field. Here is an example of a visualization made by combining the different tools above:

```
mlab.figure(fgcolor=(0., 0., 0.), bgcolor=(1, 1, 1))
src = mlab.pipeline.vector_field(u, v, w)
magnitude = mlab.pipeline.extract_vector_norm(src)

# We apply the following modules on the magnitude object, in order to
# be able to display the norm of the vectors, eg as the color.
iso = mlab.pipeline.iso_surface(magnitude, contours=[1.9, ], opacity=0.3)

vec = mlab.pipeline.vectors(magnitude, mask_points=40,
                                    line_width=1,
                                    color=(.8, .8, .8),
                                    scale_factor=4.)

flow = mlab.pipeline.streamline(magnitude, seedtype='plane',
                                        seed_visible=False,
                                        seed_scale=0.5,
                                        seed_resolution=1,
                                        linetype='ribbon',)

vcp = mlab.pipeline.vector_cut_plane(magnitude, mask_points=2,
                                        scale_factor=4,
                                        colormap='jet',
                                        plane_orientation='x_axes')
```



Note: Although most of this section has been centered on snippets of code to create visualization objects, it is important to remember that Mayavi is an interactive program, and that the properties of these objects can be modified interactively, as described in *Changing object properties interactively*. It is often impossible to choose the best parameters for a visualization before hand. Colors, contour values, colormap, view angle, etc... should be chosen interactively. If reproducibility is required, the chosen values can be added in the original script.

Moreover, the *mlab* functions expose only a small fraction of the possibilities of the visualization objects. The dialogs expose more of these functionalities, that are entirely controlled by the attributes of the objects returned by the mlab functions. These objects are very rich, as they are built from VTK objects. It can be hard to find the right attribute to modify when exploring them, or in the VTK documentation, thus using the interactive dialog and recording to a script, as described in *Recording Mayavi actions to a script* is the prefered way of tweaking a visualization.

CHAPTER

SIX

ADVANCED USE OF MAYAVI

Section summary

This section give details on the working principles Mayavi. Read it to gain a better understanding, in order to use Mayavi's full power.

- First we describe data structures, how they are defined and how you can build them. This information is useful for a better understanding of how to build efficient pipelines.
- Second we describe the object-oriented structure behind Mayavi and the pipeline. This information opens the door to advanced scripting of the Mayavi application, and is especially useful if you whish to develop custom tools with Mayavi.

6.1 Data representation in Mayavi

Describing data in three dimension in the general case is a complex problem. Mayavi helps you focus on your visualization work and not worry too much about the underlying data structures, for instance using mlab (see *mlab: Python scripting for 3D plotting*). We suggest you create sources for Mayavi using *mlab* or Mayavi sources when possible. However, it helps to understand the VTK data structures that Mayavi uses if you want to create data with a specific structure for a more efficient visualization, or if you want to extract the data from the Mayavi pipeline.

Outline

- Introduction to TVTK datasets
- The flow of data
- Retrieving the data from Mayavi pipelines
- Dissection of the different TVTK datasets
- Inserting TVTK datasets in the Mayavi pipeline.

Mayavi data sources and VTK datasets

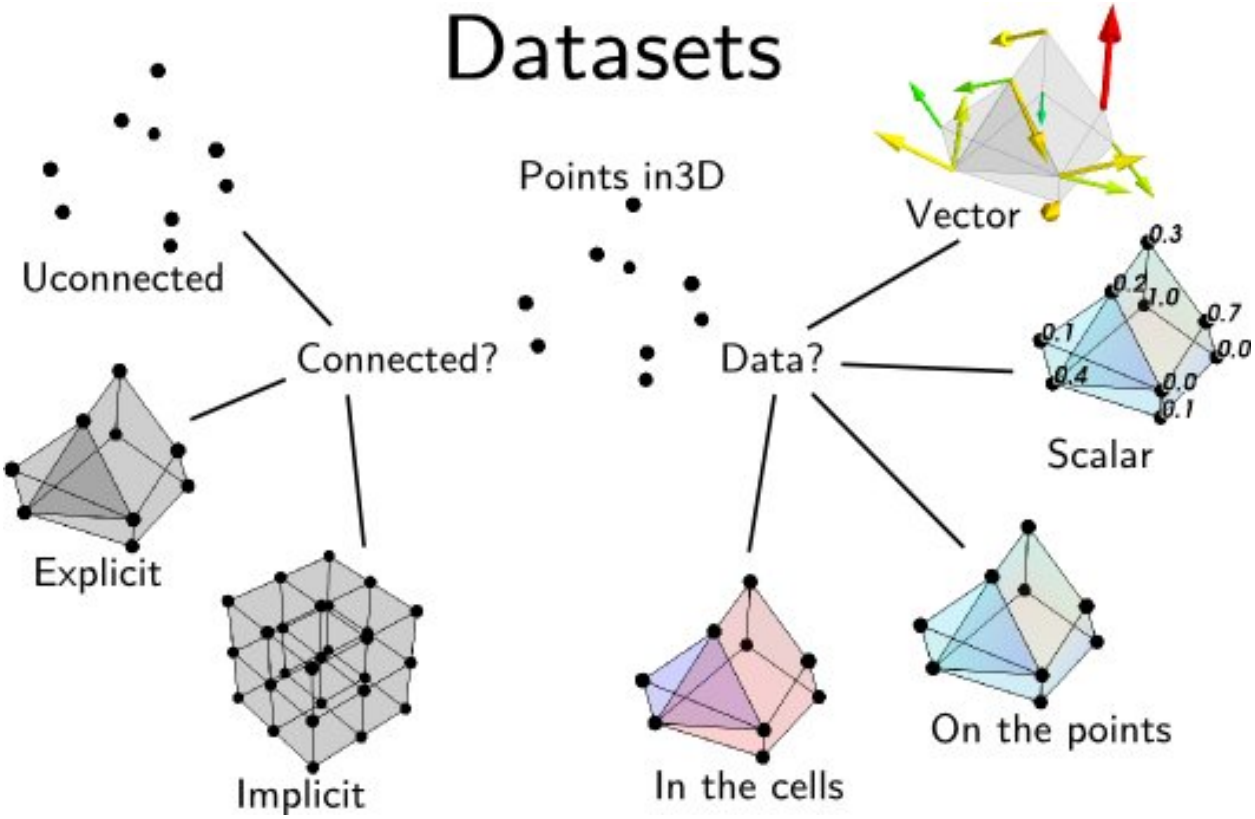
- When you load a file, or you expose data in Mayavi using one of the *mlab.pipeline* source functions (see *Data sources*), you create an object in the Mayavi pipeline that is attached to a scene. This object is a Mayavi source, and serves to describe the data and its properties to the Mayavi pipeline.
- The internal structures use to represent to data in 3D all across Mayavi are VTK datasets, as described below.

One should not confuse VTK (or TVTK) *datasets* and Mayavi *data sources*. There is a finite and small number of datasets. However, many pipeline objects could be constructed to fit in the pipeline below a scene and providing datasets to the pipeline.

6.1.1 Introduction to TVTK datasets

Mayavi uses the VTK library for all its visualization needs, via TVTK (Traited VTK). The data is exposed internally, by the sources, or at the output of the filters, as VTK datasets, described below. Understanding these structures is useful not only to manipulate them, but also to understand what happens when using filters to transform the data in the pipeline.

A dataset is defined by many different characteristics:



Connectivity Connectivity is not only necessary to draw lines between the different points, it is also needed to define a volume.

Implicit connectivity: connectivity or positioning is implicit. In this case the data is considered as arranged on a lattice-like structure, with equal number of layers in each direction, x increasing first along the array, then y and finally z.

Data Dataset are made of points positioned in 3D, with the corresponding data. Each dataset can carry several data components.

Scalar or Vectors data: The data can be scalar, in which case VTK can perform operations such as taking the gradient and display the data with a colormap, or vector, in which case VTK can perform an integration to display streamlines, display the vectors, or extract the norm of the vectors, to create a scalar dataset.

Cell data and point data: Each VTK dataset is defined by vertices and cells, explicitly or implicitly. The data, scalar or vector, can be positioned either on the vertices, in which case it is called point data, or associated with a cell, in which case it is called cell data. Point data is stored in the *.point_data* attribute of the dataset, and the cell data is stored in the *.cell_data* attribute.

In addition the data arrays have an associated name, which is used in Mayavi to specify on which data component module or filter apply (eg using the'SetActiveAttribute' filter.

All VTK arrays, whether it be for data or position, are exposed as (n, 3) numpy arrays for 3D components, and flat (n,) array for 1D components. The index vary in the opposite order as numpy: z first, y and then x. Thus to go from a 3D numpy array to the corresponding flatten VTK array, the operation is:

```
vtk_array = numpy_array.T.ravel()
```

An complete list of the VTK datasets used by Mayavi is given below, after a tour of the Mayavi pipeline.

6.1.2 The flow of data

As described *earlier*, Mayavi builds visualization by assembling pipelines, where the data is loaded in Mayavi by a *data source*, and it can be transformed by *filters* and visualized by *modules*.

To retrieve the data displayed by Mayavi, to modify it via Python code, or to benefit from the data processing steps performed by the Mayavi filters, it can be useful to "open up" the Mayavi pipeline and understand how the data flows in it.

Inside the Mayavi pipeline, the 3D data flowing between sources filters and modules is stored in VTK datasets. Each source or filter has an *outputs* attribute, which is a list of VTK *datasets* describing the data output by the object.

For example:

```
>>> import numpy as np
>>> from enthought.mayavi import mlab
>>> data = np.random.random((10, 10, 10))
>>> iso = mlab.contour3d(data)
```

The parent of *iso* is its 'Colors and legend' node, the parent of which is the source feeding into *iso*:

```
>>> iso.parent.parent.outputs
[<tvtk_classes.image_data.ImageData object at 0xf08220c>]
```

Thus we can see that the Mayavi source created by *mlab.surf* exposes an ImageData VTK dataset.

Note: To retrieve the VTK datasets feeding in an arbitrary object, the mlab function `pipeline.get_vtk_src()` may be useful. In the above example:

```
>>> mlab.pipeline.get_vtk_src(iso)
[<tvtk_classes.image_data.ImageData object at 0xf08220c>]
```

6.1.3 Retrieving the data from Mayavi pipelines

Probing data at given positions

If you simply want to retrieve the data values described by a Mayavi object a given position in space, you can use the `pipeline.probe_data()` function (**warning** the *probe_data* function is new in Mayavi 3.4.0)

For example, if you have a set of irregularly spaced data points with no connectivity information:

```
>>> x, y, z = np.random.random((3, 100))
>>> data = x**2 + y**2 + z**2
```

You can expose them as a Mayavi source of unconnected points:

```
>>> src = mlab.pipeline.scalar_scatter(x, y, z, data)
```

and visualize these points for debugging:

```
>>> pts = mlab.pipeline.glyph(src, scale_mode='none',
...                           scale_factor=.1)
```

The resulting data is not defined in the volume, but only at the given position: as there is no connectivity information, Mayavi cannot interpolate between the points:

```
>>> mlab.pipeline.probe_data(pts, .5, .5, .5)
array([ 0. ])
```

To define volumetric data, you can use a Delaunay3D filter:

```
>>> field = mlab.pipeline.delaunay3d(src)
```

Now you can probe the value of the volumetric data anywhere. It will be non zero in the convex hull of the points:

```
>>> # Probe in the center of the cloud of points
>>> mlab.pipeline.probe_data(field, .5, .5, .5)
array([ 0.78386768])
>>> # Probe on the initial points
>>> data_probed = mlab.pipeline.probe_data(field, x, y, z)
>>> np.allclose(data, data_probed)
True
>>> # Probe outside the cloud
>>> mlab.pipeline.probe_data(field, -.5, -.5, -.5)
array([ 0.])
```

Inspecting the internals of the data structures

You may be interested in the data carried by the TVTK datasets themselves, rather than the values they represent, for instance to replicate them. For this, you can retrieve the TVTK datasets, and inspect them.

Extracting data points and values

The positions of all the points of a TVTK dataset can be accessed via its *points* attribute. Retrieving the dataset from the *field* object of the previous example, we can view the data points:

```
>>> dataset = field.outputs[0]
>>> dataset.points
[(0.72227946564137335, 0.23729151639368518, 0.24443798107195291), ...,
(0.13398528550831601, 0.80368395047618579, 0.31098842991116804)], length = 100
```

This is a TVTK array. For us, it is more useful to convert it to a numpy array:

```
>>> points = dataset.points.to_array()
>>> points.shape
(100, 3)
```

To retrieve the original *x*, *y*, *z* positions of the data points specified, we can transpose the array:

```
>>> x, y, z = points.T
```

The corresponding data values can be found in the *point_data.scalars* attribute of the dataset, as the data is located on the points, and not in the cells, and it is scalar data:

```
>>> dataset.point_data.scalars.to_array().shape
>>> (100,)
```

Extracting lines

If we want to extract the edges of the Delaunay tessellation, we can apply the ExtractEdges filter to the *field* from the previous example and inspect its output:

```
>>> edges = mlab.pipeline.extract_edges(field)
>>> edges.outputs
[<tvtk_classes.poly_data.PolyData object at 0xf34e5fc>]
```

We can see that the output is a PolyData dataset. Looking at how these are build (see PolyData), we see that the connectivity information is help in the *lines* attribute (that we convert to a numpy array using its *.to_array()* method):

```
>>> pd = edges.outputs[0]
>>> pd.lines.to_array()
array([ 2,  0,  1, ...,  2, 97, 18])
```

The way this array is build is a sequence of a length descriptor, followed by the indices of the data points connected together in the points array retrieved earlier. Here we have only sets of pairs of points connected together: the array is an alternation of *2* followed by a pair of indices.

A full example illustrating how to use the VTK Delaunay filter to extract a graph is given in *Delaunay graph example*.

Headless use of Mayavi for the algorithms, without visualization

As you can see from the above example, it can be interesting to use Mayavi just for the numerical algorithm operating on 3D data, as the Delaunay tessellation and interpolation demoed.

To run such examples headless, simply create the source with the keyword argument *figure=False*. As a result the sources will not be attached to any engine, but you will still be able to use filters, and to probe the data:

```
>>> src = mlab.pipeline.scalar_scatter(x, y, z, data, figure=False)
```

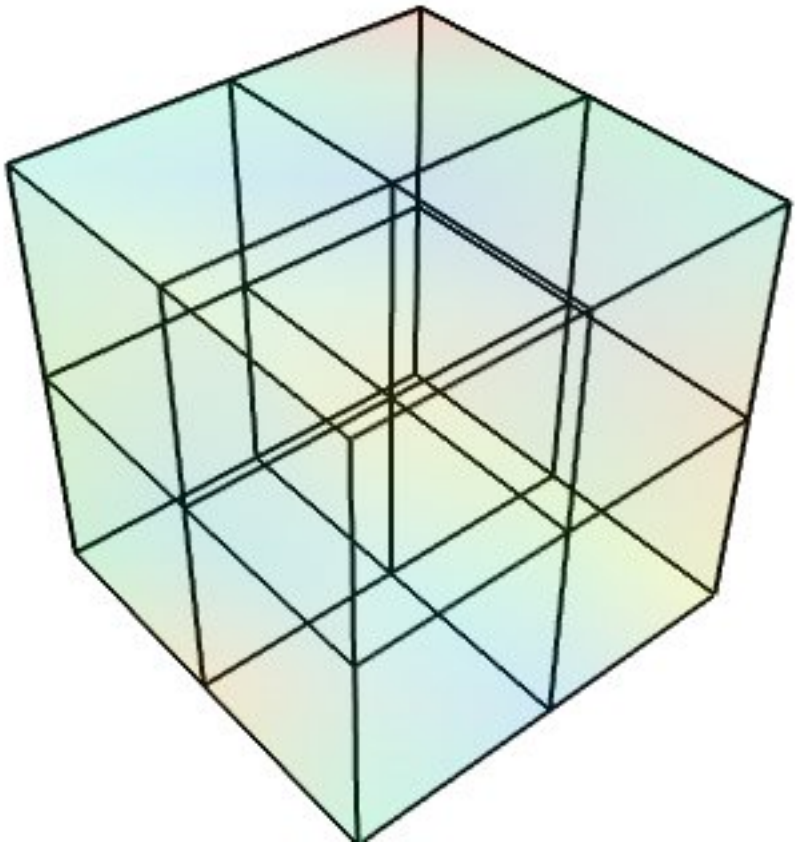
6.1.4 Dissection of the different TVTK datasets

The 5 TVTK structures used are the following (ordered by the cost of visualizing them).:

VTK name	Connectivity	Suitable for	Required information
ImageData	Implicit	Volumes and surfaces	3D data array and spacing along each axis
RectilinearGrid	Implicit	Volumes and surfaces	3D data array and 1D array of spacing for each axis
StructuredGrid	Implicit	Volumes and surfaces	3D data array and 3D position arrays for each axis
PolyData	Explicit	Points, lines and surfaces	x, y, z, positions of vertices and arrays of surface Cells
UnstructuredGrid	Explicit	Volumes and surfaces	x, y, z positions of vertices and arrays of volume Cells

ImageData

This dataset is made of data points positioned on an orthogonal grid, with constant spacing along each axis. The position of the data points are inferred from their position on the data array (implicit positioning), an origin and a spacing between 2 slices along each axis. In 2D, this can be understood as a raster image. This is the data structure created by the *ArraySource* mayavi source, from a 3D numpy array, as well as the *mlab.pipeline.scalar_field* and *mlab.pipeline.vector_field* factory functions, if the x, y and z arrays are not explicitely specified.

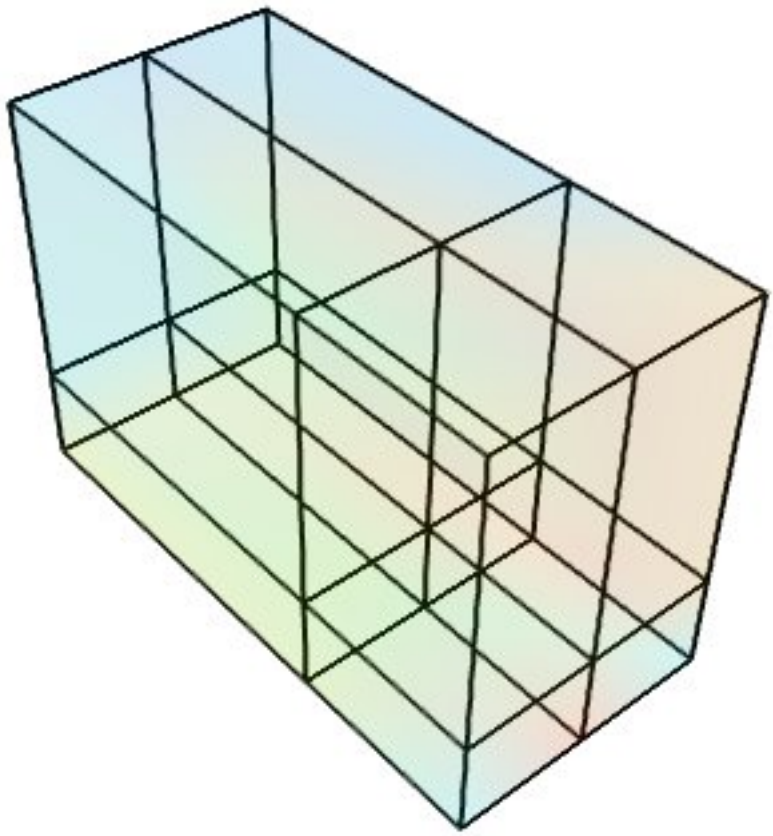


Creating a *tvtk.ImageData* object from numpy arrays:

```
from enthought.tvtk.api import tvtk
from numpy import random
data = random.random((3, 3, 3))
i = tvtk.ImageData(spacing=(1, 1, 1), origin=(0, 0, 0))
i.point_data.scalars = data.ravel()
i.point_data.scalars.name = 'scalars'
i.dimensions = data.shape
```

RectilinearGrid

This dataset is made of data points positioned on an orthogonal grid, with arbitrary spacing along the various axis. The position of the data points are inferred from their position on the data array, an origin and the list of spacings of each axis.

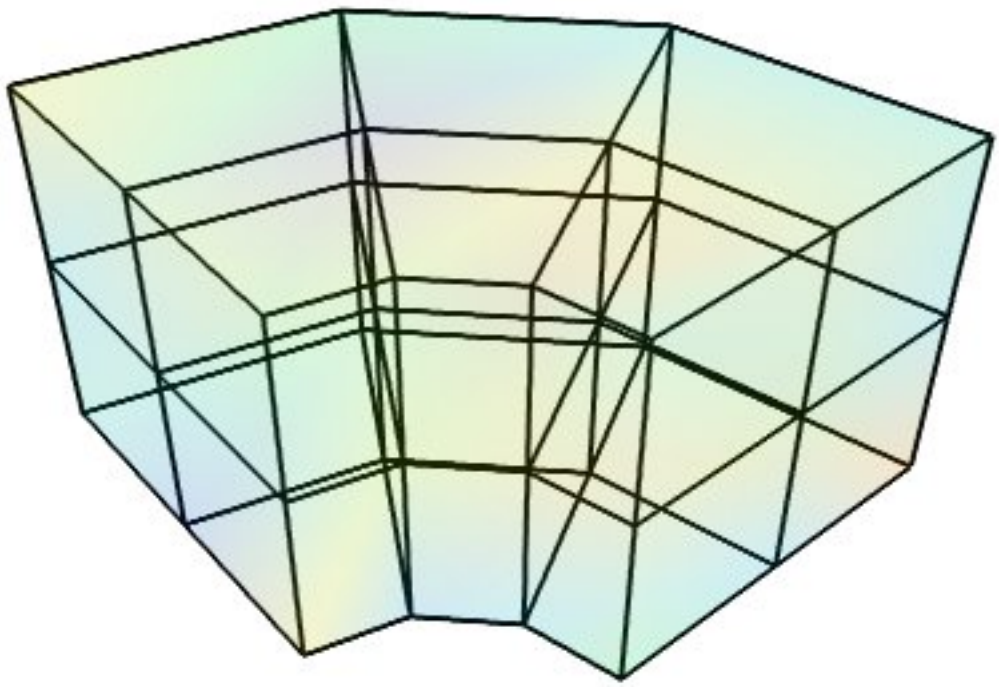


Creating a *tvtk.RectilinearGrid* object from numpy arrays:

```
from enthought.tvtk.api import tvtk
from numpy import random, array
data = random.random((3, 3, 3))
r = tvtk.RectilinearGrid()
r.point_data.scalars = data.ravel()
r.point_data.scalars.name = 'scalars'
r.dimensions = data.shape
r.x_coordinates = array((0, 0.7, 1.4))
r.y_coordinates = array((0, 1, 3))
r.z_coordinates = array((0, .5, 2))
```

StructuredGrid

This dataset is made of data points positioned on arbitrary grid: each point is connected to its nearest neighbors on the data array. The position of the data points are fully described by 1 coordinate arrays, specifying x, y and z for each point. This is the dataset created by the *mlab.pipeline.scalar_field* and *mlab.pipeline.vector_field* factory functions, if the *x*, *y* and *z* arrays are explicitely specified.



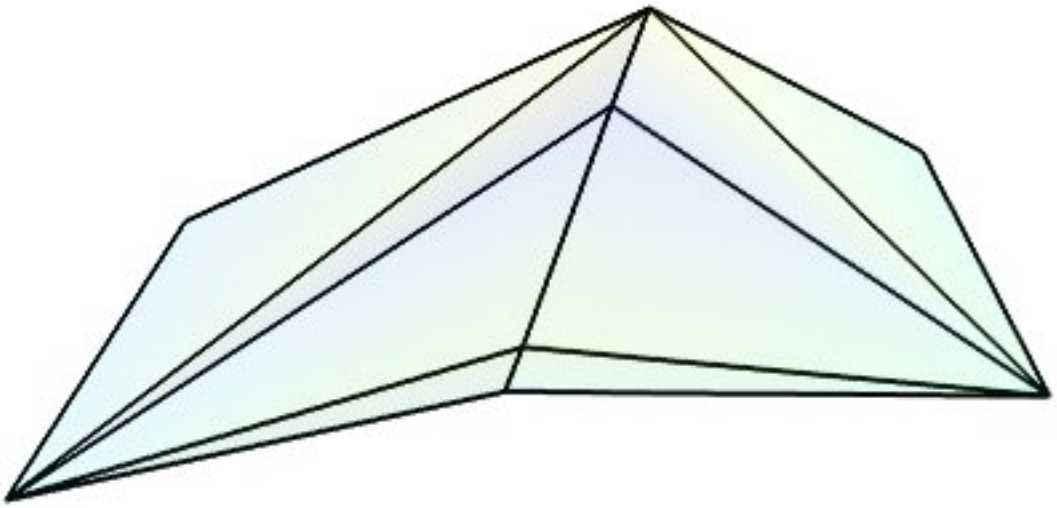
Creating a *tvtk.StructuredGrid* object from numpy arrays:

```
from numpy import pi, cos, sin, empty, linspace, random
from enthought.tvtk.api import tvtk

def generate_annulus(r, theta, z):
    """ Generate points for structured grid for a cylindrical annular
        volume.  This method is useful for generating a unstructured
        cylindrical mesh for VTK.
    """
    # Find the x values and y values for each plane.
    x_plane = (cos(theta)*r[:,None]).ravel()
    y_plane = (sin(theta)*r[:,None]).ravel()

    # Allocate an array for all the points.  We'll have len(x_plane)
    # points on each plane, and we have a plane for each z value, so
    # we need len(x_plane)*len(z) points.
    points = empty([len(x_plane)*len(z),3])

    # Loop through the points for each plane and fill them with the
    # correct x,y,z values.
    start = 0
    for z_plane in z:
        end = start+len(x_plane)
        # slice out a plane of the output points and fill it
        # with the x,y, and z values for this plane.  The x,y
        # values are the same for every plane.  The z value
        # is set to the current z
```

```
        plane_points = points[start:end]
        plane_points[:,0] = x_plane
        plane_points[:,1] = y_plane
        plane_points[:,2] = z_plane
        start = end

    return points

dims = (3, 4, 3)
r = linspace(5, 15, dims[0])
theta = linspace(0, 0.5*pi, dims[1])
z = linspace(0, 10, dims[2])
pts = generate_annulus(r, theta, z)
sgrid = tvtk.StructuredGrid(dimensions=(dims[1], dims[0], dims[2]))
sgrid.points = pts
s = random.random((dims[0]*dims[1]*dims[2]))
sgrid.point_data.scalars = ravel(s.copy())
sgrid.point_data.scalars.name = 'scalars'
```

PolyData

This dataset is made of arbitrarily positioned data points that can be connected to form lines, or grouped in polygons to from surfaces (the polygons are broken up in triangles). Unlike the other datasets, this one cannot be used to describe volumetric data. The is the dataset created by the *mlab.pipeline.scalar_scatter* and *mlab.pipeline.vector_scatter* functions.

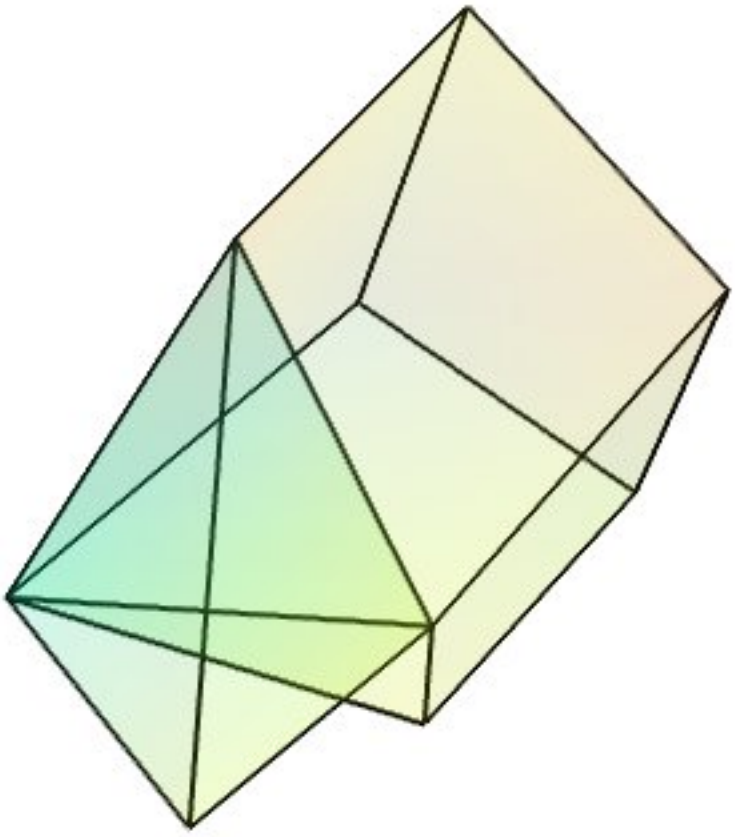


Creating a *tvtk.PolyData* object from numpy arrays:

```
from numpy import array, random
from enthought.tvtk.api import tvtk

# The numpy array data.
points = array([[0,-0.5,0], [1.5,0,0], [0,1,0], [0,0,0.5],
                [-1,-1.5,0.1], [0,-1, 0.5], [-1, -0.5, 0],
                [1,0.8,0]], 'f')
triangles = array([[0,1,3], [1,2,3], [1,0,5],
                   [2,3,4], [3,0,4], [0,5,4], [2, 4, 6],
                    [2, 1, 7]])
scalars = random.random(points.shape)

# The TVTK dataset.
mesh = tvtk.PolyData(points=points, polys=triangles)
mesh.point_data.scalars = scalars
mesh.point_data.scalars.name = 'scalars'
```

UnstructuredGrid

This dataset is the most general dataset of all. It is made of data points positioned arbitrarily. The connectivity between data points can be arbitrary (any number of neighbors). It is described by specifying connectivity, defining volumetric cells made of adjacent data points.



Creating a *tvtk.UnstructuredGrid* object from numpy arrays:

```
from numpy import array, random
from enthought.tvtk.api import tvtk

points = array([[0,1.2,0.6], [1,0,0], [0,1,0], [1,1,1], # tetra
                [1,0,-0.5], [2,0,0], [2,1.5,0], [0,1,0],
                [1,0,0], [1.5,-0.2,1], [1.6,1,1.5], [1,1,1], # Hex
                ], 'f')
# The cells
cells = array([4, 0, 1, 2, 3, # tetra
               8, 4, 5, 6, 7, 8, 9, 10, 11 # hex
               ])
# The offsets for the cells, i.e. the indices where the cells
# start.
offset = array([0, 5])
tetra_type = tvtk.Tetra().cell_type # VTK_TETRA == 10
hex_type = tvtk.Hexahedron().cell_type # VTK_HEXAHEDRON == 12
cell_types = array([tetra_type, hex_type])
# Create the array of cells unambiguously.
cell_array = tvtk.CellArray()
cell_array.set_cells(2, cells)
# Now create the UG.
ug = tvtk.UnstructuredGrid(points=points)
# Now just set the cell types and reuse the ug locations and cells.
ug.set_cells(cell_types, offset, cell_array)
scalars = random.random(points.shape[0])
ug.point_data.scalars = scalars
ug.point_data.scalars.name = 'scalars'
```

External references

This section of the user guide will be improved later. For now, the following two presentations best describe how one can create data objects or data files for Mayavi and TVTK.

- Presentation on TVTK and Mayavi2 for course at IIT Bombay

  https://svn.enthought.com/enthought/attachment/wiki/MayaVi/tvtk_mayavi2.pdf

  This presentation provides information on graphics in general, 3D data representation, creating VTK data files, creating datasets from numpy in Python, and also about mayavi.

- Presentation on making TVTK datasets using numpy arrays made for SciPy07.

  https://svn.enthought.com/enthought/attachment/wiki/MayaVi/tvtk_datasets.pdf

  This presentation focuses on creating TVTK datasets using numpy arrays.

Datasets creation examples

There are several examples in the mayavi sources that highlight the creation of the most important datasets from numpy arrays. Specifically they are:

- *Datasets example*: Generate a simple example for each type of VTK dataset.
- *Polydata example*: Demonstrates how to create Polydata datasets from numpy arrays and visualize them in mayavi.
- *Structured points2d example*: Demonstrates how to create a 2D structured points (an ImageData) dataset from numpy arrays and visualize them in mayavi. This is basically a square of equispaced points.

- *Structured points3d example*: Demonstrates how to create a 3D structured points (an ImageData) dataset from numpy arrays and visualize them in Mayavi. This is a cube of points that are regularly spaced.
- *Structured grid example*: Demonstrates the creation and visualization of a 3D structured grid.
- *Unstructured grid example*: Demonstrates the creation and visualization of an unstructured grid.

These scripts may be run like so:

```
$ mayavi2 -x structured_grid.py
```

or better yet, all in one go like so:

```
$ mayavi2 -x polydata.py -x structured_points2d.py \
> -x structured_points3d.py -x structured_grid.py -x unstructured_grid.py
```

6.1.5 Inserting TVTK datasets in the Mayavi pipeline.

TVTK datasets can be created using directly TVTK, as illustrated in the examples above. A VTK data source can be inserted in the Mayavi pipeline using the VTKDataSource. For instance we can create an *ImageData* dataset:

```
from enthought.tvtk.api import tvtk
import numpy as np
a = np.random.random((10, 10, 10))
i = tvtk.ImageData(spacing=(1, 1, 1), origin=(0, 0, 0))
i.point_data.scalars = a.ravel()
i.point_data.scalars.name = 'scalars'
i.dimensions = a.shape
```

Inserting this dataset on the pipeline with *VTKDataSource* is done as such:

```
from enthought.mayavi.sources.api import VTKDataSource
src = VTKDataSource(data=i)
from enthought.mayavi.api import Engine
e = Engine()
e.start()
s = e.new_scene()
e.add_source(src)
```

In addition, if you are scripting using *mlab*, the *mlab.pipeline* factory functions creating filters and modules accept VTK datasets, in which case they are automatically inserted on the pipeline. A surface module could have been used to visualize the *ImageData* dataset as such:

```
from enthgouth.mayavi import mlab
mlab.pipeline.surface(i)
```

Of course, unless you want specific control on the attributes of the VTK dataset, or you are using Mayavi in the context of existing code manipulating TVTK objects, creating an *ImageData* TVTK object is not advised. The *ArraySource* Mayavi will actually create an *ImageData*, but make sure you don't get the shape wrong, which can lead to a segmentation fault. An even easier way to create a data source for an *ImageData* is to use the *mlab.pipeline.scalar_field* function.

6.2 Advanced Scripting with Mayavi

As elaborated in the *An overview of Mayavi* section, Mayavi can be scripted from Python in order to visualize data. Mayavi was designed from the ground up to be highly scriptable. Everything that can be done from the user interface can be achieved using Python scripts. Scripting the Mayavi2 application is a great way to add domain-specific functionality to the existing framework. In addition, understanding this application can help you design your own applications using Mayavi as powerful visualization library.

If you are not looking to script the Mayavi2 application itself or to build an application, but looking for quick ways to get your visualization done with simple code you may want to check out Mayavi's *mlab* module. This is described in more detail in the *mlab: Python scripting for 3D plotting* section. In addition to this Mayavi features an automatic script recording feature that automatically writes Python scripts for you as you use the GUI. This is described in more detail in the *Automatic script generation* chapter. This is probably the easiest and most powerful way to script Mayavi.

However, to best understand how to script Mayavi, a reasonable understanding of the Mayavi internals is necessary. The following sections provides an overview of the basic design and objects in the Mayavi pipeline. Subsequent sections consider specific example scripts that are included with the Mayavi sources that illustrate the ideas.

Mayavi uses Traits and TVTK internally. Traits in many ways changes the way we program. So it is important to have a good idea of Traits in order to understand Mayavi's internals. If you are unsure of Traits it is a good idea to get a general idea about Traits now. Trust me, your efforts learning Traits will not be wasted!

6.2.1 Design Overview: Mayavi as a visualization framework

This section provides a brief introduction to Mayavi's internal architecture.

The "big picture" of a visualization in Mayavi is that an `Engine` (`enthought.mayavi.engine.Engine`) object manages the entire visualization. The `Engine` manages a collection of `Scene` (`enthought.mayavi.core.scene.Scene`) objects. In each `Scene`, a user may have created any number of `Source` (`enthought.mayavi.core.source.Source`) objects. A `Source` object can further contain any number of `Filters` (`enthought.mayavi.core.filter.Filter`) or `ModuleManager` (`enthought.mayavi.core.module_manager.ModuleManager`) objects. A `Filter` may contain either other filters or `ModuleManagers`. A `ModuleManager` manages any number of `Modules`. The figure below shows this hierarchy in a graphical form.

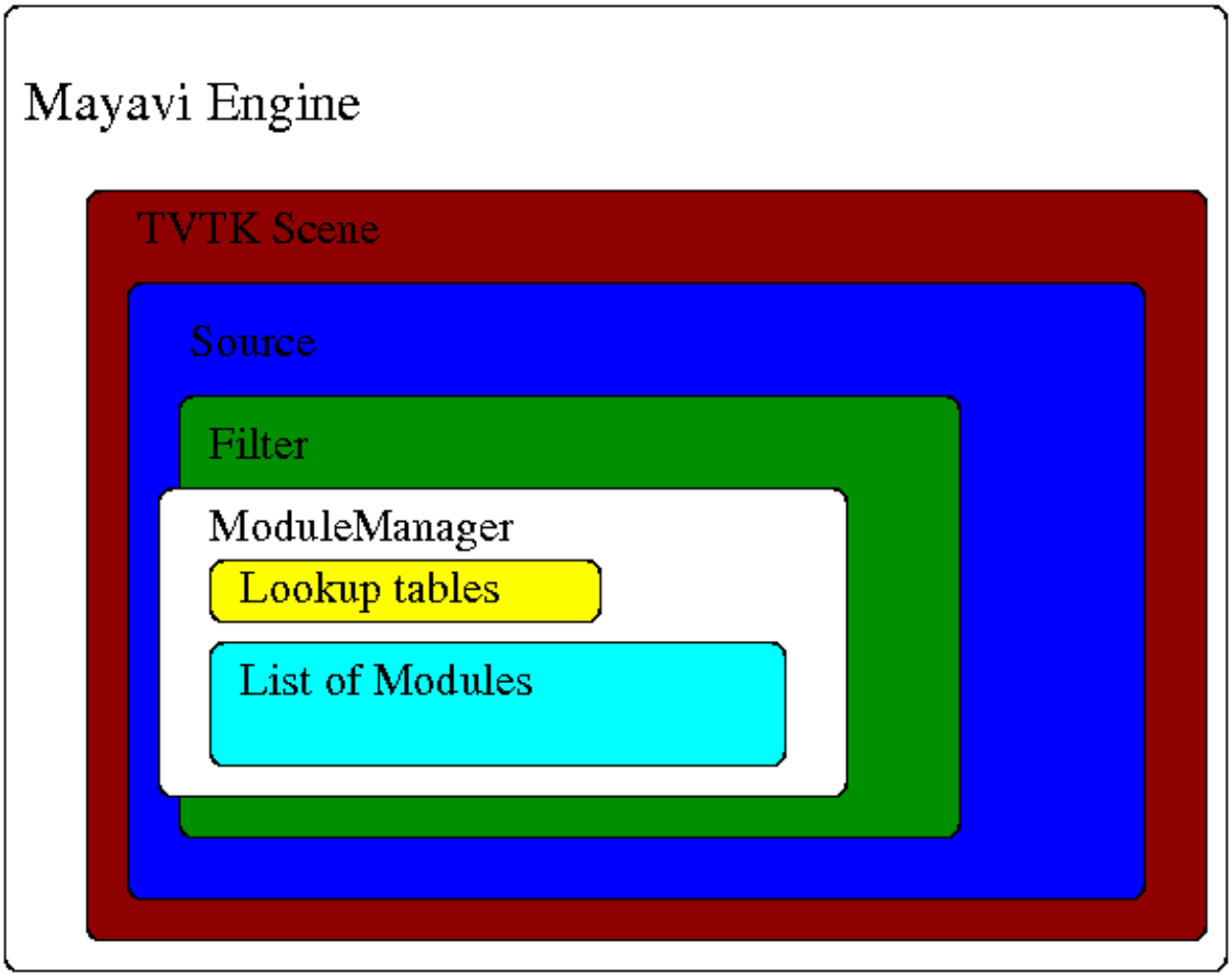


Illustration of the various objects in the Mayavi pipeline.

This hierarchy is precisely what is seen in the Mayavi tree view on the UI. The UI is therefore merely a graphical representation of this internal world-view. A little more detail on these objects is given below. For even more details please refer to the source code (hint: the source code of a class can be view in IPython by entering *Class??*).

A quick example

When scripting Mayavi to create or modify a visualization, one mainly deals with adding or removing objects to the engine, or modifying their properties. We can thus rewrite the example of building a pipeline with mlab visited in *Assembling pipelines with mlab* by explicit calls to the engine:

```
import numpy as np
a = np.random.random((4, 4))
from enthought.mayavi.api import Engine
e = Engine()
e.start()
s = e.new_scene()
from enthought.mayavi.sources.api import ArraySource
src = ArraySource(scalar_data=a)
e.add_source(src)
from enthought.mayavi.filters.api import WarpScalar, PolyDataNormals
warp = WarpScalar()
```

```
e.add_filter(warp, obj=src)
normals = PolyDataNormals()
e.add_filter(normals, obj=warp)
from enthought.mayavi.modules.api import Surface
surf = Surface()
e.add_module(surf, obj=normals)
```

As with all Mayavi code, you need to have the GUI mainloop running to have the visualization go live. Typing this code in *ipython -wthread* will do this for you.

This explicit, object-oriented, code thus mirrors the *mlab.pipeline* code. It is more fine-grained, and gives you more control. For instance it separate initialization of the objects, and their addition or removal to an engine. In general, it is more suited to developing an application, as opposed to a script.

Life-cycle of the different objects

All objects in the Mayavi pipeline feature `start` and `stop` methods. The reasoning for this is that any object in Mayavi is not usable (i.e. it may not provide any outputs) unless it has been started. Similarly the `stop` method "deactivates" the object. This is done because Mayavi is essentially driving VTK objects underneath. These objects require inputs in order to do anything useful. Thus, an object that is not connected to the pipeline cannot be used. For example, consider an `IsoSurface` module. It requires some data in order to contour anything. Thus, the module in isolation is completely useless. It is usable only when it is added to the Mayavi pipeline. When an object is added to the pipeline, its inputs are setup and its `start` method is called automatically. When the object is removed from the pipeline its `stop` method is called automatically. Note that if you are looking to remove an object from the mayavi pipeline, you can use the `remove` method to do so. For example (the following will require that you use `ipython -wthread`):

```
>>> from enthought.mayavi.api import Engine
>>> e = Engine()
>>> e.start()
>>> s = e.new_scene()
>>> from enthought.mayavi.sources.api import ParametricSurface
>>> p = ParametricSurface()
>>> e.add_source(p) # calls p.start internally.
>>> p.remove() # Removes p from the engine.
```

Apart from the `Engine` object, all other objects in the Mayavi pipeline feature a `scene` trait which refers to the current `enthought.tvtk.pyface.tvtk_scene.TVTKScene` instance that the object is associated with. The objects also feature an `add_child` method that lets one build up the pipeline by adding "children" objects. The `add_child` method is "intelligent" and will try to appropriately add the child in the right place based on the context.

Objects populating the Mayavi pipeline

Here is a brief description of the key objects in the Mayavi pipeline.

Engine The Mayavi engine is defined in the `enthought.mayavi.engine` module. It is the central object dealing with life-cycle of visualization objects and scene, as well as connecting and updating the pipeline.

- It possesses a `scenes` trait which is a Trait `List` of `Scene` objects.
- Features several methods that let one add a `Filter/Source/Module` instance to it. It allows one to create new scenes and delete them. Also has methods to load and save the entire visualization.

- The `EnvisageEngine`, defined in the `enthought.mayavi.plugins.envisage_engine` module, is a subclass of `Engine` and is the one used in the `mayavi2` application.
- The `OffScreenEngine`, defined in the `enthought.mayavi.core.off_screen_engine` module, is another subclass of `Engine`. It creates scenes that are not displayed on screen by default.
- The `NullEngine`, defined in the `enthought.mayavi.core.null_engine` module, is yet another subclass of `Engine`. With this engine, visualization objects are not added to a scene, and thus cannot be rendered. This engine is useful for testing and pure-data handling use of Mayavi's data structures.

Scene Defined in the `enthought.mayavi.core.scene` module.

- `scene` attribute: manages a `TVTKScene` (`enthought.tvtk.pyface.tvtk_scene`) object which is where all the rendering occurs.
- The `children` attribute is a `List` trait that manages a list of `Source` objects.

PipelineBase Defined in the `enthought.mayavi.core.pipeline_base` module. Derives from `Base` which merely abstracts out common functionality. The `PipelineBase` is the base class for all objects in the mayavi pipeline except the `Scene` and `Engine` (which really isn't *in* the pipeline but contains the pipeline).

- This class is characterized by two events, `pipeline_changed` and `data_changed`. These are `Event` traits. They determine when the pipeline has been changed and when the data has changed. Therefore, if one does:

```
object.pipeline_changed = True
```

  then the `pipeline_changed` event is fired. Objects downstream of `object` in the pipeline are automatically setup to listen to events from an upstream object and will call their `update_pipeline` method. Similarly, if the `data_changed` event is fired then downstream objects will automatically call their `update_data` methods.
- The `outputs` attribute is a trait `List` of outputs produced by the object.
- The `remove` method can be used to remove the object (if added) from the mayavi pipeline.

Source Defined in the `enthought.mayavi.core.source` module. All the file readers, Parametric surface etc. are subclasses of the `Source` class.

- Contains the rest of the pipeline via its `children` trait. This is a `List` of either `Modules` or other `Filters`.
- The `outputs` attribute is a trait `List` of outputs produced by the source.

Filter Defined in the `enthought.mayavi.core.filter` module. All the `Filters` described in the *Filters* section are subclasses of this.

- Contains the rest of the pipeline via its `children` trait. This is a `List` of either `Modules` or other `Filters`.
- The `inputs` attribute is a trait `List` of input data objects that feed into the filter.
- The `outputs` attribute is a trait `List` of outputs produced by the filter.
- Also features the three methods:
  - **`setup_pipeline`: used to create the underlying** TVTK pipeline objects if needed.

  - `update_pipeline`: a method that is called when the upstream pipeline has been changed, i.e. an upstream object fires a `pipeline_changed` event.
  - `update_data`: a method that is called when the upstream pipeline has **not** been changed but the data in the pipeline has been changed. This happens when the upstream object fires a `data_changed` event.

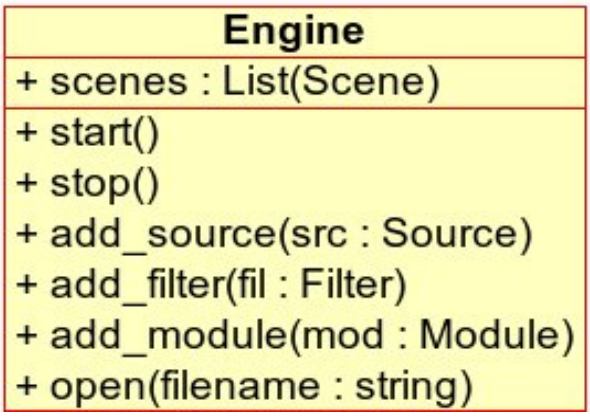
ModuleManager Defined in the `enthought.mayavi.core.module_manager` module. This object is the one called *Modules* in the tree view on the UI. The main purpose of this object is to manage `Modules` and share common data between them. All modules typically will use the same lookup table (LUT) in order to produce a meaningful visualization. This lookup table is managed by the module manager.

- The `source` attribute is the `Source` or `Filter` object that is the input of this object.
- Contains a list of `Modules` in its `children` trait.
- The `scalar_lut_manager` attribute is an instance of a `LUTManager` which basically manages the color mapping from scalar values to colors on the visualizations. This is basically a mapping from scalars to colors.
- The `vector_lut_manager` attribute is an instance of a `LUTManager` which basically manages the color mapping from vector values to colors on the visualizations.
- The class also features a `lut_data_mode` attribute that specifies the data type to use for the LUTs. This can be changed between 'auto', 'point data' and 'cell data'. Changing this setting will change the data range and name of the lookup table/legend bar. If set to 'auto' (the default), it automatically looks for cell and point data with point data being preferred over cell data and chooses the one available. If set to 'point data' it uses the input point data for the LUT and if set to 'cell data' it uses the input cell data.

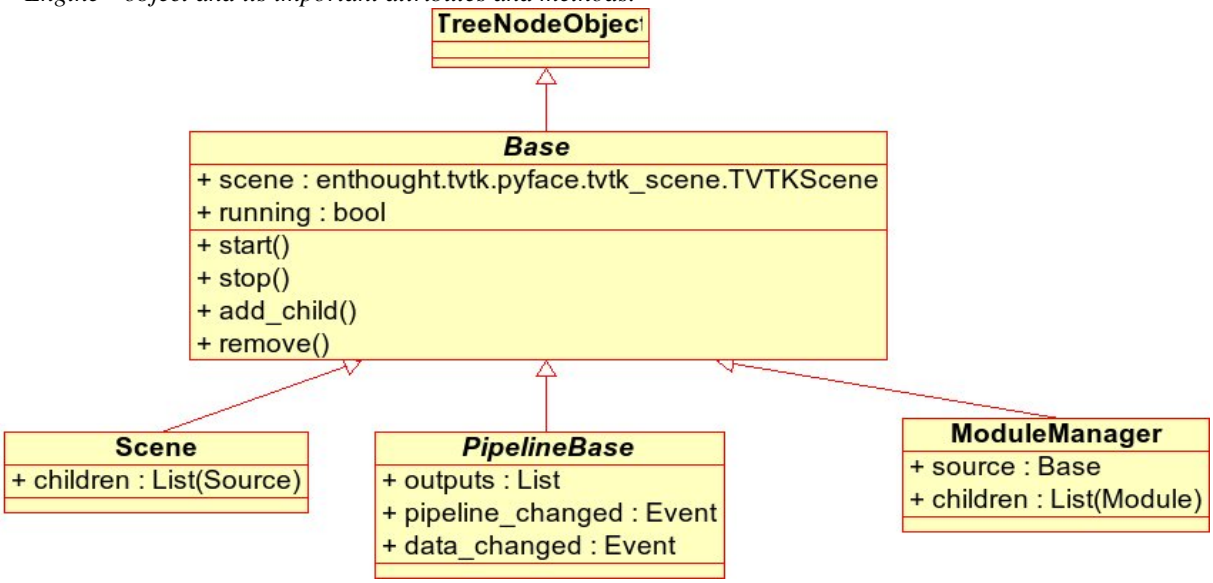
Module Defined in the `enthought.mayavi.core.module` module. These objects are the ones that typically produce a visualization on the TVTK scene. All the modules defined in the *Modules* section are subclasses of this.

- The `components` attribute is a trait `List` of various reusable components that are used by the module. These usually are never used directly by the user. However, they are extremely useful when creating new modules. A `Component` is basically a reusable piece of code that is used by various other objects. For example, almost every `Module` uses a TVTK actor, mapper and property. These are all "componentized" into a reusable *Actor* component that the modules use. Thus, components are a means to promote reuse between mayavi pipeline objects.
- The `module_manager` attribute specifies the `ModuleManager` instance that it is attached to.
- Like the `Filter` modules also feature the three methods:
  - **`setup_pipeline`: used to create the underlying** TVTK pipeline objects if needed.
  - `update_pipeline`: a method that is called when the upstream pipeline has been changed, i.e. an upstream object fires a `pipeline_changed` event.
  - `update_data`: a method that is called when the upstream pipeline has **not** been changed but the data in the pipeline has been changed. This happens when the upstream object fires a `data_changed` event.

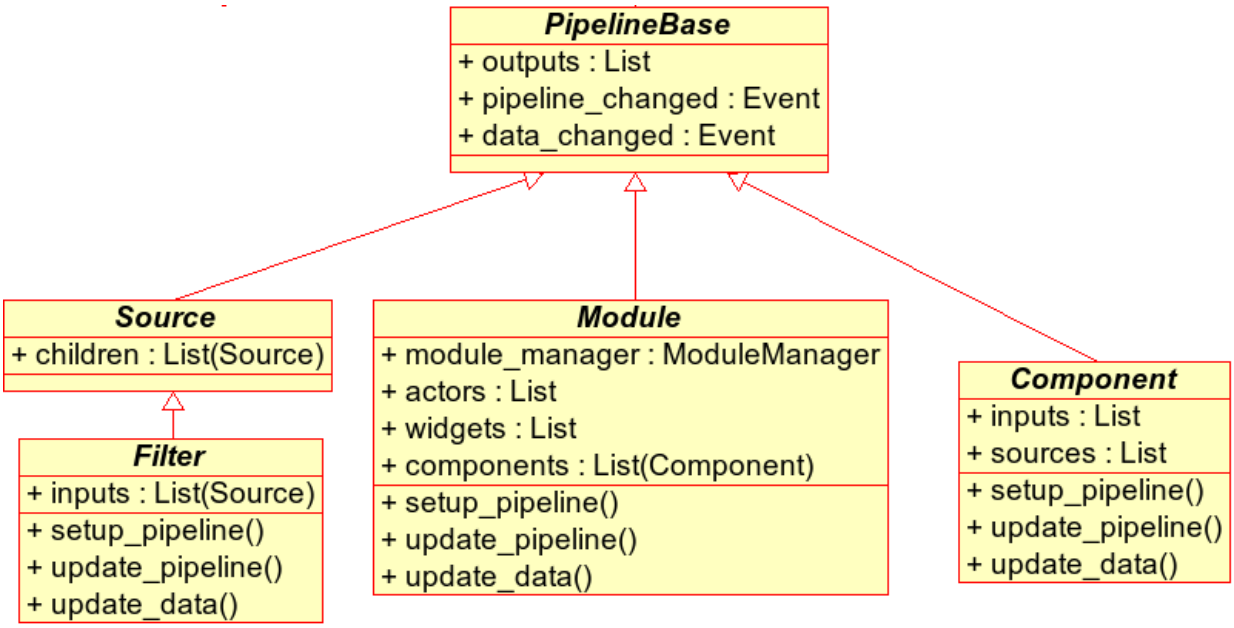
The following figures show the class hierarchy of the various objects involved.



The ‘‘Engine‘‘ object and its important attributes and methods.



This hierarchy depicts the ‘‘Base‘‘ object, the ‘‘Scene‘‘, ‘‘PipelineBase‘‘ and the ‘‘ModuleManager‘‘.



This hierarchy depicts the ''PipelineBase'' object, the ''Source'', ''Filter'', ''Module'' and the ''Component''.

6.2.2 Scripting the `mayavi2` application

The `mayavi2` application is implemented in the `enthought.mayavi.scripts.mayavi2` module (look at the `mayavi2.py` file and not the `mayavi2` script). This code handles the command line argument parsing and runs the application.

`mayavi2` is an Envisage application. It starts the Envisage application in its `main` method. The code for this is in the `enthought.mayavi.plugins.app` module. Mayavi uses several envisage plugins to build up its functionality. These plugins are defined in the `enthought.mayavi.plugins.app` module. In this module there are two functions that return a list of default plugins, `get_plugins` and the `get_non_gui_plugins`. The default application uses the former which produces a GUI that the user can use. If one uses the latter (`get_non_gui_plugins`) then the mayavi tree view, object editor and menu items will not be available when the application is run. This allows a developer to create an application that uses mayavi but does not show its user interface. An example of how this may be done is provided in `examples/mayavi/nongui.py`.

Scripting from the UI

When using the `mayavi2` application, it is possible to script from the embedded Python interpreter on the UI. On the interpreter the name `mayavi` is automatically bound to an `enthought.mayavi.plugins.script.Script` instance that may be used to easily script mayavi. This instance is a simple wrapper object that merely provides some nice conveniences while scripting from the UI. It has an `engine` trait that is a reference to the running mayavi engine. Note that it is just as convenient to use an `Engine` instance itself to script mayavi.

As described in *The embedded Python interpreter* section, one can always drag a mayavi pipeline object from the tree and drop it on the interpreter to script it directly.

One may select the *File->Open Text File...* menu to open an existing Python file in the text editor, or choose the *File->New Text File* menu to create a new file. The text editor is Python-aware and one may write a script assuming that the `mayavi` name is bound to the `Script` instance as it is on the shell. To execute this script one can press `Control-r` as described earlier. `Control-s` will save the script. `Control-b` increases the font size and `Control-n` reduces it.

The nice thing about this kind of scripting is that if one scripts something on the interpreter or on the editor, one may save the contents to a file, say `script.py` and then the next time this script can be run like so:

```
$ mayavi2 -x script.py
```

This will execute the script for automatically. The name `mayavi` is available to the script and is bound to the `Script` instance. This is very convenient. It is possible to have mayavi execute multiple scripts. For example:

```
$ mayavi2 -d foo.vtk -m IsoSurface -x setup_iso.py -x script2.py
```

will load the `foo.vtk` file, create an `IsoSurface` module, then run `setup_iso.py` and then run `script2.py`.

There are several scripts in the mayavi `examples` directory that should show how this can be done. The `examples/README.txt` contains some information on the recommended ways to script.

Scripting from IPython

It is possible to script Mayavi using IPython. IPython will have to be invoked with the `-wthread` command line option in order to allow one to interactively script the mayavi application:

```
$ ipython -wthread
```

To start a visualization do the following:

```
from enthought.mayavi.plugins.app import main
# Note, this does not process any command line arguments.
mayavi = main()
# 'mayavi' is the mayavi Script instance.
```

It is also possible to use *mlab* (see *mlab: Python scripting for 3D plotting*) for this purpose:

```
from enthought.mayavi import mlab
f = mlab.figure() # Returns the current scene.
engine = mlab.get_engine() # Returns the running mayavi engine.
```

With this it should be possible to script Mayavi just the way it is done on the embedded interpreter or on the text editor.

An example

Here is an example script that illustrates various features of scripting Mayavi (note that this will work if you execute the following from the embedded Python shell inside Mayavi or if you run it as `mayavi2 -x script.py`):

```
# Create a new mayavi scene.
mayavi.new_scene()

# Get the current active scene.
s = mayavi.engine.current_scene

# Read a data file.
d = mayavi.open('fire_ug.vtu')

# Import a few modules.
from enthought.mayavi.modules.api import Outline, IsoSurface, Streamline
```

```
# Show an outline.
o = Outline()
mayavi.add_module(o)
o.actor.property.color = 1, 0, 0 # red color.

# Make a few contours.
iso = IsoSurface()
mayavi.add_module(iso)
iso.contour.contours = [450, 570]
# Make them translucent.
iso.actor.property.opacity = 0.4
# Show the scalar bar (legend).
iso.module_manager.scalar_lut_manager.show_scalar_bar = True

# A streamline.
st = Streamline()
mayavi.add_module(st)
# Position the seed center.
st.seed.widget.center = 3.5, 0.625, 1.25
st.streamline_type = 'tube'

# Save the resulting image to a PNG file.
s.scene.save('test.png')

# Make an animation:
for i in range(36):
    # Rotate the camera by 10 degrees.
    s.scene.camera.azimuth(10)

    # Resets the camera clipping plane so everything fits and then
    # renders.
    s.scene.reset_zoom()

    # Save the scene.
    s.scene.save_png('anim%d.png'%i)
```

Sometimes, given a Mayavi `Script` instance or `Engine`, it is handy to be able to navigate to a particular module/object. In the above this could be achieved as follows:

```
x = mayavi.engine.scenes[0].children[0].children[0].children[-1]
print x
```

In this case `x` will be set to the `Streamline` instance that we just created.

There are plenty of examples illustrating various things in the `examples/mayavi` directory. These are all fairly well documented.

In particular, the `standalone.py` example illustrates how one can script mayavi without using the envisage application at all. The `offscreen.py` example illustrates how this may be done using off screen rendering (if supported by your particular build of VTK).

`examples/README.txt` contains some information on the recommended ways to script and some additional information.

6.2.3 Using the Mayavi envisage plugins

The Mayavi-related plugin definitions to use are:

- `mayavi_plugin.py`
- `mayavi_ui_plugin.py`

These are in the `enthought.mayavi.plugins` package. To see an example of how to use this see the `enthought.mayavi.plugins.app` module. The explorer3D example in `examples/mayavi/explorer` also demonstrates how to use Mayavi as an envisage plugin.

If you are writing Envisage plugins for an application and desire to use the Mayavi plugins from your plugins/applications then it is important to note that Mayavi creates three workbench service offers for your convenience. These are:

- `enthought.mayavi.plugins.script.Script`: This is an `enthought.mayavi.plugins.script.Script` instance that may be used to easily script mayavi. It is a simple wrapper object that merely provides some nice conveniences while scripting from the UI. It has an `engine` trait that is a reference to the running Mayavi engine.
- `enthought.mayavi.core.engine.Engine`: This is the running Mayavi engine instance.

A simple example that demonstrates the use of the Mayavi plugin in an envisage application is included in the `examples/mayavi/explorer` directory. This may be studied to understand how you may do the same in your envisage applications.

CHAPTER

SEVEN

BUILDING APPLICATIONS USING MAYAVI

Section summary

This section describes how Mayavi can be used as a scientific data visualization and 3D plotting tool in interactive application.

Mayavi can be used as a fully integrated and interactive 3D plotting tool in a GUI application. Using the event model behind Traits and TVTK, all the different properties of a visualization can be changed dynamically, including the data visualized itself.

In this section, we first show how an interactive dialog embedding a Mayavi scene can be built, using *Traits*. Then we show how to integrate this dialog in a WxPython or a PyQt application.

7.1 Custom interactive dialogs

Mayavi and TVTK are entirely built using the Traits library which provide easy callbacks and visualization for objects attribute. All the different properties of the pipeline and pipeline objects are expressed as Traits, ie special attributes that can be visualized in dialogs, and that fire callbacks when they are modified. In particuler this means that when a visualization object is modified, the scene can update automatically.

We strongly suggest that you refer to the *Traits* documentation for more details, and to the tutorial for a quick introduction.

7.1.1 Embedding a Mayavi scene in a Traits dialog

To build a custom dialog with a Mayavi scene, the best option is to create a class deriving from the base *Traits* class. A special attribute, called SceneModel can be used as an attribute to represent a Mayavi scene that can accept objects. This defines the *model*, ie the main *HasTraits* object in which the application logics is contained.

A view of this object, as a dialog, can be created using the *.configure_traits* method of this object. If a view is explicitely specified the embedded Mayavi scene can be represented with the usual widget for scene by specifying for it the *SceneEditor*:

```
from enthought.traits.api import HasTraits, Instance
from enthought.traits.ui.api import View, Item
from enthought.tvtk.pyface.scene_model import SceneModel
from enthought.tvtk.pyface.scene_editor import SceneEditor
```

```
class MyModel(HasTraits):
    scene = Instance(SceneModel, ())

    view = View(Item('scene', height=400, show_label=False,
                     editor=SceneEditor()))

MyModel().configure_traits()
```

A *Mayavi* button to pop up the pipeline dialog can be added on the toolbar by specifying a different scene view to the *SceneEditor*:

```
from enthought.mayavi.core.ui.mayavi_scene import MayaviScene

#...
editor=SceneEditor(scene_class=MayaviScene)
#...
```

If, on the contrary, you want a view with no toolbar, you can replace the *MayaviView* by a raw tvtk view:

```
from enthought.tvtk.pyface.api import Scene

#...
editor=SceneEditor(scene_class=Scene)
#...
```

The *Mayavi traits ui example* is a fairly comprehensive example that demonstrates how you can embed almost the entire Mayavi UI into your traits based UI.

7.1.2 A scene, with *mlab* embedded

An object representing a scene is interesting only if you can visualize data with the scene. For this we can instanciate an *Engine* and assign it to the scene. Having an *Engine* only for one scene allows us to confine action and visualization objects only to this scene.

We can also use an *MlabSceneModel* instance, rather than a *SceneModel*, imported from *enthought.mayavi.tools.mlab_scene_model*. This scene model registers the figure in *mlab* (*mlab: Python scripting for 3D plotting*). It has an embedded mlab attribute, that exposes the mlab commands (see *3D Plotting functions for numpy arrays*). For instance plotting 3D points can be achieved with *self.scene.mlab.points3d(x, y, z, s)*.

Warning: Embedding several scenes in an application
When using several 'MlabSceneModel' in an application, there is an ambiguity regarding which scene mlab should use to plot to. This is why relying on using the current figure, as mlab most often does, is dangerous.
The solution to this, is explicitely pass in the Mayavi figure to mlab's figure keyword argument:

```
mlab.points3d(x, y, z, s, figure=self.scene.mayavi_scene)
```

However, this functionnality is new in Mayavi 3.2.1.
A full example with two embedded scenes is given on *Multiple mlab scene models example*.
Another way of creating isolation between scene is to explicitely insert them in different engines. This is demonstrated in *Multiple engines example*

7.1.3 Making the visualization live

Having an interactive application is interesting only if you can do custom, domain-specific, interaction with the visualization.

An important use case is modifying the data visualized as a parameter is changed interactively. For this we can use the inplace modification of the data of an mlab object, as for animation of an mlab plot (see *Animating the data*). Suppose we are plotting a line curve defined by a function of two parameters:

```
from numpy import linspace, pi, cos, sin

def curve(n_mer, n_long):
    phi = linspace(0, 2*pi, 2000)
    return [ cos(phi*n_mer) * (1 + 0.5*cos(n_long*phi)),
             sin(phi*n_mer) * (1 + 0.5*cos(n_long*phi)),
             0.5*sin(n_long*phi),
             sin(phi*n_mer)]
```

Using *mlab*, we could plot the curve with *plot3d*:

```
x, y, z, s = curve(4, 6)
from enthought.mayavi import mlab
plot = mlab.plot3d(x, y, z, s)
```

Modifying the plot for new parameters could be written:

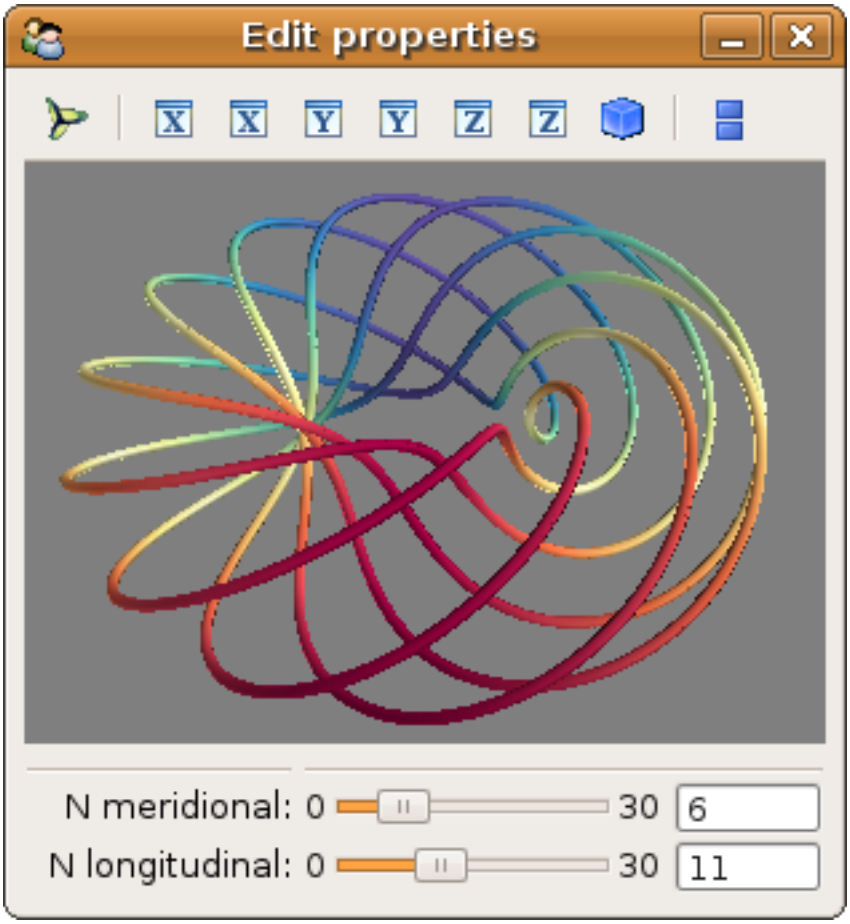
```
x, y, z, t = curve(4, 8)
plot.mlab_source.set(x=x, y=y, z=z, scalars=t)
```

In a dialog, this would be:

```
from enthought.traits.api import HasTraits, Range, Instance, \
                    on_trait_change
from enthought.traits.ui.api import View, Item, HGroup
from enthought.tvtk.pyface.scene_editor import SceneEditor
from enthought.mayavi.tools.mlab_scene_model import \
                    MlabSceneModel
from enthought.mayavi.core.ui.mayavi_scene import MayaviScene


class Visualization(HasTraits):
    meridional = Range(1, 30,  6)
    transverse = Range(0, 30, 11)
    scene      = Instance(MlabSceneModel, ())

    def __init__(self):
        # Do not forget to call the parent's __init__
        HasTraits.__init__(self)
        x, y, z, t = curve(self.meridional, self.transverse)
        self.plot = self.scene.mlab.plot3d(x, y, z, t, colormap='Spectral')

    @on_trait_change('meridional,transverse')
    def update_plot(self):
        x, y, z, t = curve(self.meridional, self.transverse)
        self.plot.mlab_source.set(x=x, y=y, z=z, scalars=t)
```

```
    # the layout of the dialog created
    view = View(Item('scene', editor=SceneEditor(scene_class=MayaviScene),
                     height=250, width=300, show_label=False),
                HGroup(
                        '_', 'meridional', 'transverse',
                    ),
                )

visualization = Visualization()
visualization.configure_traits()
```

This code creates the following dialog:



A complete, runnable, code based on the above comments is given in the *Mlab interactive dialog example*.

Warning: Visualization objects and properties created before a scene is available
When creating a traited object with an embedded scene, the scene can be created and populated before a view on it is actually open. However, some VTK objects or properties require a scene with a camera and interaction to be open to work properly, mainly because either they orient themselves to the camera, or deal with interaction with keyboard or mouse (such as interactors, eg an implicit plane). As a result some property changes on VTK objects will raise warnings or simply not work when applied without a dialog opened. When embedding a scene in a Traits object, the best option is to create and modify these objects only when the scene is activated, by listening to changes on the 'scene.activated' traits:

```
@on_trait_change('scene.activated')
def create_plot(self):
    # Do the plotting here
    # ...
```

The *Lorenz ui example* shows a good example of this situation.

Learning by examples

Several full-featured examples can be used to learn more about how to develop an application with visualization and data processing with Traits and Mayavi:

- *Lorenz ui example*: A didactic and simple example that shows how the Lorentz model can be integrated and visualized interactively while changing the model parameters.
- *Mayavi traits ui example*: An example showing how you can mimic the UI of the Mayavi application with simple code using Traits.
- *Multiple engines example*: An example showing how you can isolate different scenes by affecting them to different engines.
- *Coil design application example*: A full-blown and elaborate application enabling specification of a current-loop description for a coil, and integration of the resulting magnetic field with real-time visualization of the field and the coil structure.

7.2 Integrating in a WxPython application

Using the *Visualization* class defined above:

```
import wx

class MainWindow(wx.Frame):
    def __init__(self, parent, id):
        wx.Frame.__init__(self, parent, id, 'Mayavi in Wx')
        self.visualization = Visualization()
        self.control = self.visualization.edit_traits(parent=self,
                                kind='subpanel').control
        self.Show()

app = wx.PySimpleApp()
frame = MainWindow(None, wx.ID_ANY)
app.MainLoop()
```

Two examples of integrating Mayavi visualization with Wx applications are given:

- *Wx embedding example*: a simple example, as above.

- *Wx mayavi embed in notebook example*: a more complexe example, showing 2 different Mayavi views embedded in a Wx notebook.

7.3 Integrating in a PyQt application

Before defining the *Visualization* class:

```
import os
os.environ['ETS_TOOLKIT'] = 'qt4'
```

And using this class:

```
from PyQt4 import QtGui

class MainWindow(QtGui.QMainWindow):
    def __init__(self, parent=None):
        QtGui.QWidget.__init__(self, parent)
        self.visualization = Visualization()
        self.ui = self.visualization.edit_traits().control
        self.setCentralWidget(self.ui)

window = MainWindow()
window.show()
QtGui.qApp.exec_()
```

For a full-blown example of embedding in Qt, see *Qt embedding example*.

Warning: On definition of the model (and thus previous to the start of the event loop), Traits sets up some hooks on the main QApplication. As a result if you instanciate a new one, using for instance:

```
app = QtGui.QApplication()
```

Your Traits application will not work.

CHAPTER

EIGHT

TIPS AND TRICKS

Below are a few tips and tricks that you may find useful when you use Mayavi2.

8.1 Off screen rendering

8.1.1 Avoiding the rendering window

Often you write Mayavi scripts to render a whole batch of images to make an animation or so and find that each time you save an image, Mayavi "raises" the window to make it the active window thus disrupting your work. This is needed since VTK internally grabs the window to make a picture. Occluding the window will also produce either blank or incorrect images.

If you already have a Python script, say `script.py` that sets up your visualization that you run like so:

```
$ mayavi2 -x script.py
```

Then it is very easy to have this script run offscreen. Simply run it like so:

```
$ mayavi2 -x script.py -o
```

This will run the script in an offscreen, standalone window. On Linux, this works best with VTK-5.2 and above. For more details on the command line arguments supported by the `mayavi2` application, see the *Command line arguments* section.

When using `mlab` you will want to do this:

```
mlab.options.offscreen = True
```

before you create a figure and it will use an offscreen window for the rendering.

Another option for offscreen rendering would be to click on the scene and set the "Off screen rendering" option on. Or from a script:

```
mayavi.engine.current_scene.scene.off_screen_rendering = True
```

This will stop raising the window. However, this may not be enough. Please see below on the situation on different platforms.

8.1.2 Platform Summary

- **Windows**: If you are using win32 then off screen rendering should work well out of the box. All you will need to do is what is given above.
- **Linux and the Mac**: there are several options to get this working correctly and some major issues to consider:

  If you have VTK-5.2 the offscreen rendering option should let you generate the pictures without worrying about occluding the window. However, you will need VTK-5.2 to get this working properly. There are also situations when this does not always work – try it and if you get blank windows, you have a problem. For example:

```
from enthought.mayavi import mlab
mlab.options.offscreen = True
mlab.test_contour3d()
mlab.savefig('example.png')
```

  If this produces a clean image (even if you switch desktops or cover any windows produced), you should be golden. If not you should consider either using a virtual framebuffer or building VTK with Mesa + OSMesa to give you a pure software rendering approach.

8.1.3 Rendering using the virtual framebuffer

VTK uses openGL for all its rendering. Under any conventional Unix (including Linux), you need an Xserver running to open a GL context (especially if you want hardware acceleration). This might be a problem when rendering on a headless server. As mentioned in the above paragraph, on a desktop, using the default server may also be a problem as it interferes with your ongoing work.

A good workaround is to use the virtual framebuffer X server for X11 like so:

- Make sure you have the `Xvfb` package installed. For example under Debian and derivatives this is called the `xvfb` package.
- Create the virtual framebuffer X server like so:

```
Xvfb :1 -screen 0 1280x1024x24 -auth localhost
```

  This creates the display ":1" and creates a screen of size 1280x1024 with 24 bpp (the 24bpp is important). For more options check your `Xvfb` man page.

- Export display to :1 like so (on bash):

```
$ export DISPLAY=:1
```

- Now run your Mayavi script. It should run uninterrupted on this X server and produce your saved images.

This probably will have to be fine tuned to suit your taste.

Many Linux systems (including Ubuntu and Debian) ship with a helper script *xvfb-run* for running headless. The following command can run a Python script with Mayavi2 visualizations headless:

```
xvfb-run --server-args="-screen 0 1024x768x24" python my_script.py
```

Beware that you shouldn't call *mlab.show* or start the mainloop in the script, elsewhere the script will run endlessly, waiting for interaction in a hidden window.

Note: If you want to use Mayavi without the envisage UI or even a traits UI (i.e. with a pure TVTK window) and do off screen rendering with Python scripts you may be interested in the *examples_offscreen*. This simple example shows how you can use Mayavi without using Envisage or the Mayavi envisage application and still do off screen rendering.

If you are using mlab, outside of the Mayavi2 application, simply set:

```
mlab.options.offscreen = True
```

8.1.4 Using VTK with Mesa for pure software rendering

Sometimes you might want to run Mayavi/VTK completely headless on a machine with no X server at all and are interested in pure offscreen rendering (for example for usage on the Sage notebook interface). In these cases one could use Mesa's OSMesa library to render offscreen. The downside is that you will not get any hardware acceleration in this case. Here are brief instructions on how to build VTK to do this.

- Build a recent version of mesa. 7.0.4 (as of this time) should work as would 7.2. We assume you download MesaLib-7.0.4.tar.bz2.
- Untar, and change directory to the new directory created. We call this directory `$MESA` henceforth.
- Run `make configs/linux-x86`, change file as per your configuration. Run `make` to see list of options. Note: 7.2 has a `./configure` script that you can run.
- Get VTK-5.2 or later (CVS will also work)..
- Run `ccmake path/to/VTK`.
  - Now select advanced options 't'.
  - Set `VTK_OPENGL_HAS_OSMESA ON`
  - Configure: press 'c'
  - Set the `OSMESA_INCLUDE_DIR` to the `$MESA/include dir`
  - Set `OSMESA_LIBRARY` to `$MESA/lib/libOSMesa.so`
  - Similarly set the `OPENGL_INCLUDE_DIR`, `OPENGL_gl_LIBRARY=$MESA/lib/libGL.so`, `OPENGL_glu_LIBRARY`, and `OPENGL_xmesa_INCLUDE_DIR`.
  - Set `VTK_USE_OFFSCREEN` to `ON` if you want offscreen all the time, this will never produce an actual mapped VTK window since the default value of the render window's offscreen rendering ivar will be set to True in this case.
  - Any other settings like `VTK_USE_GL2PS, USE_RPATH` etc.
  - Configure again (press 'c') and then generate 'g'.
  - Note that if you do not want to use `ccmake` and would like to do this from the command line you may also do (for example):

```
cmake \
-DVTK_OPENGL_HAS_OSMESA=ON \
-DVTK_USE_OFFSCREEN=ON \
-DCMAKE_INSTALL_PREFIX=/path/to/vtk-offscreen \
-DVTK_WRAP_PYTHON=ON \
-DPYTHON_EXECUTABLE=/usr/bin/python2.5 \
-DPYTHON_LIBRARY=/usr/lib/libpython2.5.so \
-DBUILD_SHARED_LIBS=ON \
-DVTK_USE_GL2PS=ON \
-DOSMESA_INCLUDE_DIR=/path/to/Mesa-7.2/include/ \
-DOSMESA_LIBRARY=/home/path/to/Mesa-7.2/lib64/libOSMesa.so \
-DOPENGL_INCLUDE_DIR=/path/to/Mesa-7.2/include \
-DOPENGL_gl_LIBRARY=/path/to/Mesa-7.2/lib64/libGL.so \
```

```
-DOPENGL_glu_LIBRARY=/path/to/Mesa-7.2/lib64/libGLU.so \
path/to/VTK/
```

- Run `make` and wait till VTK has built. Let us say the build is in `$VTK_BUILD`.
- Now install VTK or set the `PYTHONPATH` and `LD_LIBRARY_PATH` suitably. Also ensure that `LD_LIBRARY_PATH` points to `$MESA/lib` (if the mesa libs are not installed on the system) this ensures that VTK links to the right GL libs. For example:

```
$ export PYTHONPATH=$VTK_BUILD/bin:$VTK_BUILD/Wrapping/Python``
$ export LD_LIBRARY_PATH=$VTK_BUILD/bin:$MESA/lib
```

  Now, you should be all set.

Once this is done you should be able to run mlab examples offscreen. This will work without an X display even.

With such a VTK built and running, one could simply build and install mayavi2. To use it in a Sage notebook for example you'd want to set `ETS_TOOLKIT='null'` and set `mlab.options.offscreen = True`. Thats it. Everything should now work offscreen.

Note that if you set `VTK_USE_OFFSCREEN` to `ON` then you'll by default only get offscreen contexts. If you do want a UI you will want to explicitly set the render window's `off_screen_rendering` ivar to `False` to force a mapped window. For this reason if you might need to popup a full UI, it might be better to *not set* `VTK_USE_OFFSCREEN=ON`.

8.2 Extending Mayavi with customizations

A developer may wish to customize Mayavi by adding new sources, filters or modules. These can be done by writing the respective filters and exposing them via a `user_mayavi.py` or a `site_mayavi.py` as described in Customizing Mayavi2. A more flexible and reusable mechanism for doing this is to create a full fledged Mayavi contrib package in the following manner.

1. Create a Python package, lets call it `mv_iitb` (for IIT Bombay specific extensions/customizations). The directory structure of this package can be something like so:

```
mv_iitb/
        __init__.py
        user_mayavi.py
        sources/
                ...
        filters/
                ...
        modules/
                ...
        docs/
            ...
```

   The two key points to note in the above are the fact that `mv_iitb` is a proper Python package (notice the `__init__.py`) and the `user_mayavi.py` is the file that adds whatever new sources/filters/modules etc. to Mayavi. The other part of the structure is really up to the developer. At the moment these packages can add new sources, filters, modules and contribute any Envisage plugins that the `mayavi2` application will load.

2. This package should then be installed somewhere on `sys.path`. Once this is done, users can find these packages and enable them from the Tools->Preferences (the UI will automatically detect the package). The `user_mayavi.py` of each selected package will then be imported next time Mayavi is started, note that this will be usable even from `mlab`.

Any number of such packages may be created and distributed. If they are installed, users can choose to enable them. Internally, the list of selected packages is stored as the `enthought.mayavi.contrib_packages` preference option. The following code shows how this may be accessed from a Python script:

```
>>> from enthought.mayavi.preferences.api import preference_manager
>>> print preference_manager.root.contrib_packages
[]
>>> preference_manager.configure_traits() # Pop up a UI.
```

For more details on how best to write `user_mayavi.py` files and what you can do in them, please refer to the examples/mayavi/user_mayavi.py example. Please pay particular attention to the warnings in that file. It is a very good idea to ensure that the `user_mayavi.py` does not implement any sources/modules/filters and only registers the metadata. This will avoid issues with circular imports.

8.3 Customizing Mayavi2

There are three ways a user can customize Mayavi:

1. Via Mayavi contributions installed on the system. This may be done by enabling any found contributions from the Tools->Preferences menu on the Mayavi component, look for the "contribution settings". Any selected contributions will be imported the next time Mayavi starts. For more details see the Extending Mayavi with customizations section.
2. At a global, system wide level via a `site_mayavi.py`. This file is to be placed anywhere on `sys.path`.
3. At a local, user level. This is achieved by placing a `user_mayavi.py` in the users `~/.mayavi2/` directory. If a `~/.mayavi2/user_mayavi.py` is found, the directory is placed in `sys.path`.

The files are similar in their content. Two things may be done in this file:

1. Registering new sources, modules or filters in the Mayavi registry (`enthought.mayavi.core.registry.registry`). This is done by registering metadata for the new class in the registry. See `examples/mayavi/user_mayavi.py` to see an example.
2. Adding additional envisage plugins to the mayavi2 application. This is done by defining a function called `get_plugins()` that returns a list of plugins that you wish to add to the mayavi2 application.

The `examples/mayavi/user_mayavi.py` example documents and shows how this can be done. To see it, copy the file to the `~/.mayavi2` directory. If you are unsure where `~` is on your platform, just run the example and it should print out the directory.

> **Warning:** In the `user_mayavi.py` or `site_mayavi.py`, avoid Mayavi imports like `from enthought.mayavi.modules.outline import Outline` etc. This is because `user_mayavi` is imported at a time when many of the imports are not complete and this will cause hard-to-debug circular import problems. The `registry` is given only metadata mostly in the form of strings and this will cause no problem. Therefore to define new modules, we strongly recommend that the modules be defined in another module or be defined in a factory function as done in the example `user_mayavi.py` provided.

8.4 Scripting Mayavi without using Envisage

The example `examples/standalone.py` demonstrates how one can use Mayavi without using Envisage. This is useful when you want to minimize dependencies. `examples/offscreen.py` demonstrates how to use Mayavi without the envisage UI or even a traits UI (i.e. with a pure TVTK window) and do off screen rendering.

8.5 Computing in a thread

`examples/compute_in_thread.py` demonstrates how to visualize a 2D numpy array and visualize it as image data using a few modules. It also shows how one can do a computation in another thread and update the Mayavi pipeline once the computation is done. This allows a user to interact with the user interface when the computation is performed in another thread.

8.6 Polling a file and auto-updating Mayavi

Sometimes you have a separate computational process that generates data suitable for visualization. You'd like Mayavi to visualize the data but automatically update the data when the data file is updated by the computation. This is easily achieved by polling the data file and checking if it has been modified. The `examples/poll_file.py` demonstrates this. To see it in action will require that you edit the scalar data in the `examples/data/heart.vtk` data file.

8.7 Serving Mayavi on the network

Say you have a little visualization script and you'd like to run some kind of server where you can script the running Mayavi UI from a TCP/UDP connection. It turns out there is a simple way to do this if you have Twisted installed. Here is a trivial example:

```
from enthought.mayavi import mlab
from enthought.mayavi.tools import server
mlab.test_plot3d()
server.serve_tcp()
```

There is no need to call `mlab.show()` in the above. The TCP server will listen on port 8007 by default in the above (this can be changed with suitable arguments to `serve_tcp()`). Any data sent to the server is simply exec'd, meaning you can do pretty much anything you want. The names `engine`, `scene`, `camera` and `mlab` are all available and can be scripted with Python code. For example after running the above you can do this:

```
$ telnet localhost 8007
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
scene.camera.azimuth(45)
mlab.clf()
mlab.test_contour3d()
scene.camera.zoom(1.5)
```

The nice thing about this is that you do not loose any interactivity of the application and can continue to use its UI as before, any network commands will be simply run on top of this. To serve on a UDP port use the `serve_udp()` function. For more details on the `server` module please look at the source code – it is thoroughly documented.

> **Warning:** While this is very powerful it is also a huge security hole since the remote user can do pretty much anything they want once connected to the server.

8.7.1 TCP server: the *serve_tcp* function

serve_tcp(*engine=None, port=8007, logto=<open file '<stdout>', mode 'w' at 0xb7779070>, max_connect=1*)
Serve the *M2TCP* protocol using the given *engine* on the specified *port* logging messages to given *logto* which is a file-like object. This function will block till the service is closed. There is no need to call *mlab.show()* after or before this. The Mayavi UI will be fully responsive.

Parameters

engine Mayavi engine to use. If this is *None*, *mlab.get_engine()* is used to find an appropriate engine.

port int: port to serve on.

logto file: File like object to log messages to. If this is *None* it disables logging.

max_connect int: Maximum number of simulataneous connections to support.

Examples

Here is a very simple example:

```
from enthought.mayavi import mlab
from enthought.mayavi.tools import server
mlab.test_plot3d()
server.serve_tcp()
```

The TCP server will listen on port 8007 by default in the above. Any data sent to the server is simply exec'd, meaning you can do pretty much anything you want. The *engine*, *scene*, *camera* and *mlab* are all available and can be used. For example after running the above you can do this:

```
$ telnet localhost 8007
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
scene.camera.azimuth(45)
mlab.clf()
mlab.test_contour3d()
scene.camera.zoom(1.5)
```

Warning

Data sent is exec'd so this is a security hole.

8.7.2 UDP server: the *serve_udp* function

serve_udp(*engine=None, port=9007, logto=<open file '<stdout>', mode 'w' at 0xb7779070>*)
Serve the *M2UDP* protocol using the given *engine* on the specified *port* logging messages to given *logto* which is a file-like object. This function will block till the service is closed. There is no need to call *mlab.show()* after or before this. The Mayavi UI will be fully responsive.

Parameters

engine Mayavi engine to use. If this is *None*, *mlab.get_engine()* is used to find an appropriate engine.

port int: port to serve on.

logto file : File like object to log messages to. If this is *None* it disables logging.

Examples

Here is a very simple example:

```
from enthought.mayavi import mlab
from enthought.mayavi.tools import server
mlab.test_plot3d()
server.serve_udp()
```

Test it like so:

```
import socket
s = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
s.bind(('', 9008))
s.sendto('camera.azimuth(10)', ('', 9007))
```

Warning

Data sent is exec'd so this is a security hole.

8.8 Animating a visualization

Often users like to animate a visualization without affecting the interactive capabilities of the view. For example you may want to rotate the camera continuously, take a snapshot while continuing to interact with the Mayavi UI. To do this one can use the very convenient `animate()` decorator provided with Mayavi. Here is a simple example:

```
from enthought.mayavi import mlab
@mlab.animate
def anim():
    f = mlab.gcf()
    while 1:
        f.scene.camera.azimuth(10)
        f.scene.render()
        yield

a = anim() # Starts the animation.
```

Notice the use of `yield` in the above, this is *very* crucial to this working. This example will continuously rotate the camera without affecting the UI's interactivity. It also pops up a little UI that lets you start and stop the animation and change the time interval between calls to your function. For more specialized use you can pass arguments to the decorator:

```
from enthought.mayavi import mlab
@mlab.animate(delay=500, ui=False)
def anim():
    # ...

a = anim() # Starts the animation without a UI.
```

Note that if you don't want to import all of `mlab`, the animate decorator is available from:

```
from enthought.mayavi.tools.animator import animate
```

For more details check the documentation of the `animate()` decorator available in the *MLab reference*. For an example using it, alongside with the *visual* handy for object-movement animation, see *Mlab visual example*.

8.8.1 Animating a series of images

Lets say you have a stack of PNG or JPEG files that are numbered serially that you want to animate on a Mayavi scene. Here is a simple script (called `img_movie.py`):

```
# img_movie.py
from enthought.pyface.timer.api import Timer

def animate(src, N=10):
    for j in range(N):
        for i in range(len(src.file_list)):
            src.timestep = i
            yield

if __name__ == '__main__':
    src = mayavi.engine.scenes[0].children[0]
    animator = animate(src)
    t = Timer(250, animator.next)
```

The `Timer` class lets you call a function without blocking the running user interface. The first argument is the time after which the function is to be called again in milliseconds. The `animate` function is a generator and changes the timestep of the source. This script will animate the stack of images 10 times. The script animates the first data source by default. This may be changed easily.

To use this script do this:

```
$ mayavi2 -d your_image000.png -m ImageActor -x img_movie.py
```

8.8.2 Making movies from a stack of images

This isn't really related to Mayavi but is a useful trick nonetheless. Lets say you generate a stack of images using Mayavi say of the form `anim%03d.png` (i.e. `anim000.png`, `anim001.png` and so on), you can make this into a movie. If you have `mencoder` installed try this:

```
$ mencoder "mf://anim%03d.png" -mf fps=10 -o anim.avi \
  -ovc lavc -lavcopts vcodec=msmpeg4v2:vbitrate=500
```

If you have ffmpeg installed you may try this:

```
$ ffmpeg -f image2 -r 10 -i anim%03d.png -sameq anim.mov -pass 2
```

8.9 Scripting from the command line

The Mayavi application allows for very powerful *Command line arguments* that lets you build a complex visualization from your shell. What follow is a bunch of simple examples illustrating these.

The following example creates a `ParametricSurface` source and then visualizes glyphs on its surface colored red:

```
$ mayavi2 -d ParametricSurface -m Glyph \
-s"glyph.glyph.scale_factor=0.1" \
-s"glyph.color_mode='no_coloring'" \
-s"actor.property.color = (1,0,0)"
```

Note that `-s"string"` applies the string on the last object (also available as `last_obj`), which is the glyph.

This example turns off coloring of the glyph and changes the glyph to display:

```
$ mayavi2 -d ParametricSurface -m Glyph\
-s"glyph.glyph.scale_factor=0.1" \
-s"glyph.color_mode='no_coloring'" \
-s"glyph.glyph_source.glyph_source = last_obj.glyph.glyph_source.glyph_list[-1]"
```

Note the use of `last_obj` in the above.

8.10 Texture mapping actors

Here is a simple example showing how to texture map an iso-surface with the data that ships with the Mayavi sources (the data files are in the examples directory):

```
$ mayavi2 -d examples/tvtk/images/masonry.jpg \
 -d examples/mayavi/data/heart.vti \
 -m IsoSurface \
 -s"actor.mapper.scalar_visibility=False" \
 -s"actor.enable_texture=True"\
 -s"actor.tcoord_generator_mode='cylinder'"\
 -s"actor.texture_source_object=script.engine.current_scene.children[0]"
```

It should be relatively straightforward to change this example to use a `ParametricSurface` instead and any other image of your choice. Notice how the texture image (`masonry.jpg`) is set in the last line of the above. The image reader is the first child of the current scene and we set it as the `texture_source_object` of the isosurface actor.

8.11 Shifting data and plotting

Sometimes you need to shift/transform your input data in space and visualize that in addition to the original data. This is useful when you'd like to do different things to the same data and see them on the same plot. This can be done with Mayavi using the `TransformData` filter for `StructuredGrid`, `PolyData` and `UnstructuredGrid` datasets. Here is an example using the `ParametricSurface` data source:

```
$ mayavi2 -d ParametricSurface \
  -m Outline -m Surface \
  -f TransformData -s "transform.translate(1,1,1)" \
  -s "widget.set_transform(last_obj.transform)" \
  -m Outline -m Surface
```

If you have an `ImageData` dataset then you can change the origin, spacing and extents alone by using the `ImageChangeInformation` filter. Here is a simple example with the standard Mayavi image data:

```
$ mayavi2 -d examples/mayavi/data/heart.vti -m Outline \
-m ImagePlaneWidget \
-f ImageChangeInformation \
-s "filter.origin_translation=(20,20,20)" \
-m Outline -m ImagePlaneWidget
```

8.12 Using the `UserDefined` filter

The `UserDefined` filter in Mayavi lets you wrap around existing VTK filters easily. Here are a few examples:

```
$ mayavi2 -d ParametricSurface -s "function='dini'" \
-f UserDefined:GeometryFilter \
-s "filter.extent_clipping=True" \
-s "filter.extent = [-1,1,-1,1,0,5]" \
-f UserDefined:CleanPolyData \
-m Surface \
-s "actor.property.representation = 'p'" \
-s "actor.property.point_size=2"
```

This one uses a `tvtk.GeometryFilter` to perform extent based clipping of the parametric surface generated. Note the specification of the `-f UserDefined:GeometryFilter`. This data is then cleaned using the `tvtk.CleanPolyData` filter.

Under mlab, the *Userdefined* can be used to wrap eg a *GeometryFilter* VTK filter with:

```
filtered_obj = mlab.pipeline.user_defined(obj, filter='GeometryFilter')
```

The *Cursor example* gives a full example of using the UserDefined curser.

8.13 Sharing the same data between scenes

If you want to display different views of the same data on different, you will have to create different Mayavi data sources, as a data source can belong on to one scene. However, this does not mean that you need to copy the data, or recreat the source from scratch. The trick is to create a second Mayavi data source pointing to the same underlying VTK dataset, and attach it to another scene.

8.13.1 Using mlab

Every visualization object returned by mlab as a *mlab_source* attribute, which exposes the VTK data source as *dataset*. In addition, the pipeline functions for adding modules know how to use raw VTK datasets. Thus exposing the dataset in a new figure can simply by done by feeding the *mlab_source.dataset* attribute of a visualization object created by mlab to an *mlab.pipeline* function:

```
from enthought.mayavi import mlab
ctr = mlab.test_contour3d()
mlab.figure()
ipw = mlab.pipeline.image_plane_widget(ctr.mlab_source.dataset)
mlab.show()
```

The above example creates two figures displaying the same data, one with iso-surfaces, the other with an image plane widget.

Alternatively, it can be useful to be explicit about the figure that the new module is added onto, rather than using the *mlab* current figure. This is important to make the code easier to read in situations where the current figure is not clear, for instance in an interactive application, rather than a script:

```
new_fig = mlab.figure()
ipw = mlab.pipeline.image_plane_widget(ctr.mlab_source.dataset, figure=new_fig)
```

The *Volume slicer example* shows a complex dialog exposing the same data through different views via *mlab.pipeline*.

8.13.2 Using the core Mayavi API

You can also do this fully explicitly by creating the objects yourself through the Mayavi core api, and adding them to the pipeline, rather than using factories:

```
import numpy as np
a = np.random.random((3, 3, 3))
from enthought.mayavi.sources.api import ArraySource, VTKDataSource
src1 = ArraySource(scalar_data=a)
engine.add_source(src1)
engine.new_scene()
scene2 = engine.current_scene

# Now create a second data source viewing the same data:
src2 = VTKDataSource(data=src1.image_data)
scene2.add_child(src2)
```

8.14 Changing the interaction with a scene

The default 3D interaction with the scene (left click on the background rotates the scene, right click scales, middle click pans) is not suited for every visualization. For instance, in can be interesting to restrict the movement to 2D, e.g. when viewing an object in the 'x' direction. This is done by changing the *interactor_style* of a scene. Here is an example to use Mayavi as a 2D image viewer:

```
from enthought.mayavi import mlab
mlab.test_imshow()
mlab.view(0, 0)
fig = mlab.gcf()
from enthought.tvtk.api import tvtk
fig.scene.interactor.interactor_style = tvtk.InteractorStyleImage()
mlab.show()
```

Another useful interactor is the 'terrain' interactor, handy to have natural movement in scenes where you want the 'up' vector to be always pointing in the 'z' direction:

```
from enthought.mayavi import mlab
mlab.test_surf()
fig = mlab.gcf()
from enthought.tvtk.api import tvtk
fig.scene.interactor.interactor_style = tvtk.InteractorStyleTerrain()
mlab.show()
```

VTK has many different interactors. An easy way to list them is to display the VTK class browser (via the help menu, in the *mayavi2* application) and to search for "Interactor". Another option is to tab complete on Ipython, on *tvtk.InteractorStyle*.

8.15 Accelerating a Mayavi script

You've just created a nice Mayavi/mlab script and now want to generate an animation or a series of images. You realize that it is way too slow rendering the images and takes ages to finish. There are two simple ways to speed up the rendering. Lets assume that `obj` is any Mayavi pipeline object that has a `scene` attribute:

```
obj.scene.disable_render = True
# Do all your scripting that takes ages.
# ...
# Once done, do the following:
obj.scene.disable_render = False
```

This will speed things up for complex visualizations sometimes by an order of magnitude.

While saving the visualization to an image you can speed up the image generation at the cost of loosing out on anti-aliasing by doing the following:

```
obj.scene.anti_aliasing_frames = 0
```

The default value is typically 8 and the rendered image will be nicely anti-aliased. Setting it to zero will not produce too much difference in the rendered image but any smooth lines will now appear slightly jagged. However, the rendering will be much faster. So if this is acceptable (try it) this is a mechanism to speed up the generation of images.

CHAPTER

NINE

MISCELLANEOUS

9.1 Getting help

Most of the user and developer discussion for Mayavi occurs on the Enthought OSS developers mailing list (enthought-dev@mail.enthought.com). This list is also available via gmane from here: http://dir.gmane.org/gmane.comp.python.enthought.devel

Discussion and bug reports are also sometimes sent to the mayavi-users mailing list (Mayavi-users@lists.sourceforge.net). We recommend sending messages to the enthought-dev list though.

The Mayavi wiki page: https://svn.enthought.com/enthought/wiki/MayaVi

is a trac page where one can also enter bug reports and feature requests.

If this manual, the Mayavi web page, the wiki page and google are of no help feel free to post on the enthought-dev mailing list for help.

9.2 Tests for Mayavi

You can easily run the Mayavi test suite using *mayavi2 -t* from the command line. Running tests is useful to find out if Mayavi works well on your particular system. Indeed, the systems can vary from one to another: in addition to the variety of existing operative system, different versions of the libraries can be installed. The Mayavi developers do their best to support many different configuration, but you can help them by running the test suite and reporting any errors.

ETS uses nose to gather and run tests. You can also run the unit tests of both packages by doing the following from the root of the Mayavi source directory:

```
$ nosetests
----------------------------------------------------------------------
Ran 170 tests in 39.254s

OK (SKIP=1)
```

If you get an "ERROR" regarding the unavailability of coverage you may safely ignore it. If for some reason nose is having difficulty running the tests, the tests may be found inside `enthought/tvtk/tests` and `enthought/mayavi/tests`. You can run each of the `test_*.py` files in these directories manually, or change your current directory to these directories and run `nosetests` there.

In addition to these unittests mayavi also has several integration tests. These are in the `integrationtests/mayavi` directory of the source distribution. You may run the tests there like so:

```
$ ./run.py
```

These tests are intrusive and will create several mayavi windows and also take a while to complete. Some of them may fail on your machine for various reasons.

9.3 Helping out

We are always on the lookout for people to help this project grow. If you need a functionnality added to Mayavi, just pitch in on the enthought-dev mailing and we'll help you code it.

9.3.1 Development quick start

To help improve Mayavi, you first need to install the development version (see *Under Mac OSX Snow Leopard*). You can then modify your local installation of Mayavi to add the functionality you are interested in (make sure the tests still run after your modifications). To keep track of your changes, you need to use subversion, if you have never used it, see http://svnbook.red-bean.com/en/1.1/ch01s07.html. Once you are done, you can generate a path that sums up your changes via by executing the following command in the root of the Mayavi source:

```
svn diff > my_patch.patch
```

Feel free to send us patches via the mailing list. Thanks!

9.3.2 Improving the documentation

Documentation of a project is incredibly important. It also takes a lot of time to write and improve. You can easily help us with documentation.

For that, you can check out only the subversion tree of Mayavi, using:

```
svn co http://svn.enthought.com/svn/enthought/Mayavi/trunk/ mayavi
```

You will find the documentation sources in *docs/sources/mayavi*. The documentation is writen in sphinx. It is easy to edit the *.rst* files to modify or extend the text. Once you have done your modifications, you can build the documentation using by running:

```
python setup.py build_docs
```

in the base directory of your checkout. You will need sphinx installed for that. The documentation is then built as an HTML documentation that you can find in the sub directory *build/docs/html/mayavi*. Once you are confortable with the modifications, just generate an SVN patch using:

```
svn diff > my_patch.patch
```

And send us the patch via the mailing list. Thanks!

CHAPTER

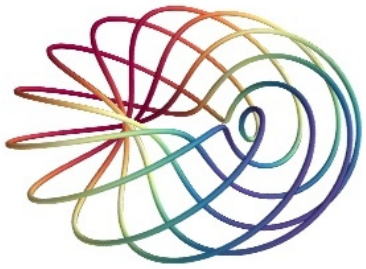
TEN

EXAMPLE GALLERY

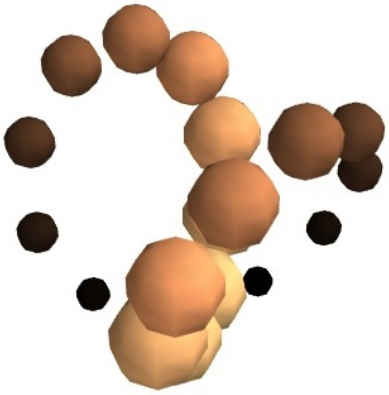
10.1 Mlab functions gallery

These are the examples of the mlab plotting functions. They are copied out here for convenience. Please refer to the corresponding section of the user guide for more information (*3D Plotting functions for numpy arrays*).

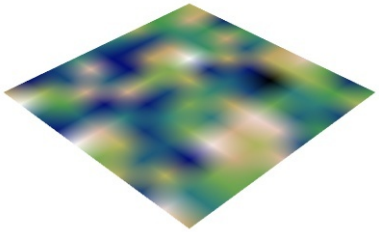
plot3d()



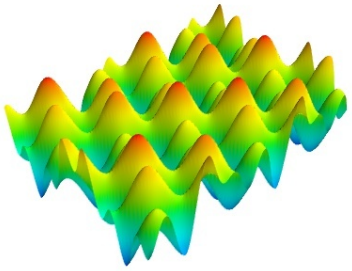
points3d()



imshow()

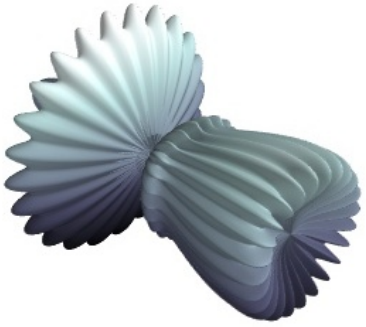


surf()

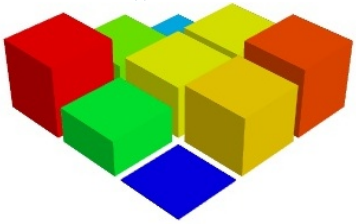


contour_surf()

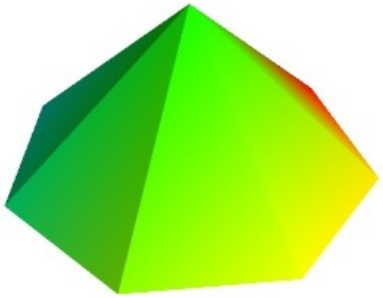
mesh()



barchart()

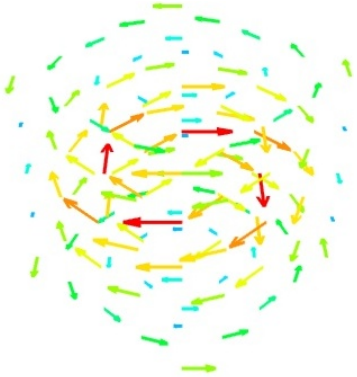


triangular_mesh()

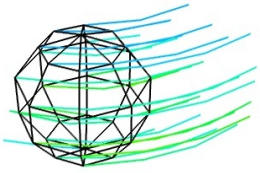


contour3d()

quiver3d()



flow()

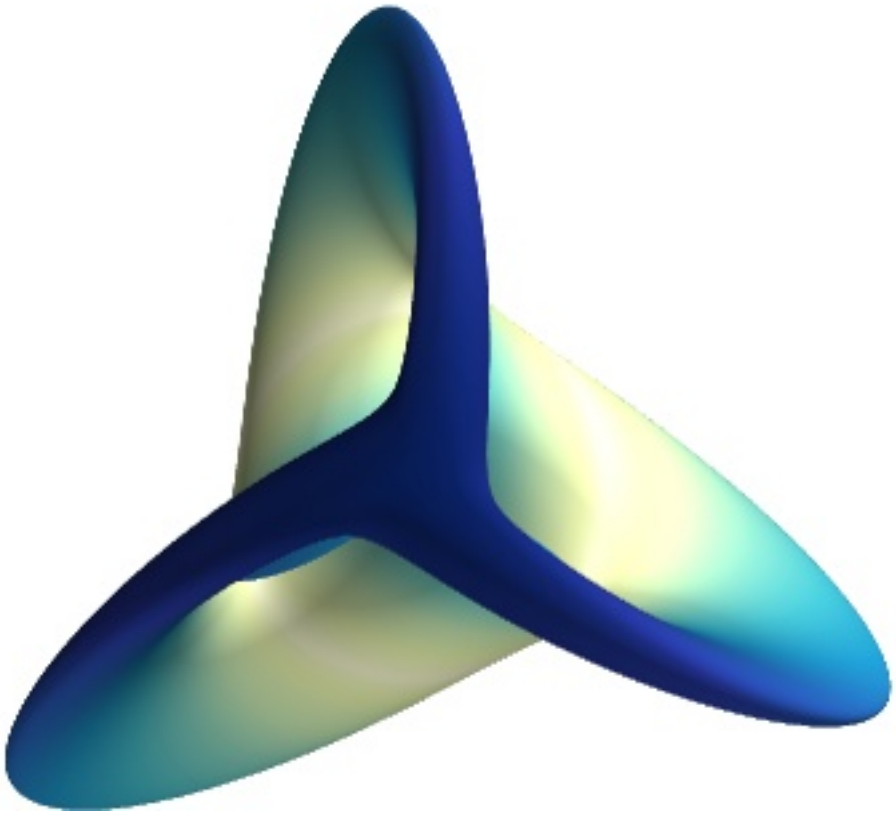


10.2 Advanced mlab examples

10.2.1 Boy example

A script to generate the Mayavi logo: a Boy surface.

The boy surface is a mathematical parametric surface, see http://en.wikipedia.org/wiki/Boy%27s_surface . We display it by sampling the two parameters of the surface on a grid and using the mlab's mesh function: `enthought.mayavi.mlab.mesh()`.



Source code: boy.py

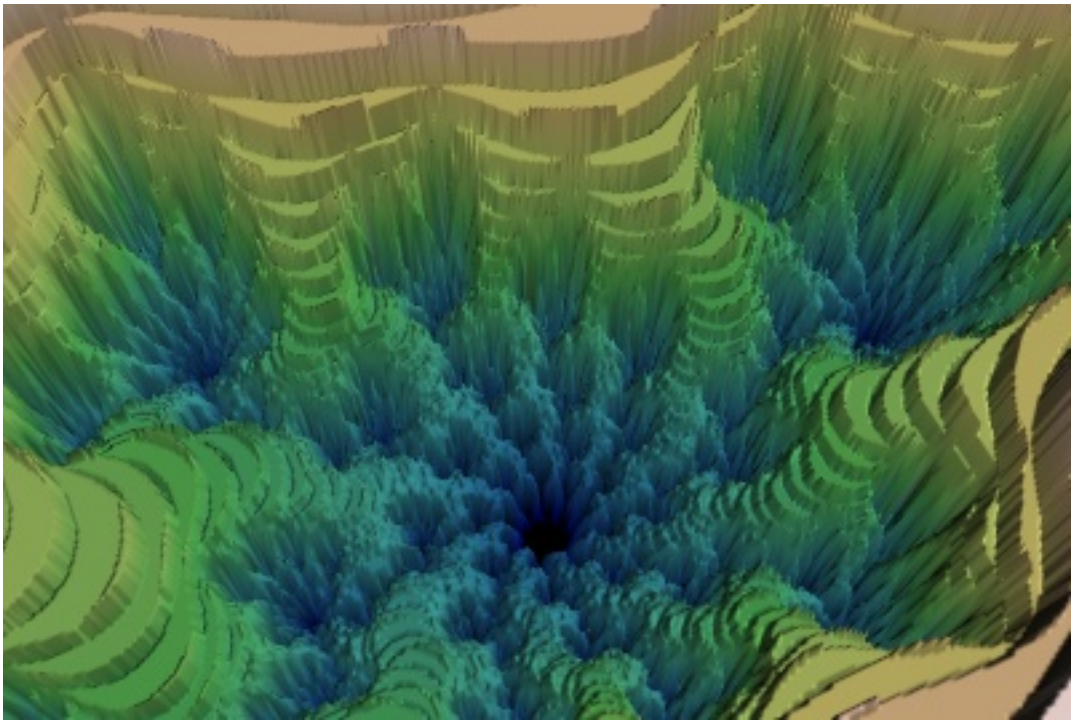
```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD Style.


from numpy import sin, cos, mgrid, pi, sqrt
from enthought.mayavi import mlab

mlab.figure(fgcolor=(0, 0, 0), bgcolor=(1, 1, 1))
u, v = mgrid[-0.035:pi:0.01, -0.035:pi:0.01]

X = 2/3.* (cos(u)* cos(2*v)
        + sqrt(2)* sin(u)* cos(v))* cos(u) / (sqrt(2) - sin(2*u)* sin(3*v))
Y = 2/3.* (cos(u)* sin(2*v) - sqrt(2)* sin(u)* sin(v))* cos(u) / (sqrt(2)
        - sin(2*u)* sin(3*v))
Z = -sqrt(2)* cos(u)* cos(u) / (sqrt(2) - sin(2*u)* sin(3*v))
```

```
S = sin(u)

mlab.mesh(X, Y, Z, scalars=S, colormap='YlGnBu', )

# Nice view from the front
mlab.view(.0, -5.0, 4)
mlab.show()
```

10.2.2 Julia set example

An example showing the Julia set displayed as a z-warped surface.

The Julia set is a fractal (see http://en.wikipedia.org/wiki/Julia_set). We display it here in a canyon-like view using mlab's surf function: `enthought.mayavi.mlab.surf()`.



Source code: julia_set.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.


from enthought.mayavi import mlab
import numpy as np

# Calculate the Julia set on a grid
x, y = np.ogrid[-1.5:0.5:500j, -1:1:500j]
z = x + 1j*y

julia = np.zeros(z.shape)
```

```
for i in range(50):
    z = z**2 -0.70176 -0.3842j
    julia += 1/float(2+i)*(z*np.conj(z) > 4)

# Display it
mlab.figure(size=(400, 300))
mlab.surf(julia, colormap='gist_earth', warp_scale='auto', vmax=1.5)

# A view into the "Canyon"
mlab.view(65, 27, 390, [ 6.,  -47,  169])
mlab.show()
```

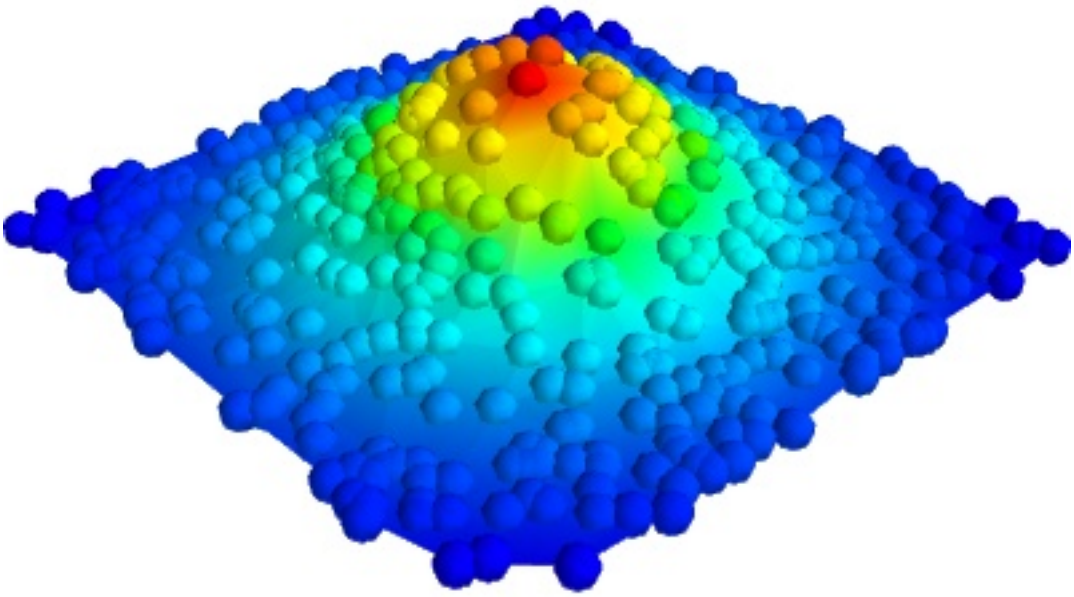
10.2.3 Surface from irregular data example

An example which shows how to plot a surface from data acquired irregularly.

Data giving the variation of a parameter 'z' as a function of two others ('x' and 'y') is often plotted as a *carpet plot*, using a surface to visualize the underlying function. when the data has been acquired on a regular grid for parameters 'x' and 'y', it can simply be view with the mlab.surf function. However, when there are some missing points, or the data has been acquired at random, the surf function cannot be used.

The difficulty stems from the fact that points positionned in 3D do not define a surface if no connectivity information is given. With the surf function, this information is implicite from the shape of the input arrays.

In this example, randomly-positionned points in the (x, y) plane are embedded in a surface in the z axis. We first visualize the points using mlab.points3d. We then use the delaunay2d filter to extract the mesh by nearest-neighboor matching, and visualize it using the surface module.



Source code: surface_from_irregular_data.py

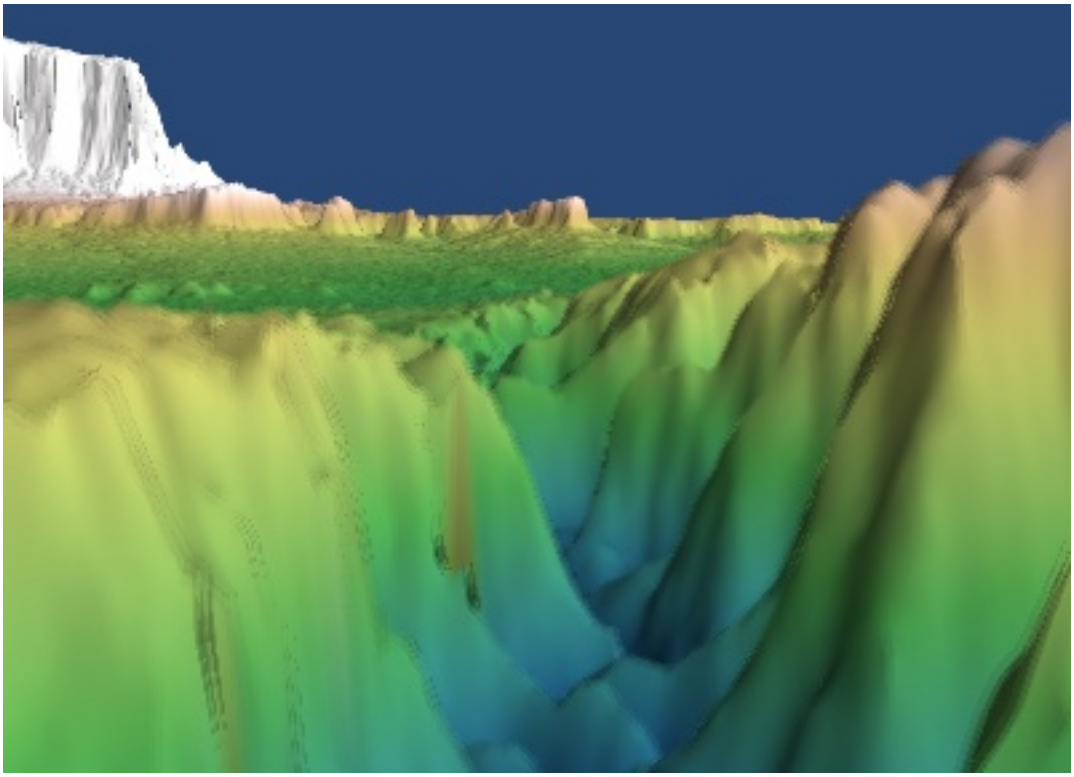
```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2009, Enthought, Inc.
# License: BSD Style.

import numpy as np

# Create data with x and y random in the [-2, 2] segment, and z a
# Gaussian function of x and y.
np.random.seed(12345)
x = 4*(np.random.random(500) - 0.5)
y = 4*(np.random.random(500) - 0.5)

def f(x, y):
    return np.exp(-(x**2 + y**2))

z = f(x, y)

from enthought.mayavi import mlab
mlab.figure(1, fgcolor=(0, 0, 0), bgcolor=(1, 1, 1))

# Visualize the points
pts = mlab.points3d(x, y, z, z, scale_mode='none', scale_factor=0.2)

# Create and visualize the mesh
mesh = mlab.pipeline.delaunay2d(pts)
surf = mlab.pipeline.surface(mesh)

mlab.view(47, 57, 8.2, (0.1, 0.15, 0.14))
mlab.show()
```

10.2.4 Canyon example

Retrieve radar data from the NASA and plot a view of the Grand Canyon landscape.

We cannot display the whole data, as it would be too big. To display more, see the canyon decimation example.

This example is interesting as it shows how numpy can be used to load and crop data completly foreign to Mayavi.



Source code: canyon.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.

# Retrieve the grand Canyon topological data ##################################
import os
if not os.path.exists('N36W113.hgt.zip'):
    # Download the data
    import urllib
    print 'Downloading data, please wait (10M)'
    opener = urllib.urlopen(
    'ftp://e0srp01u.ecs.nasa.gov/srtm/version2/SRTM1/Region_04/N36W113.hgt.zip'
        )
    open('N36W113.hgt.zip', 'w').write(opener.read())

# Load the data (signed 2 byte integers, big endian) ##########################
import zipfile
import numpy as np

data = np.fromstring(zipfile.ZipFile('N36W113.hgt.zip').read('N36W113.hgt'),
                     '>i2')
data.shape = (3601, 3601)
data = data.astype(np.float32)

# Plot an interesting section #################################################
from enthought.mayavi import mlab
data = data[:1000, 900:1900]
# Convert missing values into something more sensible.
data[data==-32768] = data[data>0].min()
```

```
mlab.figure(size=(400, 320), bgcolor=(0.16, 0.28, 0.46))
mlab.surf(data, colormap='gist_earth', warp_scale=0.2,
            vmin=1200, vmax=1610)
# The data takes a lot of memory, and the surf command has created a
# copy. We free the inital memory.
del data

# A view of the canyon
mlab.view(-5.9, 83, 570, [5.3, 20, 238])
mlab.show()
```

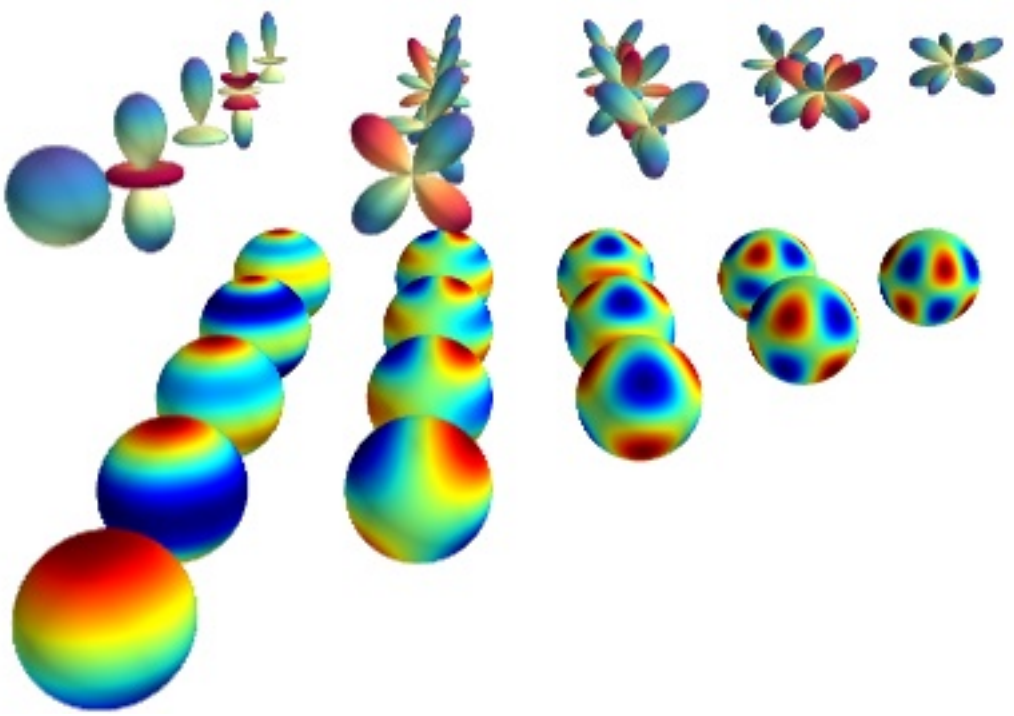
10.2.5 Spherical harmonics example

Plot spherical harmonics on the surface of the sphere, as well as a 3D polar plot.

This example requires scipy.

In this example we use the mlab's mesh function: `enthought.mayavi.mlab.mesh()`. For plotting surfaces this is a very versatile function. The surfaces can be defined as functions of a 2D grid.

For each spherical harmonic, we plot its value on the surface of a sphere, and then in polar. The polar plot is simply obtained by varying the radius of the previous sphere.



Source code: spherical_harmonics.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.

from enthought.mayavi import mlab
import numpy as np
```

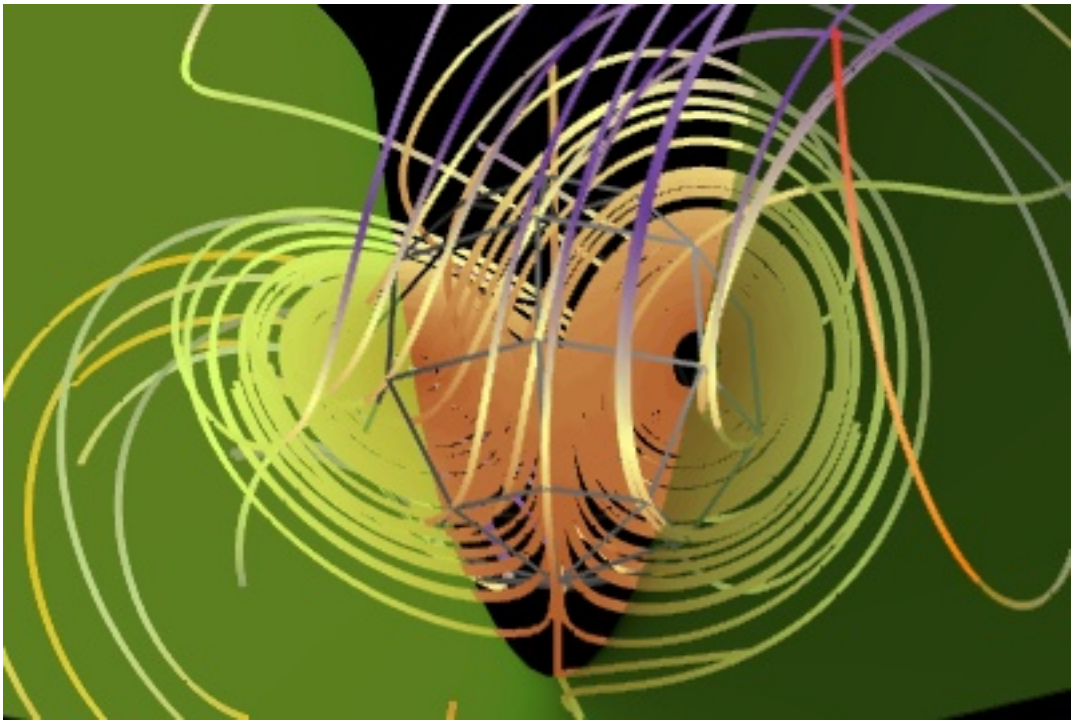
```
from scipy.special import sph_harm

# Create a sphere
r = 0.3
pi = np.pi
cos = np.cos
sin = np.sin
phi, theta = np.mgrid[0:pi:101j, 0:2*pi:101j]

x = r*sin(phi)*cos(theta)
y = r*sin(phi)*sin(theta)
z = r*cos(phi)

mlab.figure(1, bgcolor=(1, 1, 1), fgcolor=(0, 0, 0), size=(400, 300))
mlab.clf()
# Represent spherical harmonics on the surface of the sphere
for n in range(1, 6):
    for m in range(n):
        s = sph_harm(m, n, theta, phi).real

        mlab.mesh(x-m, y-n, z, scalars=s, colormap='jet')

        s[s<0] *= 0.97

        s /= s.max()
        mlab.mesh(s*x-m, s*y-n, s*z+1.3, scalars=s, colormap='Spectral')

mlab.view(90, 70, 6.2, (-1.3, -2.9, 0.25))
mlab.show()
```

10.2.6 Lorenz example

An example displaying the trajectories for the Lorenz system of equations along with the z-nullcline.

The vector field of the Lorenz system flow is integrated to display trajectories using mlab's flow function: `enthought.mayavi.mlab.flow()`.

The z-nullcline is plotted by extracting the z component of the vector field data source with the ExtractVectorComponent filter, and applying an IsoSurface module on this scalar component.



Source code: lorenz.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2008-2009, Enthought, Inc.
# License: BSD Style.

import numpy
from enthought.mayavi import mlab

def lorenz(x, y, z, s=10.,r=28., b=8./3.):
    """The Lorenz system."""
    u = s*(y-x)
    v = r*x -y - x*z
    w = x*y - b*z
    return u, v, w

# Sample the space in an interesting region.
x, y, z = numpy.mgrid[-50:50:100j,-50:50:100j,-10:60:70j]
u, v, w = lorenz(x, y, z)
fig = mlab.figure(size=(400, 300), bgcolor=(0, 0, 0))

# Plot the flow of trajectories with suitable parameters.
f = mlab.flow(x, y, z, u, v, w, line_width=3, colormap='Paired')
f.module_manager.scalar_lut_manager.reverse_lut = True
f.stream_tracer.integration_direction = 'both'
f.stream_tracer.maximum_propagation = 200
# Uncomment the following line if you want to hide the seed:
#f.seed.widget.enabled = False

# Extract the z-velocity from the vectors and plot the 0 level set
# hence producing the z-nullcline.
src = f.mlab_source.m_data
e = mlab.pipeline.extract_vector_components(src)
```

```
e.component = 'z-component'
zc = mlab.pipeline.iso_surface(e, opacity=0.5, contours=[0,],
            color=(0.6, 1, 0.2))
# When using transparency, hiding 'backface' triangles often gives better
# results
zc.actor.property.backface_culling = True

# A nice view of the plot.
mlab.view(140, 120, 113, [0.65, 1.5, 27])
mlab.show()
```

10.2.7 Tvtk in mayavi example

An example of pure TVTK programming to build TVTK objects, which are then added to a Mayavi scene.

This example show how pure TVTK objects can be added to a Mayavi scene.

This programming style does not allow to benefit from the data-management facilities of Mayavi (the pipeline, the data-oriented mlab functions), but it allows to easily reuse VTK code together with Mayavi or mlab code.

If you want to use arbitrary VTK filters with Mayavi, it is best to use the UserDefined Mayavi filter, which enables the user to insert any VTK filter in the Mayavi pipeline. See, for instance, the *Mri example* for example of the UserDefined filter. For a full-blown example of a complex VTK pipeline built with Mayavi, see *Tvtk segmentation example*.

Source code: tvtk_in_mayavi.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.

from enthought.mayavi import mlab

# To access any VTK object, we use 'tvtk', which is a Python wrapping of
# VTK replacing C++ setters and getters by Python properties and
# converting numpy arrays to VTK arrays when setting data.
from enthought.tvtk.api import tvtk

v = mlab.figure()

# Create a first sphere
# The source generates data points
sphere = tvtk.SphereSource(center=(0, 0, 0), radius=0.5)
# The mapper converts them into position in, 3D with optionally color (if
# scalar information is available).
sphere_mapper = tvtk.PolyDataMapper(input=sphere.output)
# The Property will give the parameters of the material.
p = tvtk.Property(opacity=0.2, color=(1, 0, 0))
# The actor is the actually object in the scene.
sphere_actor = tvtk.Actor(mapper=sphere_mapper, property=p)
v.scene.add_actor(sphere_actor)

# Create a second sphere
sphere2 = tvtk.SphereSource(center=(7, 0, 1), radius=0.2)
sphere_mapper2 = tvtk.PolyDataMapper(input=sphere2.output)
p = tvtk.Property(opacity=0.3, color=(1, 0, 0))
sphere_actor2 = tvtk.Actor(mapper=sphere_mapper2, property=p)
v.scene.add_actor(sphere_actor2)

# Create a line between the two spheres
line = tvtk.LineSource(point1=(0, 0, 0), point2=(7, 0, 1))
line_mapper = tvtk.PolyDataMapper(input=line.output)
line_actor = tvtk.Actor(mapper=line_mapper)
v.scene.add_actor(line_actor)

# And display text
vtext = tvtk.VectorText()
vtext.text = 'Mayavi'
text_mapper = tvtk.PolyDataMapper(input=vtext.get_output())
p2 = tvtk.Property(color=(0, 0.3, 0.3))
text_actor = tvtk.Follower(mapper=text_mapper, property=p2)
text_actor.position = (0, 0, 0)
v.scene.add_actor(text_actor)

# Choose a view angle, and display the figure
mlab.view(85, -17, 15, [ 3.5, -0.3, -0.8])
mlab.show()
```

10.2.8 Julia set decimation example

The Julia set, but with a decimated mesh: unecessary triangles due to the initial grid and not matching the geometry of the Julia set are removed.

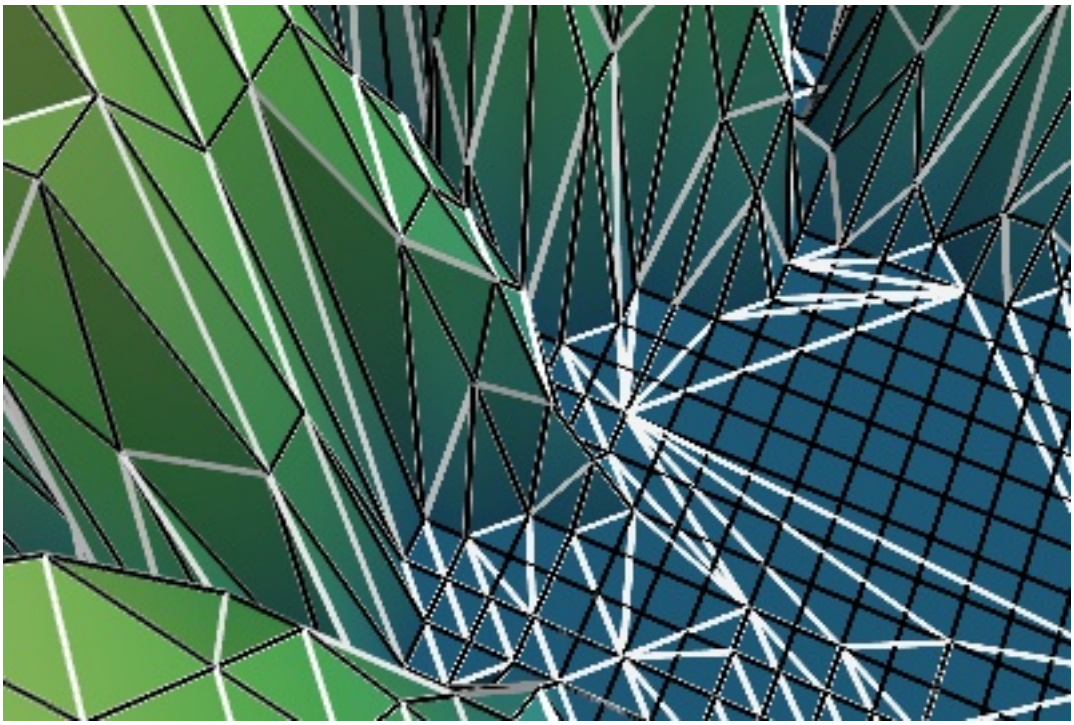
We first build the mesh, applying a warp_scalar filter to a array2d_source, to warp the Julia set along the z direction.

Then when have to convert the rectangles in the mesh to triangles, in order to apply the decimate_pro filter. This filter does the decimation, and we can represent the result using surface modules.

The triangle-generation filter generates warnings: some polygons are degenerate, as the grid has subdivided flat parts of the Julia set.

We have shown in white the decimated mesh, and in black the non-decimated one. The view is zoom to the center of the Julia set. If you turn of the wireframes and zoom out, you can appreciate the quality of the decimation.

In the specific case of decimating a surface warped from 2D data, it is more efficient to use the greedy-terrain-decimator, see the *Canyon decimation example*.



Source code: julia_set_decimation.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.


from enthought.mayavi import mlab
import numpy as np

# Calculate the Julia set on a grid
x, y = np.ogrid[-1.5:0.5:500j, -1:1:500j]
z = x + 1j*y

julia = np.zeros(z.shape)

for i in range(50):
    z = z**2 -0.70176 -0.3842j
    julia += 1/float(2+i)*(z*np.conj(z) > 4)


mlab.figure(size=(400, 300))
```

```
# Create the mesh
mesh = mlab.pipeline.warp_scalar(mlab.pipeline.array2d_source(julia),
                                 warp_scale=100)

# The decimate_pro filter works only on triangles. We need to apply the
# triangle_filter before applying decimate_pro.
dec = mlab.pipeline.decimate_pro(mlab.pipeline.triangle_filter(mesh))
# Set a very low feature_angle, so that the decimate_pro detects
dec.filter.feature_angle = 1
dec.filter.target_reduction = 0.5

# We display the lines of decimated mesh in white
mlab.pipeline.surface(dec, representation='wireframe', line_width=3,
                           color=(1, 1, 1))
# The decimated mesh itself.
mlab.pipeline.surface(dec, colormap='gist_earth', vmin=-0.1, vmax=0.4)

# The lines of the non-decimated mesh, in black, for comparisation.
mlab.pipeline.surface(mesh, representation='wireframe',  color=(0, 0, 0))

mlab.view(-66, 25, 9.7, [-5.8, -54.5,  18.4])

mlab.show()
```

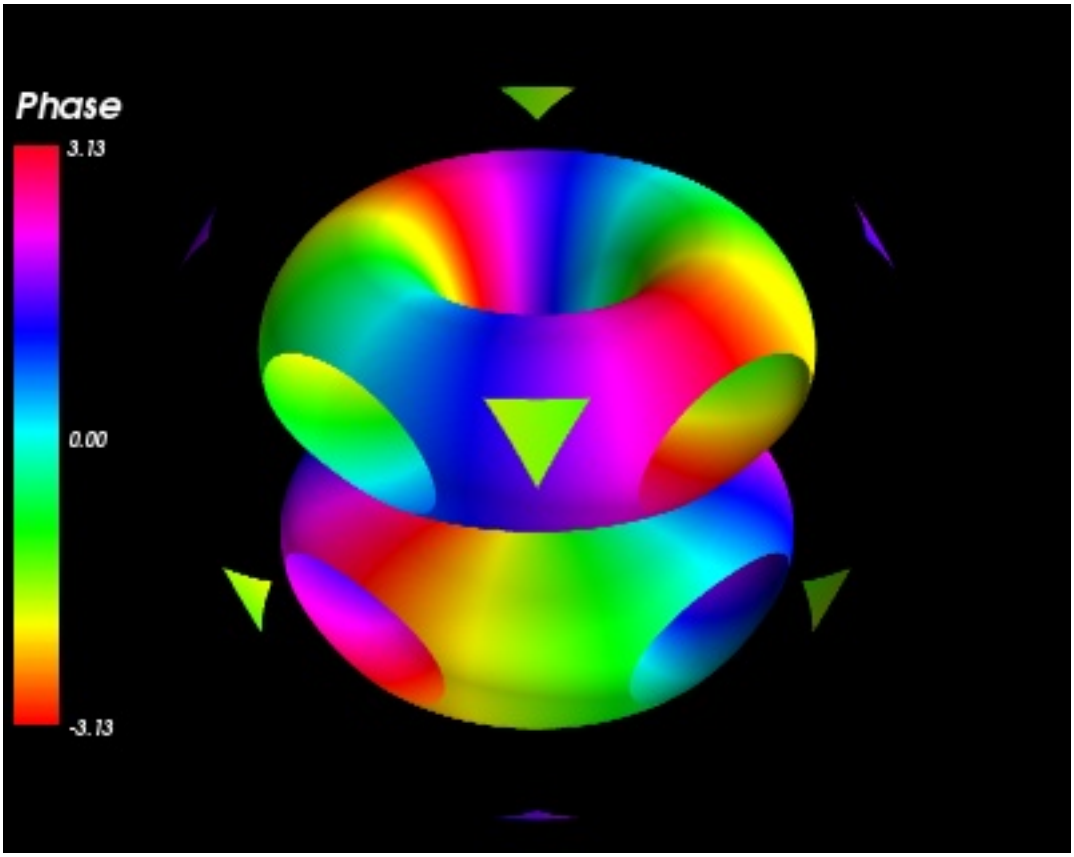
10.2.9 Atomic orbital example

An example showing the norm and phase of an atomic orbital: isosurfaces of the norm, with colors displaying the phase.

This example shows how you can apply a filter on one data set, and dislay a second data set on the output of the filter. Here we use the contour filter to extract isosurfaces of the norm of a complex field, and we display the phase of the field with the colormap.

The first step is to create a data source with two scalar datasets. The second step is to apply filters and modules, using the 'set_active_attribute' filter to select on which data these apply.

The field we choose to plot is a simplified version of the 3P_y atomic orbital for hydrogen-like atoms.



Source code: atomic_orbital.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.

# Create the data ############################################################
import numpy as np

x, y, z = np.ogrid[-.5:.5:200j, -.5:.5:200j, -.5:.5:200j]
r = np.sqrt(x**2 + y**2 + z**2)


# Generalized Laguerre polynomial (3, 2)
L = -r**3/6 + 5./2*r**2 - 10*r + 6

# Spherical harmonic (3, 2)
Y = (x+y*1j)**2*z/r**3

Phi = L*Y*np.exp(-r)*r**2

# Plot it ####################################################################
from enthought.mayavi import mlab
mlab.figure(1, fgcolor=(1, 1, 1), bgcolor=(0, 0, 0))
# We create a scalar field with the module of Phi as the scalar
src = mlab.pipeline.scalar_field(np.abs(Phi))

# And we add the phase of Phi as an additional array
```

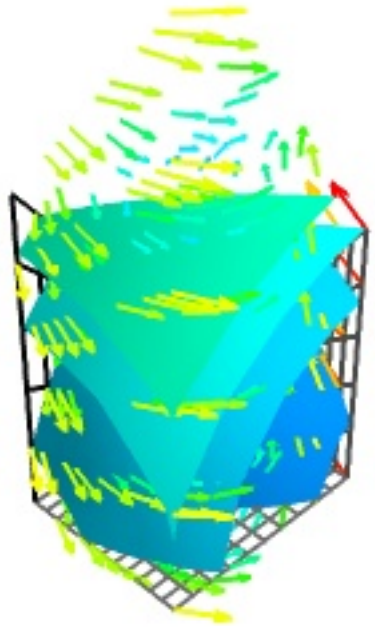
```
# This is a tricky part: the layout of the new array needs to be the same
# as the existing dataset, and no checks are performed. The shape needs
# to be the same, and so should the data. Failure to do so can result in
# segfaults.
src.image_data.point_data.add_array(np.angle(Phi).T.ravel())
# We need to give a name to our new dataset.
src.image_data.point_data.get_array(1).name = 'angle'
# Make sure that the dataset is up to date with the different arrays:
src.image_data.point_data.update()

# We select the 'scalar' attribute, ie the norm of Phi
src2 = mlab.pipeline.set_active_attribute(src,
                                    point_scalars='scalar')

# Cut isosurfaces of the norm
contour = mlab.pipeline.contour(src2)

# Now we select the 'angle' attribute, ie the phase of Phi
contour2 = mlab.pipeline.set_active_attribute(contour,
                                    point_scalars='angle')

# And we display the surface. The colormap is the current attribute: the phase.
mlab.pipeline.surface(contour2, colormap='hsv')

mlab.colorbar(title='Phase', orientation='vertical', nb_labels=3)

mlab.show()
```

10.2.10 Simple structured grid example

An example creating a structured grid data set from numpy arrays using TVTK and visualizing it using mlab.

In this example, we create a structured-grid data set: we describe data, both scalar and vector, lying on a structured-grid, ie a grid where each vertex has 6 neighboors. For this we directly create a StructuredGrid tvtk object, rather than using the mlab.pipeline source functions, as it gives us more control.

To visualize the resulting dataset, we apply several modules, using the mlab.pipeline interface (see *Assembling pipelines with mlab*)



Source code: simple_structured_grid.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2008, Prabhu Ramachandran.
# License: BSD Style.

from numpy import mgrid, empty, sin, pi
from enthought.tvtk.api import tvtk
from enthought.mayavi import mlab

# Generate some points.
x, y, z = mgrid[1:6:11j,0:4:13j,0:3:6j]
base = x[...,0] + y[...,0]
# Some interesting z values.
for i in range(z.shape[2]):
    z[...,i] = base*0.25*i

# The actual points.
pts = empty(z.shape + (3,), dtype=float)
pts[...,0] = x
pts[...,1] = y
pts[...,2] = z

# Simple scalars.
scalars = x*x + y*y + z*z
# Some vectors
vectors = empty(z.shape + (3,), dtype=float)
vectors[...,0] = (4 - y*2)
```

```
vectors[...,1] = (x*3 - 12)
vectors[...,2] = sin(z*pi)

# We reorder the points, scalars and vectors so this is as per VTK's
# requirement of x first, y next and z last.
pts = pts.transpose(2, 1, 0, 3).copy()
pts.shape = pts.size/3, 3
scalars = scalars.T.copy()
vectors = vectors.transpose(2, 1, 0, 3).copy()
vectors.shape = vectors.size/3, 3

# Create the dataset.
sg = tvtk.StructuredGrid(dimensions=x.shape, points=pts)
sg.point_data.scalars = scalars.ravel()
sg.point_data.scalars.name = 'temperature'
sg.point_data.vectors = vectors
sg.point_data.vectors.name = 'velocity'

# Thats it!

# Now visualize the data.
d = mlab.pipeline.add_dataset(sg)
gx = mlab.pipeline.grid_plane(d)
gy = mlab.pipeline.grid_plane(d)
gy.grid_plane.axis = 'y'
gz = mlab.pipeline.grid_plane(d)
gz.grid_plane.axis = 'z'
iso = mlab.pipeline.iso_surface(d)
iso.contour.maximum_contour = 75.0
vec = mlab.pipeline.vectors(d)
vec.glyph.mask_input_points = True
vec.glyph.glyph.scale_factor = 1.5

mlab.show()
```

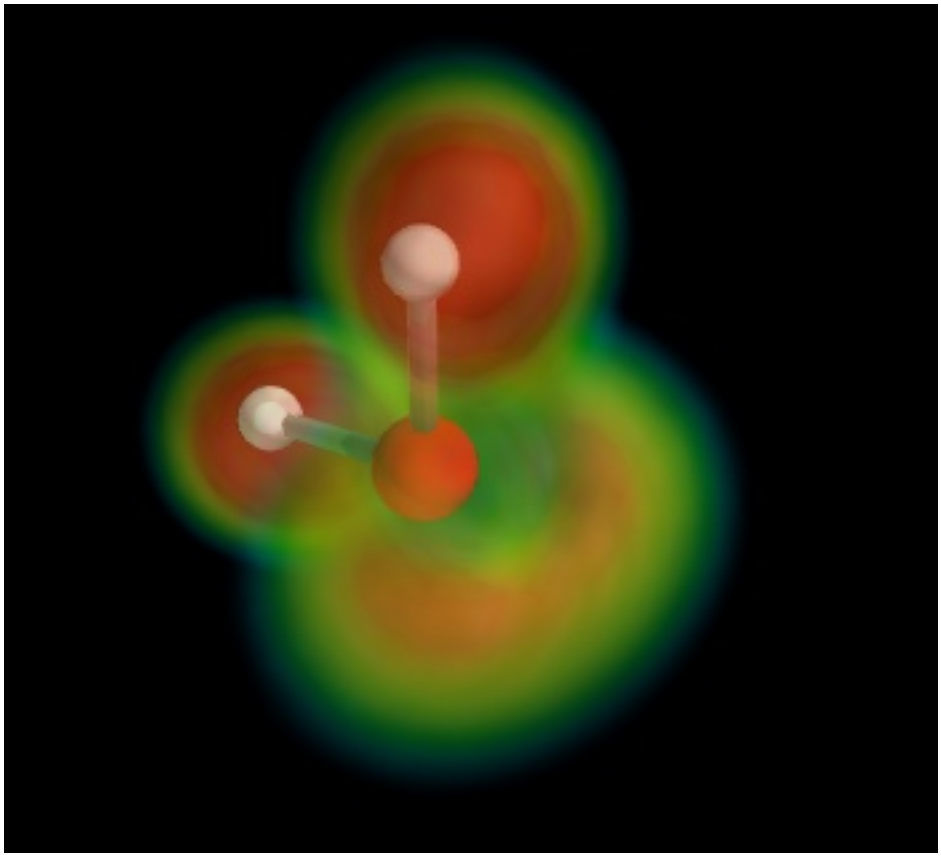
10.2.11 Chemistry example

In this example, we display the H2O molecule, and use volume rendering to display the electron localization function.

The atoms and the bounds are displayed using mlab.points3d and mlab.plot3d, with scalar information to control the color.

The electron localization function is displayed using volume rendering. Good use of the *vmin* and *vmax* argument to *mlab.pipeline.volume* is critical to achieve a good visualization: the *vmin* threshold should placed high-enough for features to stand out.

The original is an electron localization function from Axel Kohlmeyer.



Source code: chemistry.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.

# Retrieve the electron localization data for H2O ##############################
import os
if not os.path.exists('h2o-elf.cube'):
    # Download the data
    import urllib
    print 'Downloading data, please wait'
    opener = urllib.urlopen(
        'http://code.enthought.com/projects/mayavi/data/h2o-elf.cube'
        )
    open('h2o-elf.cube', 'w').write(opener.read())


# Plot the atoms and the bonds #################################################
import numpy as np
from enthought.mayavi import mlab
mlab.figure(1, bgcolor=(0, 0, 0), size=(350, 350))
mlab.clf()

# The position of the atoms
atoms_x = np.array([2.9, 2.9, 3.8])*40/5.5
atoms_y = np.array([3.0, 3.0, 3.0])*40/5.5
atoms_z = np.array([3.8, 2.9, 2.7])*40/5.5
```

```
O = mlab.points3d(atoms_x[1:-1], atoms_y[1:-1], atoms_z[1:-1],
                  scale_factor=3,
                  resolution=20,
                  color=(1, 0, 0),
                  scale_mode='none')

H1 = mlab.points3d(atoms_x[:1], atoms_y[:1], atoms_z[:1],
                   scale_factor=2,
                   resolution=20,
                   color=(1, 1, 1),
                   scale_mode='none')

H2 = mlab.points3d(atoms_x[-1:], atoms_y[-1:], atoms_z[-1:],
                   scale_factor=2,
                   resolution=20,
                   color=(1, 1, 1),
                   scale_mode='none')

# The bounds between the atoms, we use the scalar information to give
# color
mlab.plot3d(atoms_x, atoms_y, atoms_z, [1, 2, 1],
            tube_radius=0.4, colormap='Reds')

# Display the electron localization function ##################################

# Load the data, we need to remove the first 8 lines and the '\n'
str = ' '.join(file('h2o-elf.cube').readlines()[9:])
data = np.fromstring(str, sep=' ')
data.shape = (40, 40, 40)

source = mlab.pipeline.scalar_field(data)
min = data.min()
max = data.max()
vol = mlab.pipeline.volume(source, vmin=min+0.65*(max-min),
                                   vmax=min+0.9*(max-min))

mlab.view(132, 54, 45, [21, 20, 21.5])

mlab.show()
```

10.2.12 Wigner example

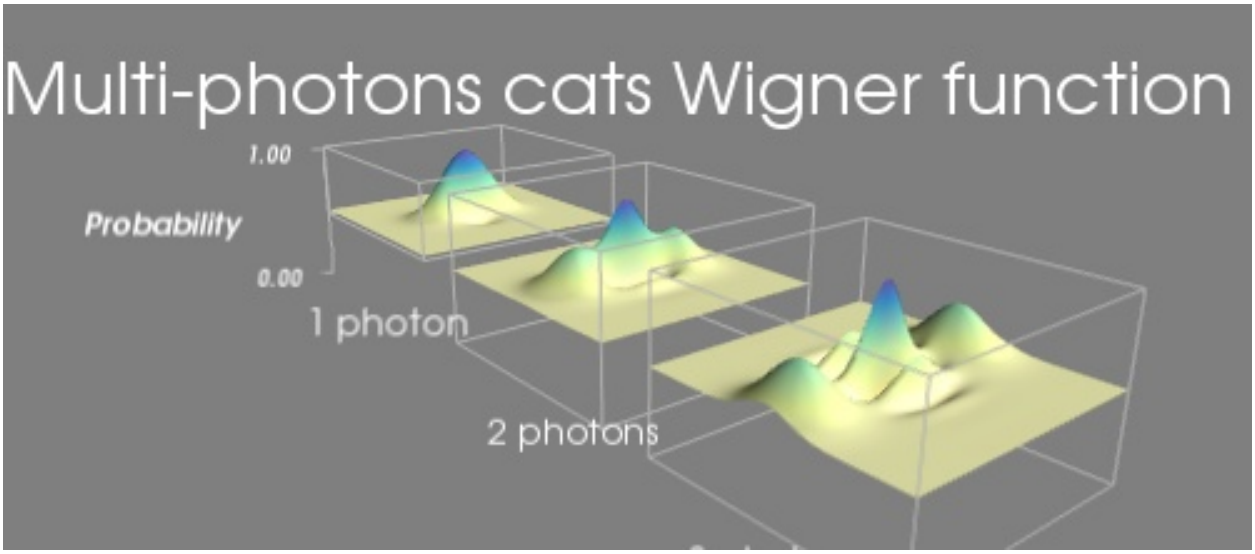
An example in which 3 functions of x and y are displayed with a surf plot, while the z scaling is kept constant, to allow comparison between them.

The important aspect of this example is that the 3 functions should not be displayed on top of each other, but side by side. For this we use the extent keyword argument.

In addition, the relative scale between the different plots is important. This is why we also use the *warp_scale* keyword argument, to have the same scale on all plots.

Finally, we have to adjust the data bounds: as we want the "horizon" of the wigner function in the middle of our extents, we put this to zero.

We add a set of axes and outlines to the plot. We have to play we extents and ranges in order to make them fit with the data.



Source code: wigner.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD Style.


import numpy
from enthought.mayavi import mlab

def cat(x, y, alpha, eta=1, purity=1):
    """ Multiphoton shrodinger cat. eta is the fidelity, alpha the number
        of photons"""
    cos = numpy.cos
    exp = numpy.exp
    return (1 + eta*(exp(-x**2 -(y-alpha)**2)  + exp(-x**2 -
    (y+alpha)**2) + 2 * purity * exp(-x**2 - y**2) * cos(2* alpha * x))/(2
    * (1 + exp(- alpha**2))))/2

x, y = numpy.mgrid[-4:4.15:0.1, -4:4.15:0.1]

mlab.figure(1, size=(500, 250), fgcolor=(1, 1, 1),
                                    bgcolor=(0.5, 0.5, 0.5))
mlab.clf()

cat1 = cat(x, y, 1)
cat2 = cat(x, y, 2)
cat3 = cat(x, y, 3)

# The cats lie in a [0, 1] interval, with .5 being the assymptotique
# value. We want to reposition this value to 0, so as to put it in the
# center of our extents.
cat1 -= 0.5
cat2 -= 0.5
cat3 -= 0.5

cat1_extent = (-14,-6, -4,4, 0,5)
surf_cat1 = mlab.surf(x-10, y, cat1, colormap='Spectral', warp_scale=5,
            extent=cat1_extent, vmin=-0.5, vmax=0.5)
```

```
mlab.outline(surf_cat1, color=(.7, .7, .7))
mlab.axes(surf_cat1, color=(.7, .7, .7), extent=cat1_extent,
            ranges=(0,1, 0,1, 0,1), xlabel='', ylabel='',
            zlabel='Probability',
            x_axis_visibility=False, z_axis_visibility=False)

mlab.text(-18, -4, '1 photon', z=-4, width=0.13)

cat2_extent = (-4,4, -4,4, 0,5)
surf_cat2 = mlab.surf(x, y, cat2, colormap='Spectral', warp_scale=5,
            extent=cat2_extent, vmin=-0.5, vmax=0.5)
mlab.outline(surf_cat2, color=(0.7, .7, .7), extent=cat2_extent)

mlab.text(-4, -3, '2 photons', z=-4, width=0.14)

cat3_extent = (6,14, -4,4, 0,5)
surf_cat3 = mlab.surf(x+10, y, cat3, colormap='Spectral', warp_scale=5,
            extent=cat3_extent, vmin=-0.5, vmax=0.5)
mlab.outline(surf_cat3, color=(.7, .7, .7), extent=cat3_extent)

mlab.text(6, -2.5, '3 photons', z=-4, width=0.14)

mlab.title('Multi-photons cats Wigner function')

mlab.view(142, -72, 32)

mlab.show()
```

10.2.13 Canyon decimation example

Use the greedy-terrain-decimator to display a decimated terrain view.

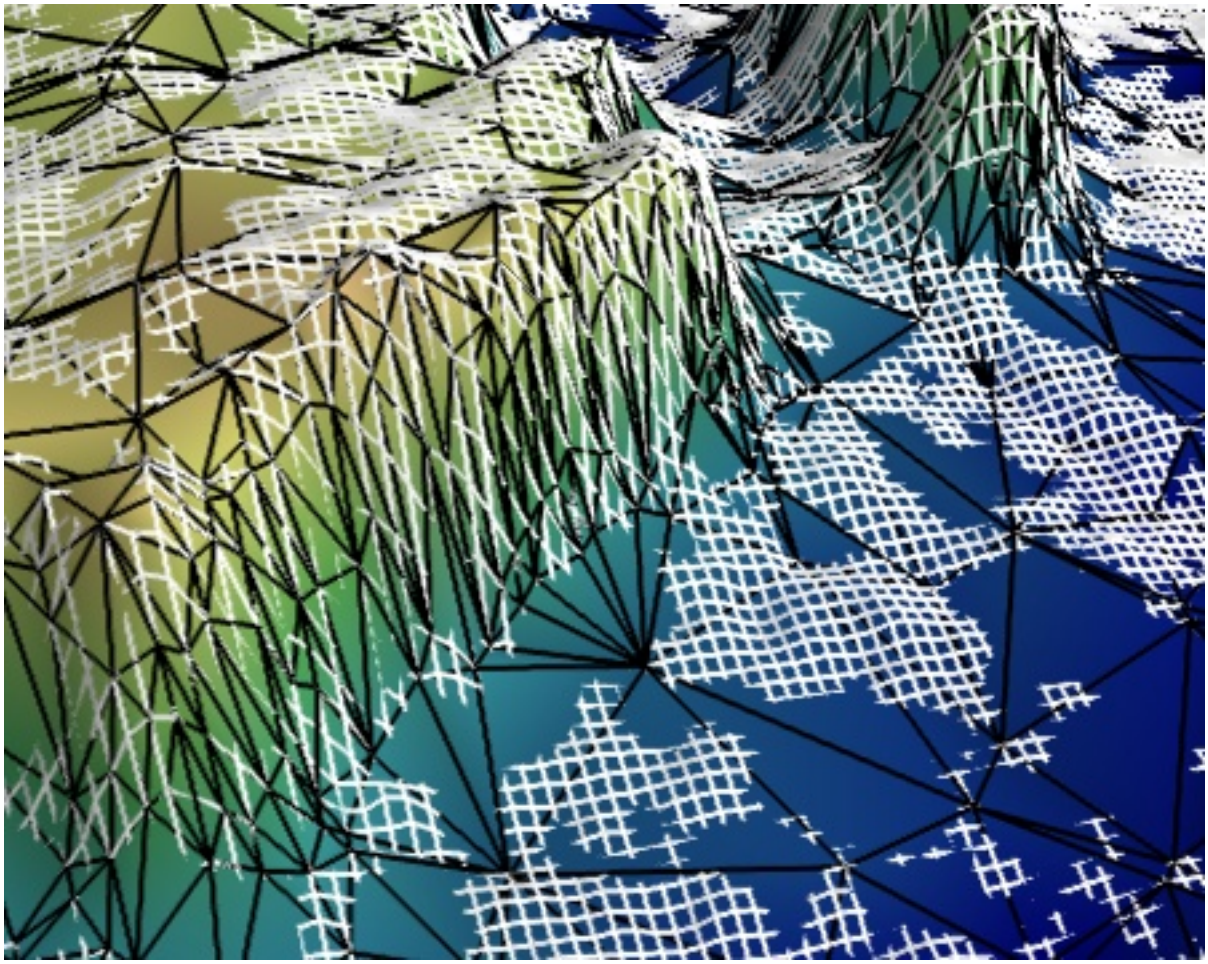
This example illustrates decimating a terrain. We use the greedy-terrain-decimator to create a reduced mesh with an optimized grid that approximates the initial regular grid.

The initial grid is displayed in white, and the optimized grid is displayed in black, with the surface it creates. The initial grid can be seen disappearing as it goes under the surface of the approximated grid: although the decimated mesh follows closely the orginal, it is not exactly the same.

One can see that the reduction in number of polygons is huge: the white grid is much finer than the black grid. It is interesting to note that the decimated mesh follows closely the original mesh, including in number of polygons, in spots where the terrain changes most quickly.

This example uses the Grand Canyon topological radar data, from NASA.

The greedy-terrain-decimator is only useful to decimate a surface warped from 2D data. To decimated more general meshes, you can use the less-efficient decimate-pro filter (see *Julia set decimation example*).



Source code: canyon_decimation.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.

# Retrieve the grand Canyon topological data ##################################
import os
if not os.path.exists('N36W113.hgt.zip'):
    # Download the data
    import urllib
    print 'Downloading data, please wait (10M)'
    opener = urllib.urlopen(
    'ftp://e0srp01u.ecs.nasa.gov/srtm/version2/SRTM1/Region_04/N36W113.hgt.zip'
        )
    open('N36W113.hgt.zip', 'w').write(opener.read())

# Load the data (signed 2 byte integers, big endian) ##########################
import zipfile
import numpy as np

data = np.fromstring(zipfile.ZipFile('N36W113.hgt.zip').read('N36W113.hgt'),
                     '>i2')
data.shape = (3601, 3601)
data = data[200:400, 1200:1400]
```

```
data = data.astype(np.float32)

# Plot an interecting section ########################################################
from enthought.mayavi import mlab
mlab.figure(1, size=(450, 390))
mlab.clf()
data = mlab.pipeline.array2d_source(data)

# Use a greedy_terrain_decimation to created a decimated mesh
terrain = mlab.pipeline.greedy_terrain_decimation(data)
terrain.filter.error_measure = 'number_of_triangles'
terrain.filter.number_of_triangles = 5000
terrain.filter.compute_normals = True

# Plot it black the lines of the mesh
lines = mlab.pipeline.surface(terrain, color=(0, 0, 0),
                                        representation='wireframe')
# The terrain decimator has done the warping. We control the warping
# scale via the actor's scale.
lines.actor.actor.scale = [1, 1, 0.2]

# Display the surface itself.
surf = mlab.pipeline.surface(terrain, colormap='gist_earth',
                                        vmin=1450, vmax=1650)
surf.actor.actor.scale = [1, 1, 0.2]

# Display the original regular grid. This time we have to use a
# warp_scalar filter.
warp = mlab.pipeline.warp_scalar(data, warp_scale=0.2)
grid = mlab.pipeline.surface(warp, color=(1, 1, 1),
                                        representation='wireframe')

mlab.view(-17, 46, 143, [1.46, 8.46, 269.4])

mlab.show()
```

10.2.14 Magnetic field lines example

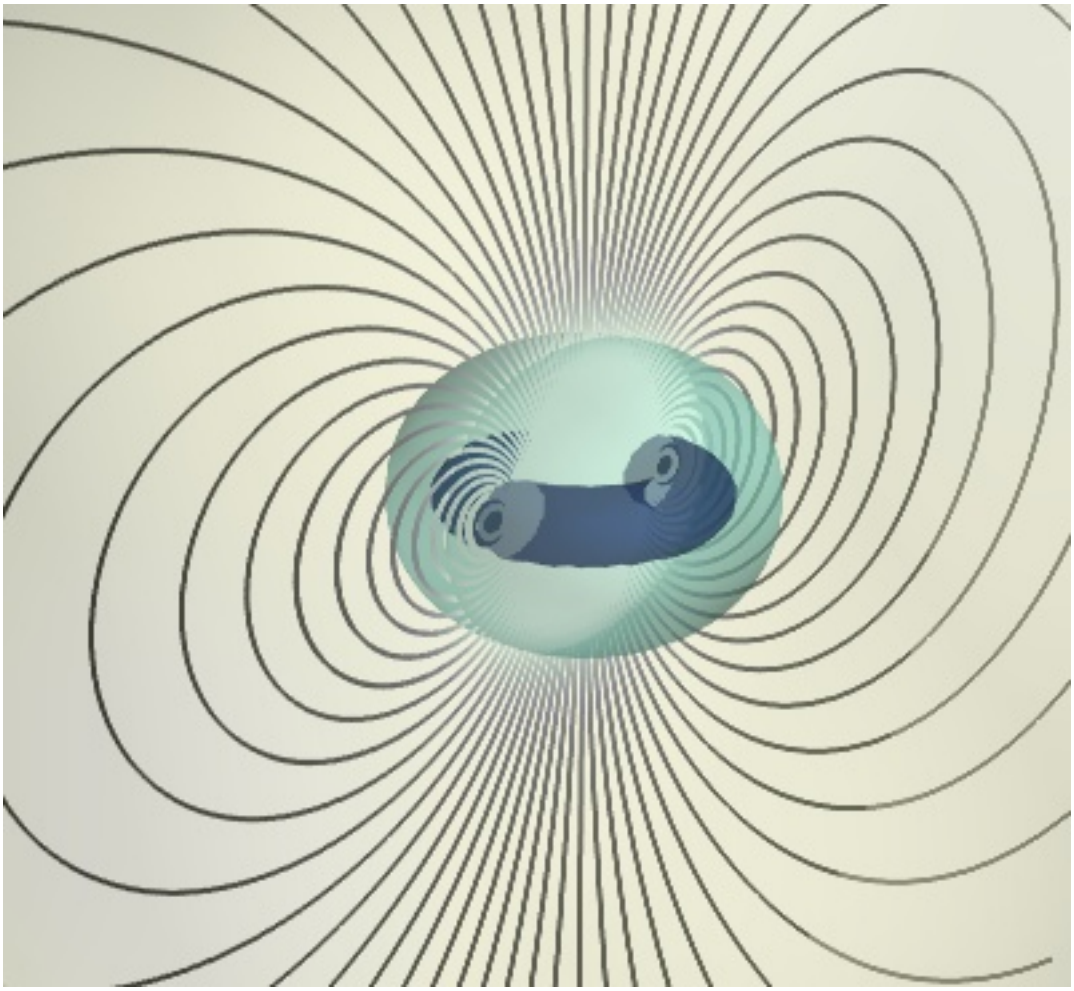
This example uses the streamline module to display field lines of a magnetic dipole (a current loop).

This example requires scipy.

The magnetic field from an arbitrary current loop is calculated from eqns (1) and (2) in Phys Rev A Vol. 35, N 4, pp. 1535-1546; 1987.

To get a prettier result, we use a fairly large grid to sample the field. As a consequence, we need to clear temporary arrays as soon as possible.

For a more thorough example of magnetic field calculation and visualization with Mayavi and scipy, see *Magnetic field example*.



Source code: magnetic_field_lines.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD Style.

import numpy as np
from scipy import special

#### Calculate the field ######################################################
radius = 1 # Radius of the coils

x, y, z = [e.astype(np.float32) for e in
            np.ogrid[-10:10:150j, -10:10:150j, -10:10:150j] ]

# express the coordinates in polar form
rho = np.sqrt(x**2 + y**2)
x_proj = x/rho
y_proj = y/rho
# Free memory early
del x, y

E = special.ellipe((4 * radius * rho)/( (radius + rho)**2 + z**2))
K = special.ellipk((4 * radius * rho)/( (radius + rho)**2 + z**2))
```

```
Bz =  1/np.sqrt((radius + rho)**2 + z**2) * (
                K
                + E * (radius**2 - rho**2 - z**2)/((radius - rho)**2 + z**2)
            )
Brho = z/(rho*np.sqrt((radius + rho)**2 + z**2)) * (
                -K
                + E * (radius**2 + rho**2 + z**2)/((radius - rho)**2 + z**2)
            )
del E, K, z, rho
# On the axis of the coil we get a divided by zero. This returns a
# NaN, where the field is actually zero :
Brho[np.isnan(Brho)] = 0

Bx, By = x_proj*Brho, y_proj*Brho

del x_proj, y_proj, Brho

#### Visualize the field ################################################
from enthought.mayavi import mlab
fig = mlab.figure(1, size=(400, 400), bgcolor=(1, 1, 1), fgcolor=(0, 0, 0))

field = mlab.pipeline.vector_field(Bx, By, Bz)
# Unfortunately, the above call makes a copy of the arrays, so we delete
# this copy to free memory.
del Bx, By, Bz

magnitude = mlab.pipeline.extract_vector_norm(field)
contours = mlab.pipeline.iso_surface(magnitude,
                                     contours=[0.01, 0.8, 3.8, ],
                                     transparent=True,
                                     opacity=0.4,
                                     colormap='YlGnBu',
                                     vmin=0, vmax=2)


field_lines = mlab.pipeline.streamline(magnitude, seedtype='line',
                                     integration_direction='both',
                                     colormap='bone',
                                     vmin=0, vmax=1)

# Tweak a bit the streamline.
field_lines.stream_tracer.maximum_propagation = 100.
field_lines.seed.widget.point1 = [69, 75.5, 75.5]
field_lines.seed.widget.point2 = [82, 75.5, 75.5]
field_lines.seed.widget.resolution = 50
field_lines.seed.widget.enabled = False

mlab.view(42, 73, 104, [ 79,  75,  76])

mlab.show()
```

10.2.15 Mri example

Viewing MRI data with cut plane and iso surface.

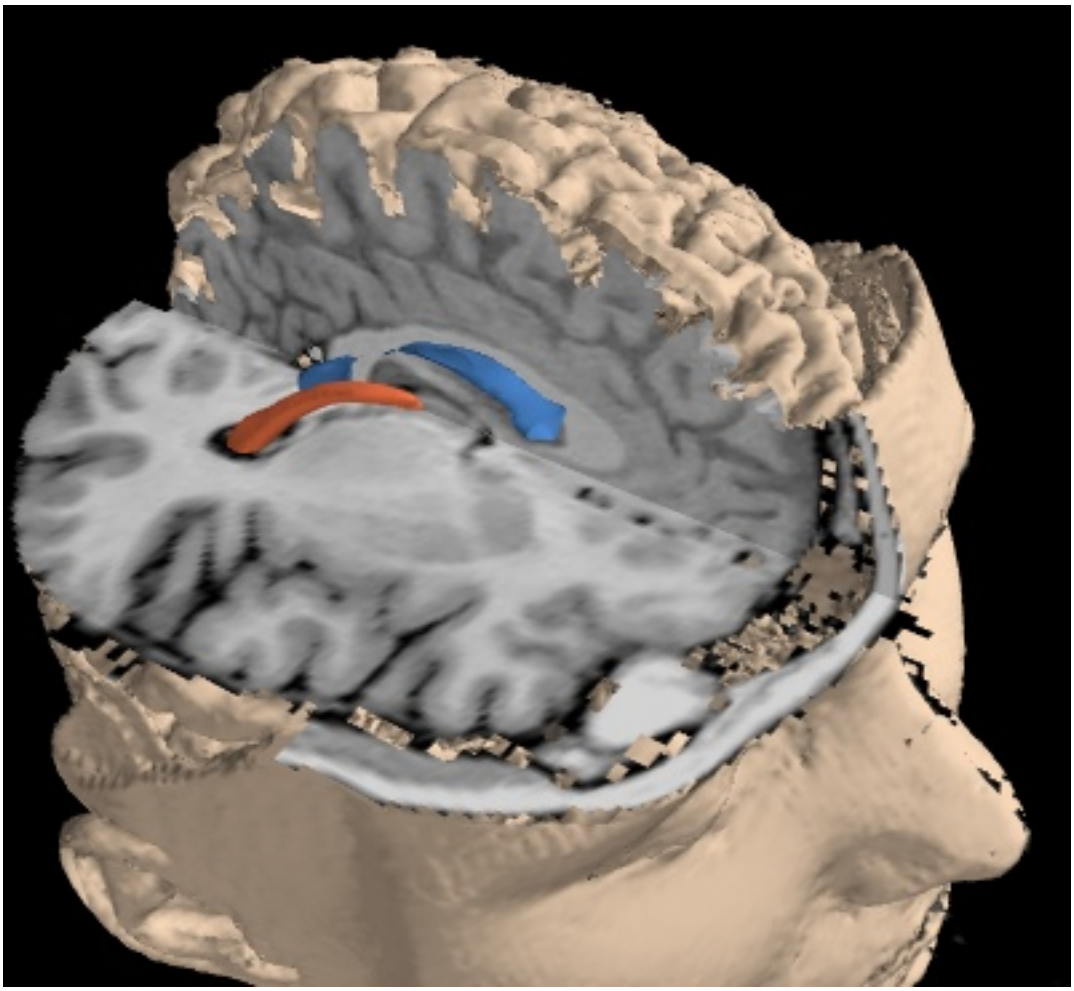
This example downloads an MRI scan, turns it into a 3D numpy array and visualizes it.

First we extract some internal structures of the brain by defining a volume of interest around them, and using iso surfaces.

Then we display two cut planes to show the raw MRI data itself.

Finally we display the outer surface, but we restrict it to volume of interest to leave a cut for the cut planes.

For an example of feature extraction from MRI data using Mayavi and vtk, see *Tvtk segmentation example*.



Source code: mri.py

```
### Download the data, if not already on disk ##################################
import os
if not os.path.exists('mri_data.tar.gz'):
    # Download the data
    import urllib
    print "Downloading data, Please Wait (7.8MB)"
    opener = urllib.urlopen(
                'http://www-graphics.stanford.edu/data/voldata/MRbrain.tar.gz')
    open('mri_data.tar.gz', 'wb').write(opener.read())

# Extract the data
import tarfile
tar_file = tarfile.open('mri_data.tar.gz')
try:
```

```
    os.mkdir('mri_data')
except:
    pass
tar_file.extractall('mri_data')
tar_file.close()


### Read the data in a numpy 3D array ############################################
import numpy as np
data = np.array([np.fromfile(os.path.join('mri_data', 'MRbrain.%i' % i),
                                        dtype='>u2') for i in range(1, 110)])
data.shape = (109, 256, 256)
data = data.T

# Display the data #############################################################
from enthought.mayavi import mlab

mlab.figure(bgcolor=(0, 0, 0), size=(400, 400))

src = mlab.pipeline.scalar_field(data)
# Our data is not equally spaced in all directions:
src.spacing = [1, 1, 1.5]
src.update_image_data = True


# Extract some inner structures: the ventricles and the inter-hemisphere
# fibers. We define a volume of interest (VOI) that restricts the
# iso-surfaces to the inner of the brain. We do this with the ExtractGrid
# filter.
blur = mlab.pipeline.user_defined(src, filter='ImageGaussianSmooth')
voi = mlab.pipeline.extract_grid(blur)
voi.set(x_min=125, x_max=193, y_min=92, y_max=125, z_min=34, z_max=75)

mlab.pipeline.iso_surface(voi, contours=[1610, 2480], colormap='Spectral')

# Add two cut planes to show the raw MRI data. We use a threshold filter
# to remove cut the planes outside the brain.
thr = mlab.pipeline.threshold(src, low=1120)
cut_plane = mlab.pipeline.scalar_cut_plane(thr,
                                plane_orientation='y_axes',
                                colormap='black-white',
                                vmin=1400,
                                vmax=2600)
cut_plane.implicit_plane.origin = (136, 111.5, 82)
cut_plane.implicit_plane.widget.enabled = False

cut_plane2 = mlab.pipeline.scalar_cut_plane(thr,
                                plane_orientation='z_axes',
                                colormap='black-white',
                                vmin=1400,
                                vmax=2600)
cut_plane2.implicit_plane.origin = (136, 111.5, 82)
cut_plane2.implicit_plane.widget.enabled = False

# Extract two views of the outside surface. We need to define VOIs in
# order to leave out a cut in the head.
voi2 = mlab.pipeline.extract_grid(src)
voi2.set(y_min=112)
```

```
outer = mlab.pipeline.iso_surface(voi2, contours=[1776, ],
                                   color=(0.8, 0.7, 0.6))

voi3 = mlab.pipeline.extract_grid(src)
voi3.set(y_max=112, z_max=53)
outer3 = mlab.pipeline.iso_surface(voi3, contours=[1776, ],
                                    color=(0.8, 0.7, 0.6))


mlab.view(-125, 54, 326, (145.5, 138, 66.5))
mlab.roll(-175)

mlab.show()

import shutil
shutil.rmtree('mri_data')
```

10.2.16 Protein example

Visualize a protein graph structure downloaded from the protein database in standard pdb format.

We parse the pdb file, but extract only a very small amount of information: the type of atoms, their positions, and the links between them.

Most of the complexity of this example comes from the code turning the PDB information into a list of 3D positions, with associated scalar and connection information.

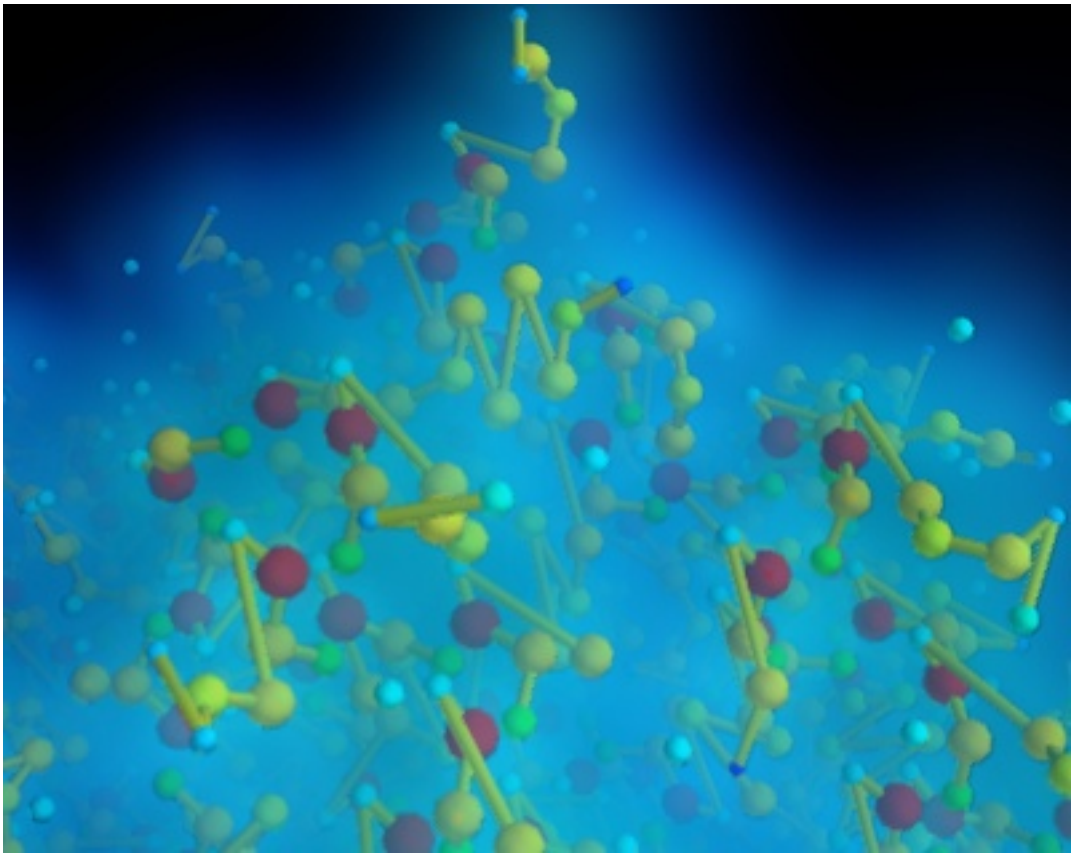
We assign a scalar value for the atoms to differenciate the different types of atoms, but it does not correspond to the atomic mass. The size and the color of the atom on the visualization is therefore not chemicaly-significant.

The atoms are plotted using mlab.points3d, and connections between atoms are added to the dataset, and visualized using a surface module.

The graph is created by adding connection information to points. For this, each point is designated by its number (in the order of the array passed to mlab.points3d), and the connection array, made of pairs of these numbers, is constructed. There is some slightly tedious data manipulation to go from the named-node graph representation as stored in the pdb file, to the index-based connection pairs. A similar technique to plot the graph is done in the *Flight graph example*. Another example of graph plotting, showing a different technique to plot the graph, can be seen on *Delaunay graph example*.

To visualize the local atomic density, we use a gaussian splatter filter that builds a kernel density estimation of the continuous density field: each point is convoluted by a Gaussian kernel, and the sum of these Gaussians form the resulting density field. We visualize this field using volume rendering.

Reference for the pdb file standard: http://mmcif.pdb.org/dictionaries/pdb-correspondence/pdb2mmcif.html



Source code: protein.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.

# The pdb code for the protein.
protein_code = '2q09'

# Retrieve the file from the protein database ##################################
import os
if not os.path.exists('pdb%s.ent.gz' % protein_code):
    # Download the data
    import urllib
    print 'Downloading protein data, please wait'
    opener = urllib.urlopen(
      'ftp://ftp.wwpdb.org/pub/pdb/data/structures/divided/pdb/q0/pdb%s.ent.gz'
      % protein_code)
    open('pdb%s.ent.gz' % protein_code, 'w').write(opener.read())

# Parse the pdb file ###########################################################
import gzip
infile = gzip.GzipFile('pdb%s.ent.gz' % protein_code, 'rb')

# A graph represented by a dictionary associating nodes with keys
# (numbers), and edges (pairs of node keys).
nodes = dict()
edges = list()
```

```
atoms = set()

# Build the graph from the PDB information
last_atom_label = None
last_chain_label = None
for line in infile:
    line = line.split()
    if line[0] in ('ATOM', 'HETATM'):
        nodes[line[1]] = (line[2], line[6], line[7], line[8])
        atoms.add(line[2])
        chain_label = line[5]
        if chain_label == last_chain_label:
            edges.append((line[1], last_atom_label))
        last_atom_label = line[1]
        last_chain_label = chain_label
    elif line[0] == 'CONECT':
        for start, stop in zip(line[1:-1], line[2:]):
            edges.append((start, stop))

atoms = list(atoms)
atoms.sort()
atoms = dict(zip(atoms, range(len(atoms))))

# Turn the graph into 3D positions, and a connection list.
labels = dict()

x       = list()
y       = list()
z       = list()
scalars = list()

for index, label in enumerate(nodes):
    labels[label] = index
    this_scalar, this_x, this_y, this_z= nodes[label]
    scalars.append(atoms[this_scalar])
    x.append(float(this_x))
    y.append(float(this_y))
    z.append(float(this_z))

connections = list()

for start, stop in edges:
    connections.append((labels[start], labels[stop]))

import numpy as np
x       = np.array(x)
y       = np.array(y)
z       = np.array(z)
scalars = np.array(scalars)

# Visualize the data ##########################################################
from enthought.mayavi import mlab
mlab.figure(1, bgcolor=(0, 0, 0))
mlab.clf()

pts = mlab.points3d(x, y, z, 1.5*scalars.max() - scalars,
                                    scale_factor=0.015, resolution=10)
pts.mlab_source.dataset.lines = np.array(connections)
```

```
# Use a tube fiter to plot tubes on the link, varying the radius with the
# scalar value
tube = mlab.pipeline.tube(pts, tube_radius=0.15)
tube.filter.radius_factor = 1.
tube.filter.vary_radius = 'vary_radius_by_scalar'
mlab.pipeline.surface(tube, color=(0.8, 0.8, 0))

# Visualize the local atomic density
mlab.pipeline.volume(mlab.pipeline.gaussian_splatter(pts))

mlab.view(49, 31.5, 52.8, (4.2, 37.3, 20.6))

mlab.show()
```

10.2.17 Flight graph example

An example showing a graph display between cities positionned on the Earth surface.

This graph displays the longest fligh routes operated by Boing 777. The two main interests of this example are that it shows how to build a graph of arbitrary connectivity, and that it shows how to position data on the surface of the Earth.

The graph is created by first building a scalar scatter dataset with the mlab.points3d command, and adding line information to it. One of the difficulties is that the lines are specified using the indexing number of the points, so we must 'massage' our data when loading it. A similar technique to plot the graph is done in the *Protein example*. Another example of graph plotting, showing a different technique to plot the graph, can be seen on *Delaunay graph example*.

To simplify things we do not plot the connection on the surface of the Earth, but as straight lines going throught the Earth. As a result must use transparency to show the connection.

Data source: http://www.777fleetpage.com/777fleetpage3.htm

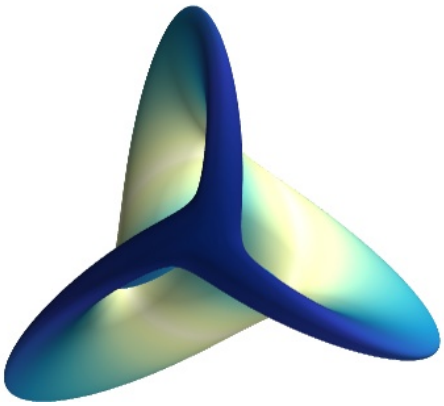
Source code: flight_graph.py

```
#############################################################################
# The data. This could be loaded from a file, or scraped from a website

routes_data = """
Bombay        Atlanta
Johannesburg        Atlanta
Dubai        Los Angeles
Dubai        Houston
Dubai        San Francisco
New York        Hong Kong
Newark        Hong Kong
Doha        Houston
Toronto        Hong Kong
Bombay        Newark
Bombay        New York
Vancouver        Hong Kong
Dubai        Sao Paulo
Los Angeles        Sydney
Chicago        Delhi
"""

cities_data = """
```

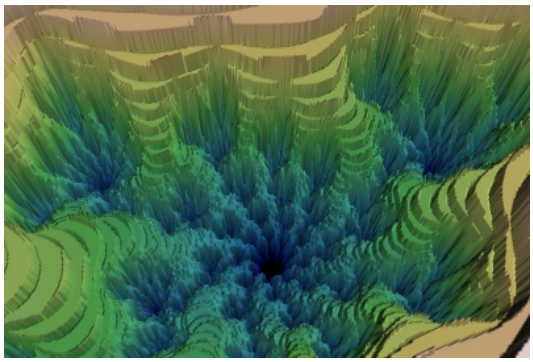
```
Toronto         -79.38         43.65
Chicago         -87.68         41.84
Houston         -95.39         29.77
New York         -73.94         40.67
Vancouver         -123.13         49.28
Los Angeles         -118.41         34.11
San Francisco         -122.45         37.77
Atlanta         -84.42         33.76
Dubai         55.33         25.27
Sydney         151.21         -33.87
Hong Kong         114.19         22.38
Bombay         72.82         18.96
Delhi         77.21         28.67
Newark         -82.43         40.04
Johannesburg         28.04         -26.19
Doha         51.53         25.29
Sao Paulo         -46.63         -23.53
"""

################################################################################
# Load the data, and put it in data structures we can use
import csv
routes_table = list(csv.reader(routes_data.split('\n'), dialect='excel-tab'))

# Build a dictionnary returning GPS coordinates for each city
cities_coord = dict()
for line in list(csv.reader(cities_data.split('\n'),
                    dialect='excel-tab'))[1:-1]:
    name, long, lat = line
    cities_coord[name] = (float(long), float(lat))

# Store all the coordinates of connected cities in a list also keep
# track of which city corresponds to a given index in the list. The
# connectivity information is specified as connecting the i-th point
# with the j-th.
cities = dict()
coords = list()
connections = list()
for city1, city2 in routes_table[1:-1]:
    if not city1 in cities:
        cities[city1] = len(coords)
        coords.append(cities_coord[city1])
    if not city2 in cities:
        cities[city2] = len(coords)
        coords.append(cities_coord[city2])
    connections.append((cities[city1], cities[city2]))


################################################################################
from enthought.mayavi import mlab
mlab.figure(1, bgcolor=(0.48, 0.48, 0.48), fgcolor=(0, 0, 0),
               size=(400, 400))
mlab.clf()

################################################################################
# Display points at city positions
import numpy as np
coords = np.array(coords)
```

```
# First we have to convert latitude/longitude information to 3D
# positioning.
lat, long = coords.T * np.pi/180
x = np.cos(long) * np.cos(lat)
y = np.cos(long) * np.sin(lat)
z = np.sin(long)

points = mlab.points3d(x, y, z,
                       scale_mode='none',
                       scale_factor=0.03,
                       color=(0, 0, 1))

################################################################################
# Display connections between cities
connections = np.array(connections)
# We add lines between the points that we have previously created by
# directly modifying the VTK dataset.
points.mlab_source.dataset.lines = connections
points.mlab_source.update()
# To represent the lines, we use the surface module. Using a wireframe
# representation allows to control the line-width.
mlab.pipeline.surface(points, color=(1, 1, 1),
                              representation='wireframe',
                              line_width=4,
                              name='Connections')

################################################################################
# Display city names
for city, index in cities.iteritems():
    label = mlab.text(x[index], y[index], city, z=z[index],
                      width=0.016*len(city), name=city)
    label.property.shadow = True

################################################################################
# Display continents outline, using the VTK Builtin surface 'Earth'
from enthought.mayavi.sources.builtin_surface import BuiltinSurface
continents_src = BuiltinSurface(source='earth', name='Continents')
# The on_ratio of the Earth source controls the level of detail of the
# continents outline.
continents_src.data_source.on_ratio = 2
continents = mlab.pipeline.surface(continents_src, color=(0, 0, 0))

################################################################################
# Display a semi-transparent sphere, for the surface of the Earth

# We use a sphere Glyph, throught the points3d mlab function, rather than
# building the mesh ourselves, because it gives a better transparent
# rendering.
sphere = mlab.points3d(0, 0, 0, scale_mode='none',
                               scale_factor=2,
                               color=(0.67, 0.77, 0.93),
                               resolution=50,
                               opacity=0.7,
                               name='Earth')

# These parameters, as well as the color, where tweaked through the GUI,
# with the record mode to produce lines of code usable in a script.
sphere.actor.property.specular = 0.45
```

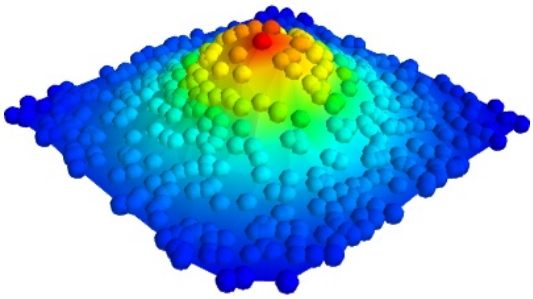
```
sphere.actor.property.specular_power = 5
# Backface culling is necessary for more a beautiful transparent
# rendering.
sphere.actor.property.backface_culling = True

###############################################################################
# Plot the equator and the tropiques
theta = np.linspace(0, 2*np.pi, 100)
for angle in (-np.pi/6, 0, np.pi/6):
    x = np.cos(theta)*np.cos(angle)
    y = np.sin(theta)*np.cos(angle)
    z = np.ones_like(theta)*np.sin(angle)

    mlab.plot3d(x, y, z, color=(1, 1, 1),
                         opacity=0.2, tube_radius=None)

mlab.view(63.4, 73.8, 4, [-0.05, 0, 0])
mlab.show()
```



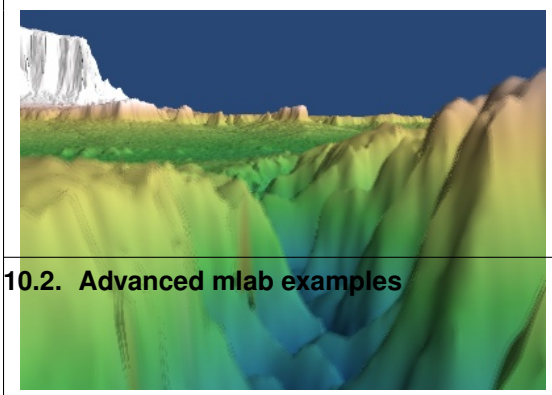
Boy example *Julia set example* *Surface from irregular data example* *Canyon example* *Spherical harm*
A script to generate the Mayavi logo: a Boy surface.



Julia set example An example showing the Julia set displayed as a z-warped surface.



Surface from irregular data example An example which shows how to plot a surface from data acquired irregularly.



Canyon example Retrieve radar data from the NASA and

10.3 Interactive examples

Examples showing how to use the interactive features of Mayavi, either via the mayavi2 application, or via specially-crafted dialogs and applications.

10.3.1 Mlab visual example

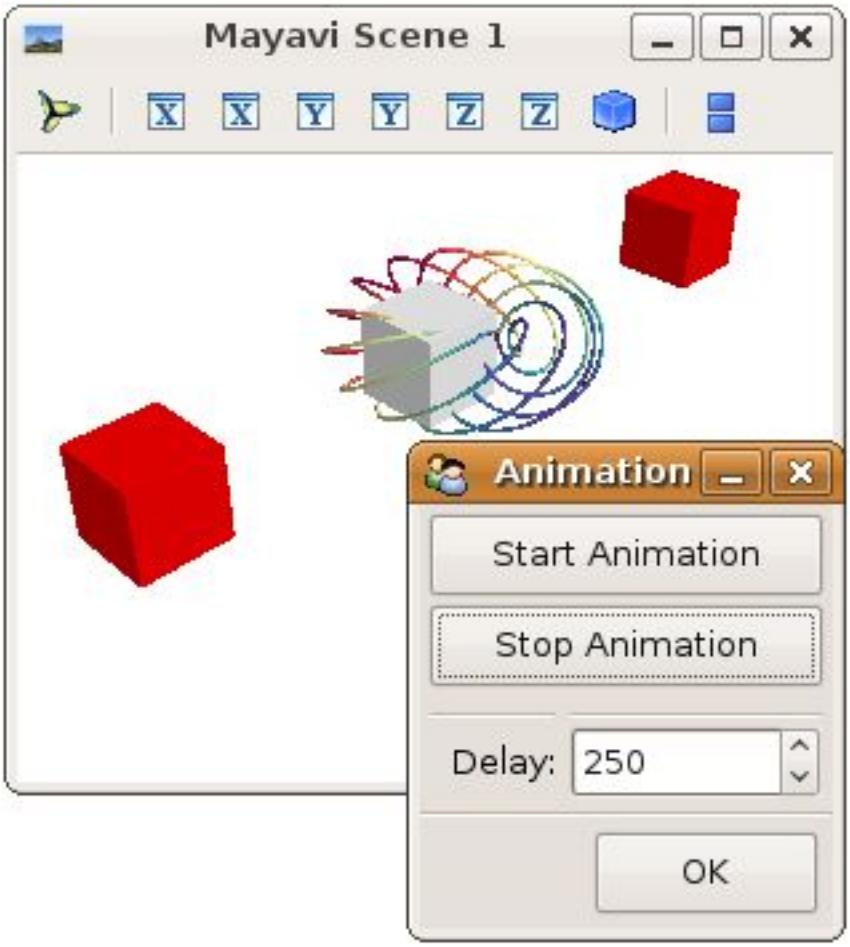
A very simple example to show how you can use TVTK's visual module with mlab and create simple animations.

In the example, the grey box bounces back and forth between the two red ones.

The *enthought.tvtk.tools.visual* module exposes an API similar to VPython and is useful to create animation based on rigid object movement.

The *@animate* decorator (`enthought.mayavi.mlab.animate()`) is detailed on section *Animating a visualization*.

If you want to modify the data plotted by the mlab (as in the *mlab.test_plot3d()* call) to create an animation, please see section *Animating the data*.



Source code: mlab_visual.py

```
# Author: Prabhu Ramachandran <prabhu [at] aero.iitb.ac.in>
# Copyright (c) 2009, Enthought, Inc.
```

```
# License: BSD Style.

from enthought.mayavi import mlab
from enthought.tvtk.tools import visual
# Create a figure
f = mlab.figure(size=(500,500))
# Tell visual to use this as the viewer.
visual.set_viewer(f)

# A silly visualization.
mlab.test_plot3d()

# Even sillier animation.
b1 = visual.box()
b2 = visual.box(x=4., color=visual.color.red)
b3 = visual.box(x=-4, color=visual.color.red)
b1.v = 5.0

@mlab.show
@mlab.animate(delay=250)
def anim():
    """Animate the b1 box."""
    while 1:
        b1.x = b1.x + b1.v*0.1
        if b1.x > 2.5 or b1.x < -2.5:
            b1.v = -b1.v
        yield

# Run the animation.
anim()
```

10.3.2 Mlab traits ui example

A simple example of how to use mayavi.mlab inside a traits UI dialog.

This example uses traitsUI (traitsUI) to create a the simplest possible dialog: a single Mayavi scene in a window.

Source code: mlab_traits_ui.py

```
# Authors: Prabhu Ramachandran <prabhu [at] aero.iitb.ac.in>
#          Gael Varoquaux
# Copyright (c) 2007, Enthought, Inc.
# License: BSD Style.

# Standard imports.
from numpy import sqrt, sin, mgrid

# Enthought imports.
from enthought.traits.api import HasTraits, Instance
from enthought.traits.ui.api import View, Item
from enthought.tvtk.pyface.scene_editor import SceneEditor

from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel
from enthought.mayavi.core.ui.mayavi_scene import MayaviScene


####################################################################
```

```
class ActorViewer(HasTraits):

    # The scene model.
    scene = Instance(MlabSceneModel, ())

    ######################
    # Using 'scene_class=MayaviScene' adds a Mayavi icon to the toolbar,
    # to pop up a dialog editing the pipeline.
    view = View(Item(name='scene',
                     editor=SceneEditor(scene_class=MayaviScene),
                     show_label=False,
                     resizable=True,
                     height=500,
                     width=500),
                resizable=True
                )

    def __init__(self, **traits):
        HasTraits.__init__(self, **traits)
        self.generate_data()

    def generate_data(self):
        # Create some data
        X, Y = mgrid[-2:2:100j, -2:2:100j]
        R = 10*sqrt(X**2 + Y**2)
        Z = sin(R)/R

        self.scene.mlab.surf(X, Y, Z, colormap='gist_earth')


if __name__ == '__main__':
    a = ActorViewer()
    a.configure_traits()
```

10.3.3 Wx embedding example

This example shows to embed a Mayavi view in a wx frame.

The trick is to create a *HasTraits* object, as in the mlab_traits_ui.py, mayavi_traits_ui.py, or the modifying_mlab_source.py examples (*Mlab traits ui example*, *Mayavi traits ui example*, *Mlab interactive dialog example*).

Calling the *edit_traits* method returns a *ui* object whose *control* attribute is the wx widget. It can thus be embedded in a standard wx application.

In this example, the wx part is very simple. See *Wx mayavi embed in notebook example* for an example of more complex embedding of Mayavi scenes in Wx applications.

Source code: wx_embedding.py

```
from numpy import ogrid, sin

from enthought.traits.api import HasTraits, Instance
from enthought.traits.ui.api import View, Item

from enthought.mayavi.sources.api import ArraySource
from enthought.mayavi.modules.api import IsoSurface
```

```
from enthought.tvtk.pyface.scene_editor import SceneEditor
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel

class MayaviView(HasTraits):

    scene = Instance(MlabSceneModel, ())

    # The layout of the panel created by Traits
    view = View(Item('scene', editor=SceneEditor(), resizable=True,
                     show_label=False),
                     resizable=True)

    def __init__(self):
        HasTraits.__init__(self)
        # Create some data, and plot it using the embedded scene's engine
        x, y, z = ogrid[-10:10:100j, -10:10:100j, -10:10:100j]
        scalars = sin(x*y*z)/(x*y*z)
        src = ArraySource(scalar_data=scalars)
        self.scene.engine.add_source(src)
        src.add_module(IsoSurface())

#---------------------------------------------------------------------------
# Wx Code
import wx

class MainWindow(wx.Frame):

    def __init__(self, parent, id):
        wx.Frame.__init__(self, parent, id, 'Mayavi in Wx')
        self.mayavi_view = MayaviView()
        # Use traits to create a panel, and use it as the content of this
        # wx frame.
        self.control = self.mayavi_view.edit_traits(
                        parent=self,
                        kind='subpanel').control
        self.Show(True)

app = wx.PySimpleApp()
frame = MainWindow(None, wx.ID_ANY)
app.MainLoop()
```

10.3.4 Multiple mlab scene models example

Example showing a dialog with multiple embedded scenes.

When using several embedded scenes with mlab, you should be very careful always to pass the scene you want to use for plotting to the mlab function used, elsewhere it uses the current scene. In this example, failing to do so would result in only one scene being used, the last one created.

The trick is to use the 'mayavi_scene' attribute of the MlabSceneModel, and pass it as a keyword argument to the mlab functions.

For more examples on embedding mlab scenes in dialog, see also: the examples *Mlab interactive dialog example*, and *Lorenz ui example*, as well as the section of the user manual *Embedding a Mayavi scene in a Traits dialog*.

Source code: multiple_mlab_scene_models.py

```
import numpy as np

from enthought.traits.api import HasTraits, Instance, Button, \
    on_trait_change
from enthought.traits.ui.api import View, Item, HSplit, Group

from enthought.mayavi import mlab
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel
from enthought.tvtk.pyface.scene_editor import SceneEditor

class MyDialog(HasTraits):

    scene1 = Instance(MlabSceneModel, ())
    scene2 = Instance(MlabSceneModel, ())

    button1 = Button('Redraw')
    button2 = Button('Redraw')

    @on_trait_change('button1')
    def redraw_scene1(self):
        self.redraw_scene(self.scene1)

    @on_trait_change('button2')
    def redraw_scene2(self):
        self.redraw_scene(self.scene2)

    def redraw_scene(self, scene):
        # Notice how each mlab
        mlab.clf(figure=scene.mayavi_scene)
        x, y, z, s = np.random.random((4, 100))
        mlab.points3d(x, y, z, s, figure=scene.mayavi_scene)

    # The layout of the dialog created
    view = View(HSplit(
                  Group(
                       Item('scene1',
                            editor=SceneEditor(), height=250,
                            width=300),
                       'button1',
                       show_labels=False,
                  ),
                  Group(
                       Item('scene2',
                            editor=SceneEditor(), height=250,
                            width=300, show_label=False),
                       'button2',
                       show_labels=False,
                  ),
                ),
                resizable=True,
                )

m = MyDialog()
m.configure_traits()
```

10.3.5 Multiple engines example

An example to show how you can have multiple engines in one application.

Mutliple engines can be useful for more separation, eg to script each engine separately, or to avoid side effects between scenes.

This example shows how to explicitely set the engine for an embedded scene.

To define default arguments, it makes use of the Traits initialization style, rather than overridding the __init__.

Source code: multiple_engines.py

```
# Author:  Gael Varoquaux <gael _dot_ varoquaux _at_ normalesup _dot_ org>
# Copyright (c) 2009, Enthought, Inc.
# License: BSD Style.

from enthought.traits.api import HasTraits, Instance, on_trait_change
from enthought.traits.ui.api import View, Group, Item

from enthought.mayavi.core.api import Engine
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel
from enthought.mayavi.core.ui.mayavi_scene import MayaviScene
from enthought.tvtk.pyface.scene_editor import SceneEditor

################################################################################
class MyApp(HasTraits):

    # The first engine. As default arguments (an empty tuple) are given,
    # traits initializes it.
    engine1 = Instance(Engine, args=())

    scene1 = Instance(MlabSceneModel)

    def _scene1_default(self):
        " The default initializer for 'scene1' "
        self.engine1.start()
        scene1 = MlabSceneModel(engine=self.engine1)
        return scene1

    engine2 = Instance(Engine, ())

    scene2 = Instance(MlabSceneModel)

    def _scene2_default(self):
        " The default initializer for 'scene2' "
        self.engine2.start()
        scene2 = MlabSceneModel(engine=self.engine2)
        return scene2

    # We populate the scenes only when it is activated, to avoid problems
    # with VTK objects that expect an active scene
    @on_trait_change('scene1.activated')
    def populate_scene1(self):
        self.scene1.mlab.test_surf()

    @on_trait_change('scene2.activated')
    def populate_scene2(self):
        self.scene2.mlab.test_mesh()
```

```
    # The layout of the view
    view = View(Group(Item('scene1',
                           editor=SceneEditor(scene_class=MayaviScene),
                           width=480, height=480)),
                Group(Item('scene2',
                           editor=SceneEditor(scene_class=MayaviScene),
                           width=480, height=480)),
                resizable=True)


if __name__ == '__main__':
    MyApp().configure_traits()
```

10.3.6 Mlab interactive dialog example

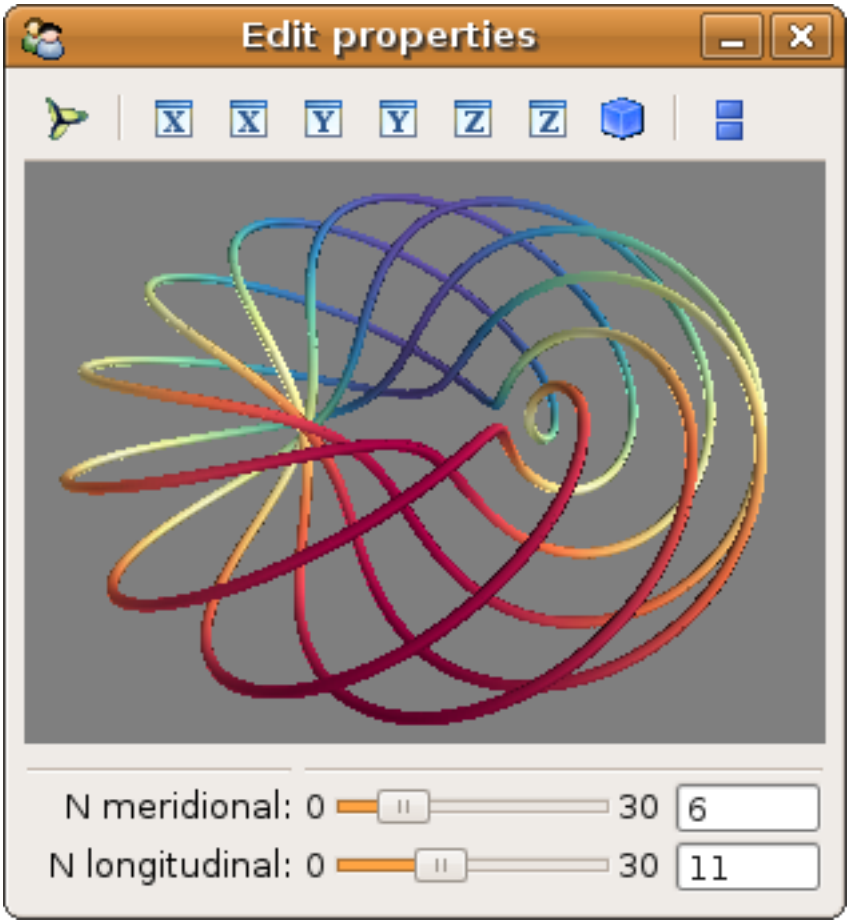
An example of how to modify the data visualized via an interactive dialog.

A dialog is created via TraitsUI from an object (MyModel). Some attributes of the objects are represented on the dialog: first a Mayavi scene, that will host our visualization, and two parameters that control the data plotted.

A curve is plotted in the embedded scene using the associated mlab.points3d function. The visualization object created is stored as an attribute on the main MyModel object, to modify it inplace later.

When the *n_meridional* and *n_longitudinal* attributes are modified, eg via the slide bars on the dialog, the curve is recomputed, and the visualization is updated by modifying inplace the stored plot object (see *Animating the data*).

This example is discussed in details in the section *Embedding a Mayavi scene in a Traits dialog*.



Source code: mlab_interactive_dialog.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD Style.


from numpy import arange, pi, cos, sin

from enthought.traits.api import HasTraits, Range, Instance, \
        on_trait_change
from enthought.traits.ui.api import View, Item, Group
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel
from enthought.mayavi.core.api import PipelineBase
from enthought.mayavi.core.ui.api import MayaviScene, SceneEditor


dphi = pi/1000.
phi = arange(0.0, 2*pi + 0.5*dphi, dphi, 'd')

def curve(n_mer, n_long):
    mu = phi*n_mer
    x = cos(mu) * (1 + cos(n_long * mu/n_mer)*0.5)
    y = sin(mu) * (1 + cos(n_long * mu/n_mer)*0.5)
    z = 0.5 * sin(n_long*mu/n_mer)
    t = sin(mu)
```

```
    return x, y, z, t


class MyModel(HasTraits):
    n_meridional    = Range(0, 30, 6, )#mode='spinner')
    n_longitudinal  = Range(0, 30, 11, )#mode='spinner')

    scene = Instance(MlabSceneModel, ())

    plot = Instance(PipelineBase)


    # When the scene is activated, or when the parameters are changed, we
    # update the plot.
    @on_trait_change('n_meridional,n_longitudinal,scene.activated')
    def update_plot(self):
        x, y, z, t = curve(self.n_meridional, self.n_longitudinal)
        if self.plot is None:
            self.plot = self.scene.mlab.plot3d(x, y, z, t,
                                tube_radius=0.025, colormap='Spectral')
        else:
            self.plot.mlab_source.set(x=x, y=y, z=z, scalars=t)


    # The layout of the dialog created
    view = View(Item('scene', editor=SceneEditor(scene_class=MayaviScene),
                     height=250, width=300, show_label=False),
                Group(
                        '_', 'n_meridional', 'n_longitudinal',
                     ),
                resizable=True,
                )

my_model = MyModel()
my_model.configure_traits()
```

10.3.7 Wx mayavi embed in notebook example

This example show how to embedded Mayavi in a wx notebook.

This is a slightly more complex example than the *wx_embedding* example (*Wx embedding example*), and can be used to see how a large wx application can use different Mayavi views.

In this example, we embed one single Mayavi scene in a Wx notebook, with 2 tabs, each one of them hosting a different view of the scene.

Source code: wx_mayavi_embed_in_notebook.py

```
# First thing, we need to make sure that we are importing a
# recent-enough version of wx
import wxversion
wxversion.ensureMinimal('2.8')

from numpy import ogrid, sin

from enthought.traits.api import HasTraits, Instance
from enthought.traits.ui.api import View, Item
```

```
from enthought.mayavi.sources.api import ArraySource
from enthought.mayavi.modules.api import IsoSurface

from enthought.mayavi.core.ui.api import MlabSceneModel, SceneEditor

#-----------------------------------------------------------------------------
class MayaviView(HasTraits):

    scene = Instance(MlabSceneModel, ())

    # The layout of the panel created by traits.
    view = View(Item('scene', editor=SceneEditor(),
                     resizable=True,
                     show_label=False),
                resizable=True)

    def __init__(self):
        HasTraits.__init__(self)
        x, y, z = ogrid[-10:10:100j, -10:10:100j, -10:10:100j]
        scalars = sin(x*y*z)/(x*y*z)
        src = ArraySource(scalar_data=scalars)
        self.scene.mayavi_scene.add_child(src)
        src.add_module(IsoSurface())


#-----------------------------------------------------------------------------
# Wx Code
import wx

class MainWindow(wx.Frame):

    def __init__(self, parent, id):
        wx.Frame.__init__(self, parent, id, 'Mayavi in a Wx notebook')
        self.notebook = wx.aui.AuiNotebook(self, id=-1,
                style=wx.aui.AUI_NB_TAB_SPLIT | wx.aui.AUI_NB_CLOSE_ON_ALL_TABS
                        | wx.aui.AUI_NB_LEFT)

        self.mayavi_view = MayaviView()

        # The edit_traits method opens a first view of our 'MayaviView'
        # object
        self.control = self.mayavi_view.edit_traits(
                        parent=self,
                        kind='subpanel').control
        self.notebook.AddPage(page=self.control, caption='Display 1')

        self.mayavi_view2 = MayaviView()

        # The second call to edit_traits opens a second view
        self.control2 = self.mayavi_view2.edit_traits(
                        parent=self,
                        kind='subpanel').control
        self.notebook.AddPage(page=self.control2, caption='Display 2')

        sizer = wx.BoxSizer()
        sizer.Add(self.notebook,1, wx.EXPAND)
        self.SetSizer(sizer)
```

```
        self.Show(True)

if __name__ == '__main__':
    app = wx.PySimpleApp()
    frame = MainWindow(None, wx.ID_ANY)
    app.MainLoop()
```

10.3.8 Subclassing mayavi application example

This script demonstrates how one can script Mayavi by subclassing the application, create a new VTK scene and create a few simple modules.

This should be run as:

```
$ python test.py
```

Source code: subclassing_mayavi_application.py

```
# Author: Prabhu Ramachandran <prabhu_r@users.sf.net>
# Copyright (c) 2005-2007, Enthought, Inc.
# License: BSD Style.

# Standard library imports
from os.path import join, abspath, dirname

# Enthought library imports
from enthought.mayavi.plugins.app import Mayavi
from enthought.mayavi.scripts.util import get_data_dir

class MyApp(Mayavi):
    def run(self):
        """This is executed once the application GUI has started.
        *Make sure all other MayaVi specific imports are made here!*
        """
        # Various imports to do different things.
        from enthought.mayavi.sources.vtk_file_reader import VTKFileReader
        from enthought.mayavi.modules.outline import Outline
        from enthought.mayavi.modules.axes import Axes
        from enthought.mayavi.modules.grid_plane import GridPlane
        from enthought.mayavi.modules.image_plane_widget import ImagePlaneWidget
        from enthought.mayavi.modules.text import Text

        script = self.script
        # Create a new scene.
        script.new_scene()

        # Read a VTK (old style) data file.
        r = VTKFileReader()
        r.initialize(join(get_data_dir(dirname(abspath(__file__))), 'heart.vtk'))
        script.add_source(r)

        # Put up some text.
        t = Text(text='MayaVi rules!', x_position=0.2,
                 y_position=0.9, width=0.8)
        t.property.color = 1, 1, 0  # Bright yellow, yeah!
```

```
        script.add_module(t)

        # Create an outline for the data.
        o = Outline()
        script.add_module(o)

        # Create an axes for the data.
        a = Axes()
        script.add_module(a)

        # Create an orientation axes for the scene.  This only works with
        # VTK-4.5 and above which is why we have the try block.
        try:
            from enthought.mayavi.modules.orientation_axes import OrientationAxes
        except ImportError:
            pass
        else:
            a = OrientationAxes()
            a.marker.set_viewport(0.0, 0.8, 0.2, 1.0)
            script.add_module(a)

        # Create three simple grid plane modules.
        # First normal to 'x' axis.
        gp = GridPlane()
        script.add_module(gp)
        # Second normal to 'y' axis.
        gp = GridPlane()
        gp.grid_plane.axis = 'y'
        script.add_module(gp)
        # Third normal to 'z' axis.
        gp = GridPlane()
        script.add_module(gp)
        gp.grid_plane.axis = 'z'

        # Create one ImagePlaneWidget.
        ipw = ImagePlaneWidget()
        script.add_module(ipw)
        # Set the position to the middle of the data.
        ipw.ipw.slice_position = 16



if __name__ == '__main__':
    a = MyApp()
    a.main()
```

10.3.9 Qt embedding example

This example demonstrates using Mayavi as a component of a large Qt application.

For this use, Mayavi is embedded in a QWidget. To understand this example, please read section :ref'builing-applications'.

Source code: qt_embedding.py

```
# First, and before importing any Enthought packages, set the ETS_TOOLKIT
# environment variable to qt4, to tell Traits that we will use Qt.
```

```
import os
os.environ['ETS_TOOLKIT'] = 'qt4'

from PyQt4 import QtGui, QtCore

from enthought.traits.api import HasTraits, Instance, on_trait_change, \
    Int, Dict
from enthought.traits.ui.api import View, Item
from enthought.mayavi.core.ui.api import MayaviScene, MlabSceneModel, \
        SceneEditor


################################################################################
#The actual visualization
class Visualization(HasTraits):
    scene = Instance(MlabSceneModel, ())

    @on_trait_change('scene.activated')
    def update_plot(self):
        # This function is called when the view is opened. We don't
        # populate the scene when the view is not yet open, as some
        # VTK features require a GLContext.

        # We can do normal mlab calls on the embedded scene.
        self.scene.mlab.test_points3d()

    # the layout of the dialog screated
    view = View(Item('scene', editor=SceneEditor(scene_class=MayaviScene),
                     height=250, width=300, show_label=False),
                resizable=True # We need this to resize with the parent widget
                )


################################################################################
# The QWidget containing the visualization, this is pure PyQt4 code.
class MayaviQWidget(QtGui.QWidget):
    def __init__(self, parent=None):
        QtGui.QWidget.__init__(self, parent)
        layout = QtGui.QVBoxLayout(self)
        layout.setMargin(0)
        layout.setSpacing(0)
        self.visualization = Visualization()

        # If you want to debug, beware that you need to remove the Qt
        # input hook.
        #QtCore.pyqtRemoveInputHook()
        #import pdb ; pdb.set_trace()
        #QtCore.pyqtRestoreInputHook()

        # The edit_traits call will generate the widget to embed.
        self.ui = self.visualization.edit_traits(parent=self,
                                                 kind='subpanel').control
        layout.addWidget(self.ui)
        self.ui.setParent(self)


if __name__ == "__main__":
    # Don't create a new QApplication, it would unhook the Events
```

```
    # set by Traits on the existing QApplication. Simply use the
    # '.instance()' method to retrieve the existing one.
    app = QtGui.QApplication.instance()
    container = QtGui.QWidget()
    container.setWindowTitle("Embedding Mayavi in a PyQt4 Application")
    # define a "complex" layout to test the behaviour
    layout = QtGui.QGridLayout(container)

    # put some stuff around mayavi
    label_list = []
    for i in range(3):
        for j in range(3):
            if (i==1) and (j==1):continue
            label = QtGui.QLabel(container)
            label.setText("Your QWidget at (%d, %d)" % (i,j))
            label.setAlignment(QtCore.Qt.AlignHCenter|QtCore.Qt.AlignVCenter)
            layout.addWidget(label, i, j)
            label_list.append(label)
    mayavi_widget = MayaviQWidget(container)

    layout.addWidget(mayavi_widget, 1, 1)
    container.show()
    window = QtGui.QMainWindow()
    window.setCentralWidget(container)
    window.show()

    # Start the main event loop.
    app.exec_()
```

10.3.10 Mayavi traits ui example

An example of how to create an almost complete Mayavi UI inside a Traits UI view.

This does not use Envisage and provides a similar UI as seen in the full Mayavi application.

This example uses traitsUI to create a dialog mimicking the mayavi2 application: a scene on the right, and on the left a pipeline tree view, and below it a panel to edit the currently-selected object.

Source code: mayavi_traits_ui.py

```
# Authors: Prabhu Ramachandran <prabhu [at] aero.iitb.ac.in>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD Style.

# Standard imports.
from numpy import sqrt, sin, mgrid

# Enthought imports.
from enthought.traits.api import HasTraits, Instance, Property, Enum
from enthought.traits.ui.api import View, Item, HSplit, VSplit, InstanceEditor
from enthought.tvtk.pyface.scene_editor import SceneEditor
from enthought.mayavi.core.ui.engine_view import EngineView
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel


######################################################################
class Mayavi(HasTraits):
```

```
    # The scene model.
    scene = Instance(MlabSceneModel, ())

    # The mayavi engine view.
    engine_view = Instance(EngineView)

    # The current selection in the engine tree view.
    current_selection = Property


    ######################
    view = View(HSplit(VSplit(Item(name='engine_view',
                                   style='custom',
                                   resizable=True,
                                   show_label=False
                                   ),
                              Item(name='current_selection',
                                   editor=InstanceEditor(),
                                   enabled_when='current_selection is not None',
                                   style='custom',
                                   springy=True,
                                   show_label=False),
                                   ),
                               Item(name='scene',
                                    editor=SceneEditor(),
                                    show_label=False,
                                    resizable=True,
                                    height=500,
                                    width=500),
                       ),
                resizable=True,
                scrollable=True
                )

    def __init__(self, **traits):
        HasTraits.__init__(self, **traits)
        self.engine_view = EngineView(engine=self.scene.engine)

        # Hook up the current_selection to change when the one in the engine
        # changes.  This is probably unnecessary in Traits3 since you can show
        # the UI of a sub-object in T3.
        self.scene.engine.on_trait_change(self._selection_change,
                                          'current_selection')

        self.generate_data_mayavi()

    def generate_data_mayavi(self):
        """Shows how you can generate data using mayavi instead of mlab."""
        from enthought.mayavi.sources.api import ParametricSurface
        from enthought.mayavi.modules.api import Outline, Surface
        e = self.scene.engine
        s = ParametricSurface()
        e.add_source(s)
        e.add_module(Outline())
        e.add_module(Surface())

    def _selection_change(self, old, new):
```

```
        self.trait_property_changed('current_selection', old, new)

    def _get_current_selection(self):
        return self.scene.engine.current_selection


if __name__ == '__main__':
    m = Mayavi()
    m.configure_traits()
```

10.3.11 Compute in thread example

This script demonstrates how one can do a computation in another thread and update the mayavi pipeline. It also shows how to create a numpy array data and visualize it as image data using a few modules.

Source code: compute_in_thread.py

```
# Author: Prabhu Ramachandran <prabhu_r@users.sf.net>
# Copyright (c) 2007-2008, Enthought, Inc.
# License: BSD Style.

# Standard library imports
import numpy
from threading import Thread
from time import sleep

# Enthought library imports
from enthought.mayavi.scripts import mayavi2
from enthought.traits.api import HasTraits, Button, Instance
from enthought.traits.ui.api import View, Item
from enthought.mayavi.sources.array_source import ArraySource
from enthought.mayavi.modules.outline import Outline
from enthought.mayavi.modules.image_plane_widget import ImagePlaneWidget
from enthought.pyface.api import GUI


def make_data(dims=(128, 128, 128)):
    """Creates some simple array data of the given dimensions to test
    with."""
    np = dims[0]*dims[1]*dims[2]

    # Create some scalars to render.
    x, y, z = numpy.ogrid[-5:5:dims[0]*1j,-5:5:dims[1]*1j,-5:5:dims[2]*1j]
    x = x.astype('f')
    y = y.astype('f')
    z = z.astype('f')

    scalars = (numpy.sin(x*y*z)/(x*y*z))
    # The copy makes the data contiguous and the transpose makes it
    # suitable for display via tvtk.  Please note that we assume here
    # that the ArraySource is configured to not transpose the data.
    s = numpy.transpose(scalars).copy()
    # Reshaping the array is needed since the transpose messes up the
    # dimensions of the data.  The scalars themselves are ravel'd and
    # used internally by VTK so the dimension does not matter for the
    # scalars.
```

```
    s.shape = s.shape[::-1]
    return s


class ThreadedAction(Thread):
    def __init__(self, data, **kwargs):
        Thread.__init__(self, **kwargs)
        self.data = data

    def run(self):
        print "Performing expensive calculation in %s..."%self.getName(),
        sleep(3)
        sd = self.data.scalar_data
        sd += numpy.sin(numpy.random.rand(*sd.shape)*2.0*numpy.pi)
        GUI.invoke_later(self.data.update)
        print 'done.'


class Controller(HasTraits):
    run_calculation = Button('Run calculation')
    data = Instance(ArraySource)

    view = View(Item(name='run_calculation'))

    def _run_calculation_changed(self, value):
        action = ThreadedAction(self.data)
        action.start()


@mayavi2.standalone
def view_numpy():
    """Example showing how to view a 3D numpy array in mayavi2.
    """
    # 'mayavi' is always defined on the interpreter.
    mayavi.new_scene()
    # Make the data and add it to the pipeline.
    data = make_data()
    src = ArraySource(transpose_input_array=False)
    src.scalar_data = data
    mayavi.add_source(src)
    # Visualize the data.
    o = Outline()
    mayavi.add_module(o)
    ipw = ImagePlaneWidget()
    mayavi.add_module(ipw)
    ipw.module_manager.scalar_lut_manager.show_scalar_bar = True

    ipw_y = ImagePlaneWidget()
    mayavi.add_module(ipw_y)
    ipw_y.ipw.plane_orientation = 'y_axes'

    computation = Controller(data=src)
    computation.edit_traits()


if __name__ == '__main__':
    view_numpy()
```

10.3.12 Poll file example

A simple script that polls a data file for changes and then updates the mayavi pipeline automatically.

This script is to be run like so:

```
$ mayavi2 -x poll_file.py
```

Or:

```
$ python poll_file.py
```

The script currently defaults to using the example data in examples/data/heart.vtk. You can try editing that data file or change this script to point to other data which you can edit.

Source code: poll_file.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2006-2007, Enthought Inc.
# License: BSD Style.

# Standard imports.
import os
from os.path import join, abspath, dirname

# Enthought library imports
from enthought.mayavi.scripts import mayavi2
from enthought.mayavi.sources.vtk_file_reader import VTKFileReader
from enthought.mayavi.modules.outline import Outline
from enthought.mayavi.modules.contour_grid_plane import ContourGridPlane
from enthought.pyface.timer.api import Timer


######################################################################
# `Pollster` class.
class Pollster(object):
    """Given a file name and a mayavi2 data reader object, this class
    polls the file for any changes and automatically updates the
    mayavi pipeline.
    """
    def __init__(self, fname, data):
        """Initialize the object.

        Parameters:
        -----------
        fname -- filename to poll.
        data -- the MayaVi source object to update.
        """
        self.fname = fname
        self.data = data
        self.last_stat = os.stat(fname)

    def poll_file(self):
        # Check the file's time stamp.
        s = os.stat(self.fname)
        if s[-2] == self.last_stat[-2]:
            return
        else:
```

```
            self.last_stat = s
            self.update_pipeline()

    def update_pipeline(self):
        """Override this to do something else if needed.
        """
        print "file changed"
        # Force the reader to re-read the file.
        d = self.data
        d.reader.modified()
        d.update()
        # Propagate the changes in the pipeline.
        d.data_changed = True



def setup_data(fname):
    """Given a VTK file name `fname`, this creates a mayavi2 reader
    for it and adds it to the pipeline.  It returns the reader
    created.
    """
    # 'mayavi' is always defined on the interpreter.
    mayavi.new_scene()
    d = VTKFileReader()
    d.initialize(fname)
    mayavi.add_source(d)
    return d

def view_data():
    """Sets up the mayavi pipeline for the visualization.
    """
    # 'mayavi' is always defined on the interpreter.
    o = Outline()
    mayavi.add_module(o)

    c = ContourGridPlane()
    mayavi.add_module(c)
    c.grid_plane.position = 16
    c.module_manager.scalar_lut_manager.show_scalar_bar = True

@mayavi2.standalone
def main():
    # Change this to suit your needs.  Edit the file after running this
    # script and the pipeline should be updated automatically.

    fname = join(mayavi2.get_data_dir(abspath(dirname(__file__))),
                 'heart.vtk')

    data = setup_data(fname)
    view_data()

    # Poll the file.
    p = Pollster(fname, data)
    timer = Timer(1000, p.poll_file)

    # To stop polling the file do:
    #timer.Stop()
```

```
if __name__ == '__main__':
    main()
```

10.3.13 Lorenz ui example

This example displays the trajectories for the Lorenz system of equations using mlab along with the z-nullcline. It provides a simple UI where a user can change the parameters and the system of equations on the fly. This primarily demonstrates how one can build powerful tools with a UI using Traits and Mayavi.

For explanations and more examples of interactive application building with Mayavi, please refer to section *Building applications using Mayavi*.

Source code: lorenz_ui.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2008-2009, Enthought, Inc.
# License: BSD Style.

import numpy
import scipy

from enthought.mayavi import mlab
from enthought.traits.api import HasTraits, Range, Instance, \
        on_trait_change, Array, Tuple, Str
from enthought.traits.ui.api import View, Item, HSplit, Group
from enthought.tvtk.pyface.scene_editor import SceneEditor
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel
from enthought.mayavi.core.ui.mayavi_scene import MayaviScene

################################################################################
# `Lorenz` class.
################################################################################
class Lorenz(HasTraits):

    # The parameters for the Lorenz system, defaults to the standard ones.
    s = Range(0.0, 20.0, 10.0, desc='the parameter s', enter_set=True,
              auto_set=False)
    r = Range(0.0, 50.0, 28.0, desc='the parameter r', enter_set=True,
              auto_set=False)
    b = Range(0.0, 10.0, 8./3., desc='the parameter b', enter_set=True,
              auto_set=False)

    # These expressions are evaluated to compute the right hand sides of
    # the ODE.  Defaults to the Lorenz system.
    u = Str('s*(y-x)', desc='the x component of the velocity',
            auto_set=False, enter_set=True)
    v = Str('r*x - y - x*z', desc='the y component of the velocity',
            auto_set=False, enter_set=True)
    w = Str('x*y - b*z', desc='the z component of the velocity',
            auto_set=False, enter_set=True)

    # Tuple of x, y, z arrays where the field is sampled.
    points = Tuple(Array, Array, Array)

    # The mayavi(mlab) scene.
    scene = Instance(MlabSceneModel, args=())
```

```
    # The "flow" which is a Mayavi streamline module.
    flow = Instance(HasTraits)

    ######################################
    # The UI view to show the user.
    view = View(HSplit(
                    Group(
                        Item('scene', editor=SceneEditor(scene_class=MayaviScene),
                             height=500, width=500, show_label=False)),
                    Group(
                        Item('s'),
                        Item('r'),
                        Item('b'),
                        Item('u'), Item('v'), Item('w')),
                    ),
                resizable=True
                )

    ########################################################################
    # Trait handlers.
    ########################################################################

    # Note that in the `on_trait_change` call below we listen for the
    # `scene.activated` trait.  This conveniently ensures that the flow
    # is generated as soon as the mlab `scene` is activated (which
    # happens when the configure/edit_traits method is called).  This
    # eliminates the need to manually call the `update_flow` method etc.
    @on_trait_change('s, r, b, scene.activated')
    def update_flow(self):
        x, y, z = self.points
        u, v, w = self.get_uvw()
        self.flow.mlab_source.set(u=u, v=v, w=w)

    @on_trait_change('u')
    def update_u(self):
        self.flow.mlab_source.set(u=self.get_vel('u'))

    @on_trait_change('v')
    def update_v(self):
        self.flow.mlab_source.set(v=self.get_vel('v'))

    @on_trait_change('w')
    def update_w(self):
        self.flow.mlab_source.set(w=self.get_vel('w'))

    def get_uvw(self):
        return self.get_vel('u'), self.get_vel('v'), self.get_vel('w')

    def get_vel(self, comp):
        """This function basically evaluates the user specified system
        of equations using scipy.
        """
        func_str = getattr(self, comp)
        try:
            g = scipy.__dict__
            x, y, z = self.points
            s, r, b = self.s, self.r, self.b
```

```
            val = eval(func_str, g,
                       {'x': x, 'y': y, 'z': z,
                        's':s, 'r':r, 'b': b})
        except:
            # Mistake, so return the original value.
            val = getattr(self.flow.mlab_source, comp)
        return val

    ######################################################################
    # Private interface.
    ######################################################################
    def _points_default(self):
        x, y, z = numpy.mgrid[-50:50:100j,-50:50:100j,-10:60:70j]
        return x, y, z

    def _flow_default(self):
        x, y, z = self.points
        u, v, w = self.get_uvw()
        f = self.scene.mlab.flow(x, y, z, u, v, w)
        f.stream_tracer.integration_direction = 'both'
        f.stream_tracer.maximum_propagation = 200
        src = f.mlab_source.m_data
        o = mlab.outline()
        mlab.view(120, 60, 150)
        return f


if __name__ == '__main__':
    # Instantiate the class and configure its traits.
    lor = Lorenz()
    lor.configure_traits()
```

10.3.14 Volume slicer example

Example of an elaborate dialog showing a multiple views on the same data, with 3 cuts synchronized.

This example shows how to have multiple views on the same data, how to embedded multiple scenes in a dialog, and the caveat in populating them with data, as well as how to add some interaction logic on an ImagePlaneWidget.

The order in which things happen in this example is important, and it is easy to get it wrong. First of all, many properties of the visualization objects cannot be changed if there is not a scene created to view them. This is why we put a lot of the visualization logic in the callback of scene.activated, which is called after creation of the scene. Second, default values created via the '_xxx_default' callback are created lazyly, that is, when the attributes are accessed. As the establishement of the VTK pipeline can depend on the order in which it is built, we trigger these access by explicitely calling the attributes. In particular, properties like scene background color, or interaction properties cannot be set before the scene is activated.

The same data is exposed in the different scenes by sharing the VTK dataset between different Mayavi data sources. See the *Sharing the same data between scenes* tip for more details.

In this example, the interaction with the scene and the various elements on it is strongly simplified by turning off interaction, and choosing specific scene interactor styles. Indeed, non-technical users can be confused with too rich interaction.

Source code: volume_slicer.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2009, Enthought, Inc.
# License: BSD Style.

import numpy as np

from enthought.traits.api import HasTraits, Instance, Array, \
    on_trait_change
from enthought.traits.ui.api import View, Item, HGroup, Group

from enthought.tvtk.api import tvtk
from enthought.tvtk.pyface.scene import Scene

from enthought.mayavi import mlab
from enthought.mayavi.core.api import PipelineBase, Source
from enthought.mayavi.core.ui.api import SceneEditor, MayaviScene
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel

################################################################################
# Create some data
x, y, z = np.ogrid[-5:5:64j, -5:5:64j, -5:5:64j]
data = np.sin(3*x)/x + 0.05*z**2 + np.cos(3*y)

################################################################################
# The object implementing the dialog
class VolumeSlicer(HasTraits):
    # The data to plot
    data = Array()

    # The 4 views displayed
    scene3d = Instance(MlabSceneModel, ())
    scene_x = Instance(MlabSceneModel, ())
    scene_y = Instance(MlabSceneModel, ())
    scene_z = Instance(MlabSceneModel, ())

    # The data source
    data_src3d = Instance(Source)

    # The image plane widgets of the 3D scene
    ipw_3d_x = Instance(PipelineBase)
    ipw_3d_y = Instance(PipelineBase)
    ipw_3d_z = Instance(PipelineBase)

    _axis_names = dict(x=0, y=1, z=2)


    #---------------------------------------------------------------------------
    def __init__(self, **traits):
        super(VolumeSlicer, self).__init__(**traits)
        # Force the creation of the image_plane_widgets:
        self.ipw_3d_x
        self.ipw_3d_y
        self.ipw_3d_z


    #---------------------------------------------------------------------------
    # Default values
```

```
    #---------------------------------------------------------------------------
    def _data_src3d_default(self):
        return mlab.pipeline.scalar_field(self.data,
                            figure=self.scene3d.mayavi_scene)

    def make_ipw_3d(self, axis_name):
        ipw = mlab.pipeline.image_plane_widget(self.data_src3d,
                        figure=self.scene3d.mayavi_scene,
                        plane_orientation='%s_axes' % axis_name)
        return ipw

    def _ipw_3d_x_default(self):
        return self.make_ipw_3d('x')

    def _ipw_3d_y_default(self):
        return self.make_ipw_3d('y')

    def _ipw_3d_z_default(self):
        return self.make_ipw_3d('z')


    #---------------------------------------------------------------------------
    # Scene activation callbaks
    #---------------------------------------------------------------------------
    @on_trait_change('scene3d.activated')
    def display_scene3d(self):
        outline = mlab.pipeline.outline(self.data_src3d,
                        figure=self.scene3d.mayavi_scene,
                        )
        self.scene3d.mlab.view(40, 50)
        # Interaction properties can only be changed after the scene
        # has been created, and thus the interactor exists
        for ipw in (self.ipw_3d_x, self.ipw_3d_y, self.ipw_3d_z):
            # Turn the interaction off
            ipw.ipw.interaction = 0
        self.scene3d.scene.background = (0, 0, 0)
        # Keep the view always pointing up
        self.scene3d.scene.interactor.interactor_style = \
                                 tvtk.InteractorStyleTerrain()


    def make_side_view(self, axis_name):
        scene = getattr(self, 'scene_%s' % axis_name)

        # To avoid copying the data, we take a reference to the
        # raw VTK dataset, and pass it on to mlab. Mlab will create
        # a Mayavi source from the VTK without copying it.
        # We have to specify the figure so that the data gets
        # added on the figure we are interested in.
        outline = mlab.pipeline.outline(
                            self.data_src3d.mlab_source.dataset,
                            figure=scene.mayavi_scene,
                            )
        ipw = mlab.pipeline.image_plane_widget(
                            outline,
                            plane_orientation='%s_axes' % axis_name)
        setattr(self, 'ipw_%s' % axis_name, ipw)
```

```
        # Synchronize positions between the corresponding image plane
        # widgets on different views.
        ipw.ipw.sync_trait('slice_position',
                           getattr(self, 'ipw_3d_%s'% axis_name).ipw)

        # Make left-clicking create a crosshair
        ipw.ipw.left_button_action = 0
        # Add a callback on the image plane widget interaction to
        # move the others
        def move_view(obj, evt):
            position = obj.GetCurrentCursorPosition()
            for other_axis, axis_number in self._axis_names.iteritems():
                if other_axis == axis_name:
                    continue
                ipw3d = getattr(self, 'ipw_3d_%s' % other_axis)
                ipw3d.ipw.slice_position = position[axis_number]

        ipw.ipw.add_observer('InteractionEvent', move_view)
        ipw.ipw.add_observer('StartInteractionEvent', move_view)

        # Center the image plane widget
        ipw.ipw.slice_position = 0.5*self.data.shape[
                    self._axis_names[axis_name]]

        # Position the view for the scene
        views = dict(x=( 0, 90),
                     y=(90, 90),
                     z=( 0,  0),
                     )
        scene.mlab.view(*views[axis_name])
        # 2D interaction: only pan and zoom
        scene.scene.interactor.interactor_style = \
                                 tvtk.InteractorStyleImage()
        scene.scene.background = (0, 0, 0)


    @on_trait_change('scene_x.activated')
    def display_scene_x(self):
        return self.make_side_view('x')

    @on_trait_change('scene_y.activated')
    def display_scene_y(self):
        return self.make_side_view('y')

    @on_trait_change('scene_z.activated')
    def display_scene_z(self):
        return self.make_side_view('z')


    #---------------------------------------------------------------------------
    # The layout of the dialog created
    #---------------------------------------------------------------------------
    view = View(HGroup(
                  Group(
                       Item('scene_y',
                            editor=SceneEditor(scene_class=Scene),
                            height=250, width=300),
                       Item('scene_z',
```

```
                        editor=SceneEditor(scene_class=Scene),
                        height=250, width=300),
                    show_labels=False,
                ),
                Group(
                    Item('scene_x',
                        editor=SceneEditor(scene_class=Scene),
                        height=250, width=300),
                    Item('scene3d',
                        editor=SceneEditor(scene_class=MayaviScene),
                        height=250, width=300),
                    show_labels=False,
                ),
            ),
            resizable=True,
            title='Volume Slicer',
            )


m = VolumeSlicer(data=data)
m.configure_traits()
```

10.3.15 Volume slicer advanced example

An efficient implementation of the triple-plane view showing 3 cut planes on volumetric data, and side views showing each cut, with a cursor to move the other cuts.

This is an example of complex callback interaction. It builds on the *Volume slicer example* but has more complex logic. You should try to understand the *Volume slicer example* first.

In this example, the VolumeSlicer object displays a position attribute giving the position of the cut in data coordinates. Traits callbacks are used to move the cut planes when this position attribute is modifed.

In the 3D window, the 3D cuts are displayed using ImagePlaneWidgets cutting the 3D volumetric data. The data extracted by the ImagePlaneWidgets for plotting is captured using the TVTK ImagePlaneWidget's *_get_reslice_output* method. The resulting dataset is plotted in each side view using another ImagePlaneWidget. As a result the data is not copied (at the VTK level, there is only one pipeline), and modifications of the data plotted on the planes in the 3D view (for instance when these planes are moved) are propagated to the 2D side views by the VTK pipeline.

A cursor is displayed in each side view using a glyph. The cursor indicates the position of the cut.

In the side view, when the mouse button is pressed on the planes, it creates a VTK *InteractionEvent*. When this happens, VTK calls an callback (observer, it VTK terms), that we use to move the position of the cut. The Traits callbacks do the rest for the updating.

Source code: volume_slicer_advanced.py

```
import numpy as np

from enthought.traits.api import HasTraits, Instance, Array, \
    Bool, Dict, on_trait_change
from enthought.traits.ui.api import View, Item, HGroup, Group

from enthought.tvtk.api import tvtk
from enthought.tvtk.pyface.scene import Scene

from enthought.mayavi import mlab
```

```
from enthought.mayavi.core.api import PipelineBase, Source
from enthought.mayavi.core.ui.api import SceneEditor
from enthought.mayavi.tools.mlab_scene_model import MlabSceneModel


################################################################################
# The object implementing the dialog
class VolumeSlicer(HasTraits):
    # The data to plot
    data = Array

    # The position of the view
    position = Array(shape=(3,))

    # The 4 views displayed
    scene3d = Instance(MlabSceneModel, ())
    scene_x = Instance(MlabSceneModel, ())
    scene_y = Instance(MlabSceneModel, ())
    scene_z = Instance(MlabSceneModel, ())

    # The data source
    data_src = Instance(Source)

    # The image plane widgets of the 3D scene
    ipw_3d_x = Instance(PipelineBase)
    ipw_3d_y = Instance(PipelineBase)
    ipw_3d_z = Instance(PipelineBase)

    # The cursors on each view:
    cursors = Dict()

    disable_render = Bool

    _axis_names = dict(x=0, y=1, z=2)

    #---------------------------------------------------------------------------
    # Object interface
    #---------------------------------------------------------------------------
    def __init__(self, **traits):
        super(VolumeSlicer, self).__init__(**traits)
        # Force the creation of the image_plane_widgets:
        self.ipw_3d_x
        self.ipw_3d_y
        self.ipw_3d_z


    #---------------------------------------------------------------------------
    # Default values
    #---------------------------------------------------------------------------
    def _position_default(self):
        return 0.5*np.array(self.data.shape)

    def _data_src_default(self):
        return mlab.pipeline.scalar_field(self.data,
                            figure=self.scene3d.mayavi_scene,
                            name='Data',)

    def make_ipw_3d(self, axis_name):
```

```
        ipw = mlab.pipeline.image_plane_widget(self.data_src,
                        figure=self.scene3d.mayavi_scene,
                        plane_orientation='%s_axes' % axis_name,
                        name='Cut %s' % axis_name)
        return ipw

    def _ipw_3d_x_default(self):
        return self.make_ipw_3d('x')

    def _ipw_3d_y_default(self):
        return self.make_ipw_3d('y')

    def _ipw_3d_z_default(self):
        return self.make_ipw_3d('z')


    #-----------------------------------------------------------------------------
    # Scene activation callbacks
    #-----------------------------------------------------------------------------
    @on_trait_change('scene3d.activated')
    def display_scene3d(self):
        outline = mlab.pipeline.outline(self.data_src,
                        figure=self.scene3d.mayavi_scene,
                        )
        self.scene3d.mlab.view(40, 50)
        # Interaction properties can only be changed after the scene
        # has been created, and thus the interactor exists
        for ipw in (self.ipw_3d_x, self.ipw_3d_y, self.ipw_3d_z):
            ipw.ipw.interaction = 0
        self.scene3d.scene.background = (0, 0, 0)
        # Keep the view always pointing up
        self.scene3d.scene.interactor.interactor_style = \
                                    tvtk.InteractorStyleTerrain()
        self.update_position()


    def make_side_view(self, axis_name):
        scene = getattr(self, 'scene_%s' % axis_name)
        scene.scene.parallel_projection = True
        ipw_3d  = getattr(self, 'ipw_3d_%s' % axis_name)

        # We create the image_plane_widgets in the side view using a
        # VTK dataset pointing to the data on the corresponding
        # image_plane_widget in the 3D view (it is returned by
        # ipw_3d._get_reslice_output())
        ipw = mlab.pipeline.image_plane_widget(
                            ipw_3d.ipw._get_reslice_output(),
                            plane_orientation='z_axes',
                            vmin=self.data.min(),
                            vmax=self.data.max(),
                            figure=scene.mayavi_scene,
                            name='Cut view %s' % axis_name,
                            )
        setattr(self, 'ipw_%s' % axis_name, ipw)

        # Make left-clicking create a crosshair
        ipw.ipw.left_button_action = 0
```

```
        x, y, z = self.position
        cursor = mlab.points3d(x, y, z,
                               mode='axes',
                               color=(0, 0, 0),
                               scale_factor=2*max(self.data.shape),
                               figure=scene.mayavi_scene,
                               name='Cursor view %s' % axis_name,
                           )
        self.cursors[axis_name] = cursor

        # Add a callback on the image plane widget interaction to
        # move the others
        this_axis_number = self._axis_names[axis_name]
        def move_view(obj, evt):
            # Disable rendering on all scene
            position = list(obj.GetCurrentCursorPosition())[:2]
            position.insert(this_axis_number, self.position[this_axis_number])
            # We need to special case y, as the view has been rotated.
            if axis_name is 'y':
                position = position[::-1]
            self.position = position

        ipw.ipw.add_observer('InteractionEvent', move_view)
        ipw.ipw.add_observer('StartInteractionEvent', move_view)

        # Center the image plane widget
        ipw.ipw.slice_position = 0.5*self.data.shape[
                                        self._axis_names[axis_name]]

        # 2D interaction: only pan and zoom
        scene.scene.interactor.interactor_style = \
                                tvtk.InteractorStyleImage()
        scene.scene.background = (0, 0, 0)

        # Some text:
        mlab.text(0.01, 0.8, axis_name, width=0.08)

        # Choose a view that makes sens
        views = dict(x=(0, 0), y=(90, 180), z=(0, 0))
        mlab.view(*views[axis_name],
                  focalpoint=0.5*np.array(self.data.shape),
                  figure=scene.mayavi_scene)
        scene.scene.camera.parallel_scale = 0.52*np.mean(self.data.shape)

    @on_trait_change('scene_x.activated')
    def display_scene_x(self):
        return self.make_side_view('x')

    @on_trait_change('scene_y.activated')
    def display_scene_y(self):
        return self.make_side_view('y')

    @on_trait_change('scene_z.activated')
    def display_scene_z(self):
        return self.make_side_view('z')


    #---------------------------------------------------------------------------
```

```
    # Traits callback
    #---------------------------------------------------------------------------
    @on_trait_change('position')
    def update_position(self):
        """ Update the position of the cursors on each side view, as well
            as the image_plane_widgets in the 3D view.
        """
        # First disable rendering in all scenes to avoid unecessary
        # renderings
        self.disable_render = True

        # For each axis, move image_plane_widget and the cursor in the
        # side view
        for axis_name, axis_number in self._axis_names.iteritems():
            ipw3d = getattr(self, 'ipw_3d_%s' % axis_name)
            ipw3d.ipw.slice_position = self.position[axis_number]

            # Go from the 3D position, to the 2D coordinates in the
            # side view
            position2d = list(self.position)
            position2d.pop(axis_number)
            if axis_name is 'y':
                position2d = position2d[::-1]
            # Move the cursor
            self.cursors[axis_name].mlab_source.set(
                                                x=[position2d[0]],
                                                y=[position2d[1]],
                                                z=[0])

        # Finally re-enable rendering
        self.disable_render = False

    @on_trait_change('disable_render')
    def _render_enable(self):
        for scene in (self.scene3d, self.scene_x, self.scene_y,
                                                  self.scene_z):
            scene.scene.disable_render = self.disable_render


    #---------------------------------------------------------------------------
    # The layout of the dialog created
    #---------------------------------------------------------------------------
    view = View(HGroup(
                  Group(
                       Item('scene_y',
                            editor=SceneEditor(scene_class=Scene),
                            height=250, width=300),
                       Item('scene_z',
                            editor=SceneEditor(scene_class=Scene),
                            height=250, width=300),
                       show_labels=False,
                  ),
                  Group(
                       Item('scene_x',
                            editor=SceneEditor(scene_class=Scene),
                            height=250, width=300),
                       Item('scene3d',
                            editor=SceneEditor(scene_class=Scene),
```

```
                            height=250, width=300),
                       show_labels=False,
                  ),
                ),
                resizable=True,
                title='Volume Slicer',
                )


################################################################################
if __name__ == '__main__':
    # Create some data
    x, y, z = np.ogrid[-5:5:64j, -5:5:64j, -5:5:64j]
    data = np.sin(3*x)/x + 0.05*z**2 + np.cos(3*y)

    m = VolumeSlicer(data=data)
    m.configure_traits()
```

10.3.16 Coil design application example

An full-blown application demoing a domain-specific usecase with Mayavi: interactive design of coils.

This is example of electromagnetic coils design, an application is built to enable a user to interactively position current loops while visualizing the resulting magnetic field. For this purpose, it is best to use object-oriented programming. Each current loop is written as an object (the *Loop* class), with position, radius and direction attributes, and that knows how to calculate the magnetic field it generates: its *Bnorm* is a property, that is recomputed when the loop characteristic changes. These loop objects are available to the main application class as a list. The total magnetic field created is the sum of each individual magnetic field. It can be visualized via a Mayavi scene embedded in the application class. As we use Traited objects for the current loops, a dialog enabling modification of their attributes can be generated by Traits and embedded in our application.

The full power of Mayavi is available to the application. Via the pipeline tree view, the user can modify the visualization. Familiar interaction and movements are possible in the figure. So is saving the visualization, or loading data. In addition, as the visualization model, described by the pipeline, is separated from the data that is visualized, contained in the data source, any visualization module added by the user will update when coils are added or changed.

Simpler examples of magnetic field visualization can be found on *Magnetic field lines example* and *Magnetic field example*. The material required to understand this example is covered in section *Building applications using Mayavi*.

Source code: coil_design_application.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2009, Enthought, Inc.
# License: BSD Style.

# Major scientific library imports
import numpy as np
from scipy import linalg, special

# Enthought library imports:
from enthought.traits.api import HasTraits, Array, CFloat, List, \
   Instance, on_trait_change, Property
from enthought.traits.ui.api import Item, View, ListEditor, \
        HSplit, VSplit
from enthought.mayavi.core.ui.api import EngineView, MlabSceneModel, \
        SceneEditor
```

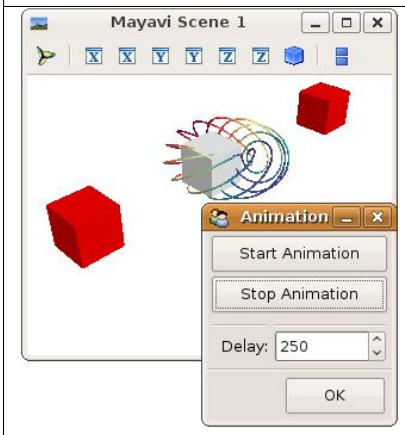
```
################################################################################
# Module-level variables

# The grid of points on which we want to evaluate the field
X, Y, Z = np.mgrid[-0.15:0.15:20j, -0.15:0.15:20j, -0.15:0.15:20j]
# Avoid rounding issues :
f = 1e4  # this gives the precision we are interested by :
X = np.round(X * f) / f
Y = np.round(Y * f) / f
Z = np.round(Z * f) / f

################################################################################
# A current loop class
class Loop(HasTraits):
    """ A current loop class.
    """

    #--------------------------------------------------------------------------
    # Public traits
    #--------------------------------------------------------------------------
    direction = Array(float, value=(0, 0, 1), cols=3,
                    shape=(3,), desc='directing vector of the loop',
                    enter_set=True, auto_set=False)

    radius    = CFloat(0.1, desc='radius of the loop',
                    enter_set=True, auto_set=False)

    position  = Array(float, value=(0, 0, 0), cols=3,
                    shape=(3,), desc='position of the center of the loop',
                    enter_set=True, auto_set=False)

    _plot      = None

    Bnorm   = Property(depends_on='direction,position,radius')

    view = View('position', 'direction', 'radius', '_')


    #--------------------------------------------------------------------------
    # Loop interface
    #--------------------------------------------------------------------------
    def base_vectors(self):
        """ Returns 3 orthognal base vectors, the first one colinear to
            the axis of the loop.
        """
        # normalize n
        n = self.direction / (self.direction**2).sum(axis=-1)

        # choose two vectors perpendicular to n
        # choice is arbitrary since the coil is symetric about n
        if  np.abs(n[0])==1 :
            l = np.r_[n[2], 0, -n[0]]
        else:
            l = np.r_[0, n[2], -n[1]]

        l /= (l**2).sum(axis=-1)
        m = np.cross(n, l)
```

```
        return n, l, m


    @on_trait_change('Bnorm')
    def redraw(self):
        if hasattr(self, 'app') and self.app.scene._renderer is not None:
            self.display()
            self.app.visualize_field()


    def display(self):
        """
        Display the coil in the 3D view.
        """
        n, l, m = self.base_vectors()
        theta = np.linspace(0, 2*np.pi, 30)[..., np.newaxis]
        coil = self.radius*(np.sin(theta)*l + np.cos(theta)*m)
        coil += self.position
        coil_x, coil_y, coil_z = coil.T
        if self._plot is None:
            self._plot = self.app.scene.mlab.plot3d(coil_x, coil_y, coil_z,
                                    tube_radius=0.007, color=(0, 0, 1),
                                    name='Coil')
        else:
            self._plot.mlab_source.set(x=coil_x, y=coil_y, z=coil_z)


    def _get_Bnorm(self):
        """
        returns the magnetic field for the current loop calculated
        from eqns (1) and (2) in Phys Rev A Vol. 35, N 4, pp. 1535-1546; 1987.
        """
        ### Translate the coordinates in the coil's frame
        n, l, m = self.base_vectors()
        R       = self.radius
        r0      = self.position
        r       = np.c_[np.ravel(X), np.ravel(Y), np.ravel(Z)]

        # transformation matrix coil frame to lab frame
        trans = np.vstack((l, m, n))

        r -= r0          #point location from center of coil
        r = np.dot(r, linalg.inv(trans) )             #transform vector to coil frame

        #### calculate field

        # express the coordinates in polar form
        x = r[:, 0]
        y = r[:, 1]
        z = r[:, 2]
        rho = np.sqrt(x**2 + y**2)
        theta = np.arctan(x/y)

        E = special.ellipe((4 * R * rho)/( (R + rho)**2 + z**2))
        K = special.ellipk((4 * R * rho)/( (R + rho)**2 + z**2))
        Bz =  1/np.sqrt((R + rho)**2 + z**2) * (
                    K
                  + E * (R**2 - rho**2 - z**2)/((R - rho)**2 + z**2)
```

```
                )
        Brho = z/(rho*np.sqrt((R + rho)**2 + z**2)) * (
                -K
                + E * (R**2 + rho**2 + z**2)/((R - rho)**2 + z**2)
                )
        # On the axis of the coil we get a divided by zero here. This returns a
        # NaN, where the field is actually zero :
        Brho[np.isnan(Brho)] = 0

        B = np.c_[np.cos(theta)*Brho, np.sin(theta)*Brho, Bz ]

        # Rotate the field back in the lab's frame
        B = np.dot(B, trans)

        Bx, By, Bz = B.T
        Bx = np.reshape(Bx, X.shape)
        By = np.reshape(By, X.shape)
        Bz = np.reshape(Bz, X.shape)

        Bnorm = np.sqrt(Bx**2 + By**2 + Bz**2)

        # We need to threshold ourselves, rather than with VTK, to be able
        # to use an ImageData
        Bmax = 10 * np.median(Bnorm)

        Bx[Bnorm > Bmax] = np.NAN
        By[Bnorm > Bmax] = np.NAN
        Bz[Bnorm > Bmax] = np.NAN
        Bnorm[Bnorm > Bmax] = np.NAN

        self.Bx = Bx
        self.By = By
        self.Bz = Bz
        return Bnorm


################################################################################
# The application object
class Application(HasTraits):

    scene = Instance(MlabSceneModel, (), editor=SceneEditor())

    # The mayavi engine view.
    engine_view = Instance(EngineView)

    coils = List(Instance(Loop, (), allow_none=False),
                        editor=ListEditor(style='custom'),
                        value=[ Loop(position=(0, 0, -0.05), ),
                                 Loop(position=(0, 0,  0.05), ), ])


    Bx    = Array(value=np.zeros_like(X))
    By    = Array(value=np.zeros_like(X))
    Bz    = Array(value=np.zeros_like(X))
    Bnorm = Array(value=np.zeros_like(X))

    vector_field = None
```

```
    def __init__(self, **traits):
        HasTraits.__init__(self, **traits)
        self.engine_view = EngineView(engine=self.scene.engine)


    @on_trait_change('scene.activated,coils')
    def init_view(self):
        if self.scene._renderer is not None:
            self.scene.scene_editor.background = (0, 0, 0)
            for coil in self.coils:
                coil.app = self
                coil.display()

            self.visualize_field()

    def visualize_field(self):
        self.Bx    = np.zeros_like(X)
        self.By    = np.zeros_like(X)
        self.Bz    = np.zeros_like(X)
        self.Bnorm = np.zeros_like(X)
        self.scene.scene.disable_render = True
        for coil in self.coils:
            self.Bnorm += coil.Bnorm
            self.Bx += coil.Bx
            self.By += coil.By
            self.Bz += coil.Bz

        if self.vector_field is None:
            self.vector_field = self.scene.mlab.pipeline.vector_field(
                                X, Y, Z, self.Bx, self.By, self.Bz,
                                scalars=self.Bnorm,
                                name='B field')
            vectors = self.scene.mlab.pipeline.vectors(self.vector_field,
                                mode='arrow', resolution=10,
                                mask_points=6, colormap='YlOrRd',
                                scale_factor=2*np.abs(X[0,0,0]
                                                      -X[1,1,1]) )
            vectors.module_manager.vector_lut_manager.reverse_lut = True
            vectors.glyph.mask_points.random_mode = False
            self.scene.mlab.axes()
            self.scp = self.scene.mlab.pipeline.scalar_cut_plane(
                                                    self.vector_field,
                                                    colormap='hot')
        else:
            # Modify in place the data source. The visualization will
            # update automaticaly
            self.vector_field.mlab_source.set(u=self.Bx, v=self.By, w=self.Bz,
                                              scalars=self.Bnorm)
        self.scene.scene.disable_render = False


    view = View(HSplit(
                    VSplit(Item(name='engine_view',
                                style='custom',
                                resizable=True),
                           Item('coils', springy=True),
                        show_labels=False),
                        'scene',
```

```
                        show_labels=False),
                    resizable=True,
                    title='Coils...',
                    height=0.8,
                    width=0.8,
                )


######################################################################
if __name__ == '__main__':
    app = Application()
    app.configure_traits()
```



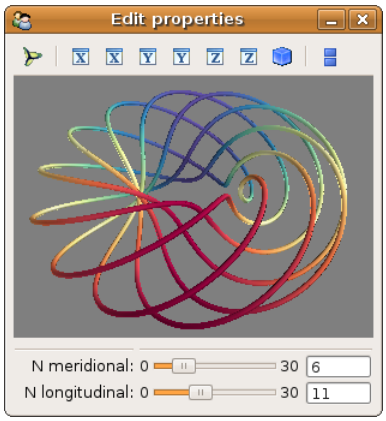
Mlab visual example *Mlab traits ui example* *Wx embedding example* *Multiple mlab scene models example* *Multiple*
A very simple example to show how you can use TVTK's visual module with mlab and create simple animations.

Mlab traits ui example A simple example of how to use mayavi.mlab inside a traits UI dialog.

Wx embedding example This example shows to embed a Mayavi view in a wx frame.

Multiple mlab scene models example Example showing a dialog with multiple embedded scenes.

Multiple engines example An example to show how you can have multiple engines in one application.



Mlab interactive dialog example An example of how to modify the data visualized via an interactive dialog.

Wx mayavi embed in notebook example This example show how to embedded Mayavi in a wx notebook.

Subclassing mayavi application example This script demonstrates how one can script Mayavi by subclassing the application, create a new VTK scene and create a few simple modules.

Qt embedding example This example demonstrates using Mayavi as a component of a large Qt application.

10.4 Advanced visualization examples

Data visualization using the core Mayavi API, object-oriented, and with more fine control than mlab.

10.4.1 Polydata example

An example of how to generate a polydata dataset using numpy arrays.

The example is similar to tvtk/examples/tiny_mesh.py. Also shown is a way to visualize this data with mayavi2. The script can be run like so:

```
$ mayavi2 -x polydata.py
```

It can be alternatively run as:

```
$ python polydata.py
```

Source code: polydata.py

```
# Author: Prabhu Ramachandran <prabhu at aero dot iitb dot ac dot in>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD style.

from numpy import array
from enthought.tvtk.api import tvtk
from enthought.mayavi.scripts import mayavi2

# The numpy array data.
points = array([[0,0,0], [1,0,0], [0,1,0], [0,0,1]], 'f')
triangles = array([[0,1,3], [0,3,2], [1,2,3], [0,2,1]])
temperature = array([10., 20., 30., 40.])

# The TVTK dataset.
mesh = tvtk.PolyData(points=points, polys=triangles)
mesh.point_data.scalars = temperature
mesh.point_data.scalars.name = 'Temperature'

# Uncomment the next two lines to save the dataset to a VTK XML file.
#w = tvtk.XMLPolyDataWriter(input=mesh, file_name='polydata.vtp')
#w.write()

# Now view the data.
@mayavi2.standalone
def view():
    from enthought.mayavi.sources.vtk_data_source import VTKDataSource
    from enthought.mayavi.modules.surface import Surface

    mayavi.new_scene()
    src = VTKDataSource(data = mesh)
    mayavi.add_source(src)
    s = Surface()
    mayavi.add_module(s)

if __name__ == '__main__':
    view()
```

10.4.2 Offscreen example

A simple example of how you can use Mayavi without using Envisage or the Mayavi Envisage application and do off screen rendering.

On Linux/Mac, with VTK < 5.2, you should see a small black window popup and disappear, see the section *Off screen rendering* to avoid this. On Win32 you will not see any windows popping up at all. In the end you should have an offscreen.png image in the same directory with the rendered visualization.

It can be run as:

```
$ python offscreen.py
```

Source code: offscreen.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD Style.

from os.path import join, abspath, dirname

# The offscreen Engine.
from enthought.mayavi.api import OffScreenEngine

# Usual MayaVi imports
from enthought.mayavi.scripts.util import get_data_dir
from enthought.mayavi.sources.api import VTKXMLFileReader
from enthought.mayavi.modules.api import Outline, ScalarCutPlane, Streamline


def main():
    # Create the MayaVi offscreen engine and start it.
    e = OffScreenEngine()
    # Starting the engine registers the engine with the registry and
    # notifies others that the engine is ready.
    e.start()

    # Create a new scene.
    win = e.new_scene()

    # Now setup a normal MayaVi pipeline.
    src = VTKXMLFileReader()
    src.initialize(join(get_data_dir(dirname(abspath(__file__))),
                        'fire_ug.vtu'))
    e.add_source(src)
    e.add_module(Outline())
    e.add_module(ScalarCutPlane())
    e.add_module(Streamline())
    win.scene.isometric_view()
    # Change the size argument to anything you want.
    win.scene.save('offscreen.png', size=(800, 800))


if __name__ == '__main__':
    main()
```

10.4.3 Surf regular mlab example

Shows how to view data created by *enthought.tvtk.tools.mlab* with mayavi2.

Source code: surf_regular_mlab.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2006-2007, Enthought Inc.
# License: BSD Style.

import numpy

from enthought.mayavi.scripts import mayavi2
from enthought.tvtk.tools import mlab
from enthought.mayavi.sources.vtk_data_source import VTKDataSource
from enthought.mayavi.filters.warp_scalar import WarpScalar
from enthought.mayavi.modules.outline import Outline
from enthought.mayavi.modules.surface import Surface


def make_data():
    """Make some test numpy data and create a TVTK data object from it
    that we will visualize.
    """
    def f(x, y):
        """Some test function.
        """
        return numpy.sin(x*y)/(x*y)

    x = numpy.arange(-7., 7.05, 0.1)
    y = numpy.arange(-5., 5.05, 0.05)
    s = mlab.SurfRegular(x, y, f)
    return s.data

def add_data(tvtk_data):
    """Add a TVTK data object `tvtk_data` to the mayavi pipleine.
    """
    d = VTKDataSource()
    d.data = tvtk_data
    mayavi.add_source(d)

def surf_regular():
    """Now visualize the data as done in mlab.
    """
    w = WarpScalar()
    mayavi.add_filter(w)
    o = Outline()
    s = Surface()
    mayavi.add_module(o)
    mayavi.add_module(s)

@mayavi2.standalone
def main():
    mayavi.new_scene()
    d = make_data()
    add_data(d)
    surf_regular()
```

```
if __name__ == '__main__':
    main()
```

10.4.4 Structured points2d example

An example of how to generate a 2D structured points dataset using numpy arrays. Also shown is a way to visualize this data with the mayavi2 application.

The script can be run like so:

```
$ mayavi2 -x structured_points2d.py
```

Alternatively, it can be run as:

```
$ python structured_points2d.py
```

Source code: structured_points2d.py

```
# Author: Prabhu Ramachandran <prabhu at aero dot iitb dot ac dot in>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD style.

from numpy import arange, sqrt, sin
from enthought.tvtk.api import tvtk
from enthought.mayavi.scripts import mayavi2

# Generate the scalar values.
x = (arange(0.1, 50.0)-25)/2.0
y = (arange(0.1, 50.0)-25)/2.0
r = sqrt(x[:,None]**2+y**2)
z = 5.0*sin(r)/r  #

# Make the tvtk dataset.
# tvtk.ImageData is identical and could also be used here.
spoints = tvtk.StructuredPoints(origin=(-12.5,-12.5,0),
                                spacing=(0.5,0.5,1),
                                dimensions=(50,50,1))
# Transpose the array data due to VTK's implicit ordering. VTK assumes
# an implicit ordering of the points: X co-ordinate increases first, Y
# next and Z last.  We flatten it so the number of components is 1.
spoints.point_data.scalars = z.T.flatten()
spoints.point_data.scalars.name = 'scalar'

# Uncomment the next two lines to save the dataset to a VTK XML file.
#w = tvtk.XMLImageDataWriter(input=spoints, file_name='spoints2d.vti')
#w.write()

# Now view the data.
@mayavi2.standalone
def view():
    from enthought.mayavi.sources.vtk_data_source import VTKDataSource
    from enthought.mayavi.filters.warp_scalar import WarpScalar
    from enthought.mayavi.filters.poly_data_normals import PolyDataNormals
    from enthought.mayavi.modules.surface import Surface

    mayavi.new_scene()
```

```
    src = VTKDataSource(data = spoints)
    mayavi.add_source(src)
    mayavi.add_filter(WarpScalar())
    mayavi.add_filter(PolyDataNormals())
    s = Surface()
    mayavi.add_module(s)

if __name__ == '__main__':
    view()
```

10.4.5 Glyph example

This script demonstrates using the Mayavi core API to add a VectorCutPlane, split the pipeline using a MaskPoints filter and then view the filtered data with the Glyph module.

Source code: glyph.py

```
# Author: Prabhu Ramachandran <prabhu_r@users.sf.net>
# Copyright (c) 2005-2008, Enthought, Inc.
# License: BSD Style.

# Standard library imports
from os.path import join, abspath, dirname

# Enthought library imports
from enthought.mayavi.scripts import mayavi2
from enthought.mayavi.sources.vtk_xml_file_reader import VTKXMLFileReader
from enthought.mayavi.modules.outline import Outline
from enthought.mayavi.modules.glyph import Glyph
from enthought.mayavi.modules.vector_cut_plane import VectorCutPlane
from enthought.mayavi.filters.mask_points import MaskPoints

@mayavi2.standalone
def glyph():
    """The script itself.  We needn't have defined a function but
    having a function makes this more reusable.
    """
    # 'mayavi' is always defined on the interpreter.
    # Create a new VTK scene.
    mayavi.new_scene()

    # Read a VTK (old style) data file.
    r = VTKXMLFileReader()
    r.initialize(join(mayavi2.get_data_dir(dirname(abspath(__file__))),
                      'fire_ug.vtu'))
    mayavi.add_source(r)

    # Create an outline and a vector cut plane.
    mayavi.add_module(Outline())

    v = VectorCutPlane()
    mayavi.add_module(v)
    v.glyph.color_mode = 'color_by_scalar'

    # Now mask the points and show glyphs (we could also use
    # Vectors but glyphs are a bit more generic)
```

```
    m = MaskPoints()
    m.filter.set(on_ratio=10, random_mode=True)
    mayavi.add_filter(m)

    g = Glyph()
    mayavi.add_module(g)
    # Note that this adds the module to the filtered output.
    g.glyph.scale_mode = 'scale_by_vector'
    # Use arrows to view the scalars.
    gs = g.glyph.glyph_source
    gs.glyph_source = gs.glyph_dict['arrow_source']


if __name__ == '__main__':
    glyph()
```

10.4.6 Contour contour example

This example shows how you can produce contours on an IsoSurface.

Source code: contour_contour.py

```
# Author: Prabhu Ramachandran <prabhu [at] aero . iitb . ac . in>
# Copyright (c) 2008,  Enthought, Inc.
# License: BSD Style.

# Standard library imports
from os.path import join, abspath, dirname

# Mayavi imports.
from enthought.mayavi.scripts import mayavi2
from enthought.mayavi.sources.api import VTKXMLFileReader
from enthought.mayavi.filters.contour import Contour
from enthought.mayavi.filters.api import PolyDataNormals
from enthought.mayavi.filters.set_active_attribute import SetActiveAttribute
from enthought.mayavi.modules.api import Surface, Outline

@mayavi2.standalone
def main():
    mayavi.new_scene()

    # Read the example data: fire_ug.vtu.
    r = VTKXMLFileReader()
    filename = join(mayavi2.get_data_dir(dirname(abspath(__file__))),
                    'fire_ug.vtu')
    r.initialize(filename)
    mayavi.add_source(r)
    # Set the active point scalars to 'u'.
    r.point_scalars_name = 'u'

    # Simple outline for the data.
    o = Outline()
    mayavi.add_module(o)

    # Branch the pipeline with a contour -- the outline above is
    # directly attached to the source whereas the contour below is a
```

```
    # filter and will branch the flow of data.   An isosurface in the
    # 'u' data attribute is generated and normals generated for it.

    c = Contour()
    mayavi.add_filter(c)
    n = PolyDataNormals()
    mayavi.add_filter(n)

    # Now we want to show the temperature 't' on the surface of the 'u'
    # iso-contour.  This is easily done by using the SetActiveAttribute
    # filter below.

    aa = SetActiveAttribute()
    mayavi.add_filter(aa)
    aa.point_scalars_name = 't'

    # Now view the iso-contours of 't' with a Surface filter.
    s = Surface(enable_contours=True)
    mayavi.add_module(s)


if __name__ == "__main__":
    main()
```

10.4.7 Scatter plot example

An example of plotting scatter points with Mayavi's core API.

This script creates a bunch of random points with random scalar data and then shows these as a "scatter" plot of points. The script illustrates how to

1. create a dataset easily using tvtk and numpy,
2. use a created dataset in Mayavi and visualize it.

This example achieve the same functionnality as mlab's points3d function (`enthought.mayavi.mlab.points3d()`), but explicitely creating the objects and adding them to the pipeline engine via the Mayavi core API. Compared to using mlab, this method has the advantage of giving more control on which objects are created, and there life cycle.

Run this script like so:

```
$ mayavi2 -x scatter_plot.py
```

Alternatively it can be run as:

```
$ python scatter_plot.py
```

Source code: scatter_plot.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2007 Prabhu Ramachandran.
# License: BSD Style.

import numpy as np
from enthought.tvtk.api import tvtk
from enthought.mayavi.scripts import mayavi2
```

```
@mayavi2.standalone
def main():
    # Create some random points to view.
    pd = tvtk.PolyData()
    pd.points = np.random.random((1000, 3))
    verts = np.arange(0, 1000, 1)
    verts.shape = (1000, 1)
    pd.verts = verts
    pd.point_data.scalars = np.random.random(1000)
    pd.point_data.scalars.name = 'scalars'

    # Now visualize it using mayavi2.
    from enthought.mayavi.sources.vtk_data_source import VTKDataSource
    from enthought.mayavi.modules.outline import Outline
    from enthought.mayavi.modules.surface import Surface

    mayavi.new_scene()
    d = VTKDataSource()
    d.data = pd
    mayavi.add_source(d)
    mayavi.add_module(Outline())
    s = Surface()
    mayavi.add_module(s)
    s.actor.property.set(representation='p', point_size=2)
    # You could also use glyphs to render the points via the Glyph module.

if __name__ == '__main__':
    main()
```

10.4.8 Structured points3d example

An example of how to generate a 3D structured points dataset using numpy arrays. Also shown is a way to visualize this data with the mayavi2 application.

The script can be run like so:

```
$ mayavi2 -x structured_points3d.py
```

Alternatively, it can be run as:

```
$ python structured_points3d.py
```

Source code: structured_points3d.py

```
# Author: Prabhu Ramachandran <prabhu at aero dot iitb dot ac dot in>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD style.

from enthought.tvtk.api import tvtk
from enthought.tvtk.array_handler import get_vtk_array_type
from numpy import array, ogrid, sin, ravel
from enthought.mayavi.scripts import mayavi2

# Make the data.
```

```
dims = array((128, 128, 128))
vol = array((-5., 5, -5, 5, -5, 5))
origin = vol[::2]
spacing = (vol[1::2] - origin)/(dims -1)
xmin, xmax, ymin, ymax, zmin, zmax = vol
x, y, z = ogrid[xmin:xmax:dims[0]*1j,
                ymin:ymax:dims[1]*1j,
                zmin:zmax:dims[2]*1j]
x, y, z = [t.astype('f') for t in (x, y, z)]
scalars = sin(x*y*z)/(x*y*z)

# Make the tvtk dataset.
spoints = tvtk.StructuredPoints(origin=origin, spacing=spacing,
                                dimensions=dims)
# The copy makes the data contiguous and the transpose makes it
# suitable for display via tvtk.  Note that it is not necessary to
# make the data contiguous since in that case the array is copied
# internally.
s = scalars.transpose().copy()
spoints.point_data.scalars = ravel(s)
spoints.point_data.scalars.name = 'scalars'

# This is needed in slightly older versions of VTK (like the 5.0.2
# release) to prevent a segfault.  VTK does not detect the correct
# data type.
spoints.scalar_type = get_vtk_array_type(s.dtype)

# Uncomment the next two lines to save the dataset to a VTK XML file.
#w = tvtk.XMLImageDataWriter(input=spoints, file_name='spoints3d.vti')
#w.write()

# Now view the data.
@mayavi2.standalone
def view():
    from enthought.mayavi.sources.vtk_data_source import VTKDataSource
    from enthought.mayavi.modules.outline import Outline
    from enthought.mayavi.modules.image_plane_widget import ImagePlaneWidget

    mayavi.new_scene()
    src = VTKDataSource(data = spoints)
    mayavi.add_source(src)
    mayavi.add_module(Outline())
    mayavi.add_module(ImagePlaneWidget())

if __name__ == '__main__':
    view()
```

10.4.9 Streamline example

This script demonstrates how one can script Mayavi's core API to display streamlines and an iso surface.

Source code: streamline.py

```
# Author: Prabhu Ramachandran <prabhu_r@users.sf.net>
# Copyright (c) 2005-2007, Enthought, Inc.
# License: BSD Style.
```

```
# Standard library imports
from os.path import join, abspath, dirname

# Enthought library imports
from enthought.mayavi.scripts import mayavi2
from enthought.mayavi.sources.vtk_xml_file_reader import VTKXMLFileReader
from enthought.mayavi.sources.vrml_importer import VRMLImporter
from enthought.mayavi.modules.outline import Outline
from enthought.mayavi.modules.streamline import Streamline
from enthought.mayavi.modules.iso_surface import IsoSurface

def setup_data(fname):
    """Given a VTK XML file name 'fname', this creates a mayavi2
    reader for it and adds it to the pipeline.  It returns the reader
    created.
    """
    r = VTKXMLFileReader()
    r.initialize(fname)
    mayavi.add_source(r)
    return r

def show_vrml(fname):
    """Given a VRML file name it imports it into the scene.
    """
    r = VRMLImporter()
    r.initialize(fname)
    mayavi.add_source(r)
    return r

def streamline():
    """Sets up the mayavi pipeline for the visualization.
    """
    # Create an outline for the data.
    o = Outline()
    mayavi.add_module(o)

    s = Streamline(streamline_type='tube')
    mayavi.add_module(s)
    s.stream_tracer.integration_direction = 'both'
    s.seed.widget.center = 3.5, 0.625, 1.25
    s.module_manager.scalar_lut_manager.show_scalar_bar = True

    i = IsoSurface()
    mayavi.add_module(i)
    i.contour.contours[0] = 550
    i.actor.property.opacity = 0.5

@mayavi2.standalone
def main():
    mayavi.new_scene()

    data_dir = mayavi2.get_data_dir(dirname(abspath(__file__)))
    vrml_fname = join(data_dir, 'room_vis.wrl')
    r = show_vrml(vrml_fname)

    fname = join(data_dir, 'fire_ug.vtu')
    r = setup_data(fname)
```

```
    streamline()


if __name__ == '__main__':
    main()
```

10.4.10 Numeric source example

This script demonstrates how to create a numpy array data and visualize it as image data using a few modules.

Source code: numeric_source.py

```
# Author: Prabhu Ramachandran <prabhu_r@users.sf.net>
# Copyright (c) 2005-2008, Enthought, Inc.
# License: BSD Style.

# Standard library imports
import numpy

# Enthought library imports
from enthought.mayavi.scripts import mayavi2
from enthought.mayavi.sources.array_source import ArraySource
from enthought.mayavi.modules.outline import Outline
from enthought.mayavi.modules.image_plane_widget import ImagePlaneWidget


def make_data(dims=(128, 128, 128)):
    """Creates some simple array data of the given dimensions to test
    with."""
    np = dims[0]*dims[1]*dims[2]

    # Create some scalars to render.
    x, y, z = numpy.ogrid[-5:5:dims[0]*1j,-5:5:dims[1]*1j,-5:5:dims[2]*1j]
    x = x.astype('f')
    y = y.astype('f')
    z = z.astype('f')

    scalars = (numpy.sin(x*y*z)/(x*y*z))
    # The copy makes the data contiguous and the transpose makes it
    # suitable for display via tvtk.  Please note that we assume here
    # that the ArraySource is configured to not transpose the data.
    s = numpy.transpose(scalars).copy()
    # Reshaping the array is needed since the transpose messes up the
    # dimensions of the data.  The scalars themselves are ravel'd and
    # used internally by VTK so the dimension does not matter for the
    # scalars.
    s.shape = s.shape[::-1]

    return s


@mayavi2.standalone
def view_numpy():
    """Example showing how to view a 3D numpy array in mayavi2.
    """
    # 'mayavi' is always defined on the interpreter.
```

```
    mayavi.new_scene()
    # Make the data and add it to the pipeline.
    data = make_data()
    src = ArraySource(transpose_input_array=False)
    src.scalar_data = data
    mayavi.add_source(src)
    # Visualize the data.
    o = Outline()
    mayavi.add_module(o)
    ipw = ImagePlaneWidget()
    mayavi.add_module(ipw)
    ipw.module_manager.scalar_lut_manager.show_scalar_bar = True

    ipw_y = ImagePlaneWidget()
    mayavi.add_module(ipw_y)
    ipw_y.ipw.plane_orientation = 'y_axes'


if __name__ == '__main__':
    view_numpy()
```

10.4.11 Image cursor filter example

Excample using the UserDefined filter to paint a cross-shaped cursor on data, in order to point out a special position.

We use the UserDefined filter *ImageCursor3D* to create the cursor. A Gaussian data field is painted with the cursor, and then visualized using the ImagePlaneWIdget module.

ImageCursor3D is one example among many of the use of the UserDefined, which allows to use TVTK filters that are not. See *Using the UserDefined filter* for more details. Also, another example using the UserDefined filter is provided in *Mri example*.

Selecting the UserDefined filter in the Mayavi pipeline is a convenient way to look for additional filters. This pops up a dialog called *TVTK class chooser*, with a *Search* field that allows to search for desired actions or properties. For example, searching for *cursor* returns several filters, among which Cursor3D and ImageCursor3D. As a rule of thumb, the name of TVTK filters acting on TVTK ImageData dataset starts with *Image* (ImageData is the type of VTK data set created by e.g. mlab.pipeline.scalar_field. See *Data representation in Mayavi* for more details about VTK datasets). In the dialog used to interactively add the UserDefined filet, we can therefore select *ImageCursor3D*. The documentation of the filter is displayed when selecting its name within the *Class name* field of the dialog.

Source code: image_cursor_filter.py

```
# Authors: Emmanuelle Gouillart <emmanuelle.gouillart@normalesup.org>
# and Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2009, Enthought, Inc.
# License: BSD Style.


from enthought.mayavi import mlab
import numpy as np

# Define Gaussian data field
x, y, z = np.ogrid[0:1:40j, 0:1:40j, 0:1:40j]
sig = 0.5
center = 0.5
g = np.exp(-((x-center)**2 + (y-center)**2 + (z-center)**2)/(2*sig**2))
```

```
##############################################################################

mlab.figure(fgcolor=(0, 0, 0), bgcolor=(1, 1, 1))

# Define the cursor
s = mlab.pipeline.scalar_field(g)
cursor = mlab.pipeline.user_defined(s, filter='ImageCursor3D')

# The TVTK filter used by Mayavi is accessible as the '.filter'
# attribute of the Mayavi filtered returned by user_defined.
# We can set the graphical properties of the cross via attributes of
# cursor.filter, and not of cursor itself. Here cursor is a Mayavi filter,
# that is an object that inserts in the Mayavi pipeline, whereas
# cursor.filter is the TVTK filter that actually does the work.

# Put the cursor at the center of the field volume (default is (0, 0, 0))
cursor.filter.cursor_position = np.array([20, 20, 20])
# Define the value of the cursor (default is 255) so that there is
# enough contrast between the cursor and the data values in the neighbourhood
# of the cursor. The cursor value is within the data value range so that
# the contrast of the data is not altered.
cursor.filter.cursor_value = 0
# Define the radius of the cross (the extent of the cross is 2xcursor_radius)
cursor.filter.cursor_radius = 10


# Display data and cursor using an image_plane_widget that intersects the
# cursor.
ipw = mlab.pipeline.image_plane_widget(cursor, plane_orientation='x_axes',
            slice_index=20)

# View
mlab.colorbar()
mlab.view(15, 70, 100, [20, 20, 20])
mlab.show()
```

10.4.12 Contour example

This script demonstrates how one can script Mayavi and use its contour related modules.

Source code: contour.py

```
# Author: Prabhu Ramachandran <prabhu_r@users.sf.net>
# Copyright (c) 2005-2008, Enthought, Inc.
# License: BSD Style.

# Standard library imports
from os.path import join, abspath, dirname

# Enthought library imports
from enthought.mayavi.scripts import mayavi2
from enthought.mayavi.sources.vtk_file_reader import VTKFileReader
from enthought.mayavi.modules.outline import Outline
from enthought.mayavi.modules.grid_plane import GridPlane
from enthought.mayavi.modules.contour_grid_plane import ContourGridPlane
from enthought.mayavi.modules.iso_surface import IsoSurface
```

```
from enthought.mayavi.modules.scalar_cut_plane import ScalarCutPlane

@mayavi2.standalone
def contour():
    """The script itself.  We needn't have defined a function but
    having a function makes this more reusable.
    """
    # 'mayavi' is always defined on the interpreter.
    # Create a new scene.
    mayavi.new_scene()

    # Read a VTK (old style) data file.
    r = VTKFileReader()
    filename = join(mayavi2.get_data_dir(dirname(abspath(__file__))),
                    'heart.vtk')
    r.initialize(filename)
    mayavi.add_source(r)

    # Create an outline for the data.
    o = Outline()
    mayavi.add_module(o)

    # Create three simple grid plane modules.
    # First normal to 'x' axis.
    gp = GridPlane()
    mayavi.add_module(gp)
    # Second normal to 'y' axis.
    gp = GridPlane()
    mayavi.add_module(gp)
    gp.grid_plane.axis = 'y'
    # Third normal to 'z' axis.
    gp = GridPlane()
    mayavi.add_module(gp)
    gp.grid_plane.axis = 'z'

    # Create one ContourGridPlane normal to the 'x' axis.
    cgp = ContourGridPlane()
    mayavi.add_module(cgp)
    # Set the position to the middle of the data.
    cgp.grid_plane.position = 15

    # Another with filled contours normal to 'y' axis.
    cgp = ContourGridPlane()
    mayavi.add_module(cgp)
    # Set the axis and position to the middle of the data.
    cgp.grid_plane.axis = 'y'
    cgp.grid_plane.position = 15
    cgp.contour.filled_contours = True

    # An isosurface module.
    iso = IsoSurface(compute_normals=True)
    mayavi.add_module(iso)
    iso.contour.contours = [220.0]

    # An interactive scalar cut plane.
    cp = ScalarCutPlane()
    mayavi.add_module(cp)
    cp.implicit_plane.normal = 0,0,1
```

```
if __name__ == '__main__':
    contour()
```

10.4.13 Unstructured grid example

A MayaVi example of how to generate an unstructured grid dataset using numpy arrays. Also shown is a way to visualize this data with mayavi2. The script can be run like so:

$ mayavi2 -x unstructured_grid.py

Alternatively, it can be run as:

$ python unstructured_grid.py

Author: Prabhu Ramachandran <prabhu at aero dot iitb dot ac dot in>

Copyright (c) 2007, Enthought, Inc. License: BSD style.

Source code: unstructured_grid.py

```
from numpy import array, arange, random
from enthought.tvtk.api import tvtk
from enthought.mayavi.scripts import mayavi2

def single_type_ug():
    """Simple example showing how to create an unstructured grid
    consisting of cells of a single type.
    """
    points = array([[0,0,0], [1,0,0], [0,1,0], [0,0,1], # tets
                    [1,0,0], [2,0,0], [1,1,0], [1,0,1],
                    [2,0,0], [3,0,0], [2,1,0], [2,0,1],
                    ], 'f')
    tets = array([[0, 1, 2, 3], [4, 5, 6, 7], [8, 9, 10, 11]])
    tet_type = tvtk.Tetra().cell_type
    ug = tvtk.UnstructuredGrid(points=points)
    ug.set_cells(tet_type, tets)
    return ug

def mixed_type_ug():
    """A slightly more complex example of how to generate an
    unstructured grid with different cell types.  Returns a created
    unstructured grid.
    """
    points = array([[0,0,0], [1,0,0], [0,1,0], [0,0,1], # tetra
                    [2,0,0], [3,0,0], [3,1,0], [2,1,0],
                    [2,0,1], [3,0,1], [3,1,1], [2,1,1], # Hex
                    ], 'f')
    # shift the points so we can show both.
    points[:,1] += 2.0
    # The cells
    cells = array([4, 0, 1, 2, 3, # tetra
                   8, 4, 5, 6, 7, 8, 9, 10, 11 # hex
                   ])
    # The offsets for the cells, i.e. the indices where the cells
    # start.
    offset = array([0, 5])
    tetra_type = tvtk.Tetra().cell_type # VTK_TETRA == 10
```

```
    hex_type = tvtk.Hexahedron().cell_type # VTK_HEXAHEDRON == 12
    cell_types = array([tetra_type, hex_type])
    # Create the array of cells unambiguously.
    cell_array = tvtk.CellArray()
    cell_array.set_cells(2, cells)
    # Now create the UG.
    ug = tvtk.UnstructuredGrid(points=points)
    # Now just set the cell types and reuse the ug locations and cells.
    ug.set_cells(cell_types, offset, cell_array)
    return ug

def save_xml(ug, file_name):
    """Shows how you can save the unstructured grid dataset to a VTK
    XML file."""
    w = tvtk.XMLUnstructuredGridWriter(input=ug, file_name=file_name)
    w.write()

# ----------------------------------------------------------------------
# Create the unstructured grids and assign scalars and vectors.
ug1 = single_type_ug()
ug2 = mixed_type_ug()
temperature = arange(0, 120, 10, 'd')
velocity = random.randn(12, 3)
for ug in ug1, ug2:
    ug.point_data.scalars = temperature
    ug.point_data.scalars.name = 'temperature'
    # Some vectors.
    ug.point_data.vectors = velocity
    ug.point_data.vectors.name = 'velocity'

# Uncomment this to save the file to a VTK XML file.
#save_xml(ug2, 'file.vtu')

# Now view the data.
@mayavi2.standalone
def view():
    from enthought.mayavi.sources.vtk_data_source import VTKDataSource
    from enthought.mayavi.modules.outline import Outline
    from enthought.mayavi.modules.surface import Surface
    from enthought.mayavi.modules.vectors import Vectors

    mayavi.new_scene()
    # The single type one
    src = VTKDataSource(data = ug1)
    mayavi.add_source(src)
    mayavi.add_module(Outline())
    mayavi.add_module(Surface())
    mayavi.add_module(Vectors())

    # Mixed types.
    src = VTKDataSource(data = ug2)
    mayavi.add_source(src)
    mayavi.add_module(Outline())
    mayavi.add_module(Surface())
    mayavi.add_module(Vectors())

if __name__ == '__main__':
    view()
```

10.4.14 Structured grid example

An example of how to generate a structured grid dataset using numpy arrays. Also shown is a way to visualize this data with the mayavi2 application.

The script can be run like so:

```
$ mayavi2 -x structured_grid.py
```

Alternatively, it can be run as:

```
$ python structured_grid.py
```

Source code: structured_grid.py

```
# Authors: Eric Jones <eric at enthought dot com>
#          Prabhu Ramachandran <prabhu at aero dot iitb dot ac dot in>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD style.

import numpy as np
from numpy import cos, sin, pi
from enthought.tvtk.api import tvtk
from enthought.mayavi.scripts import mayavi2

def generate_annulus(r=None, theta=None, z=None):
    """ Generate points for structured grid for a cylindrical annular
        volume.  This method is useful for generating a structured
        cylindrical mesh for VTK (and perhaps other tools).

        Parameters
        ----------
        r : array : The radial values of the grid points.
                    It defaults to linspace(1.0, 2.0, 11).

        theta : array : The angular values of the x axis for the grid
                        points. It defaults to linspace(0,2*pi,11).

        z: array : The values along the z axis of the grid points.
                   It defaults to linspace(0,0,1.0, 11).

        Return
        ------
        points : array
            Nx3 array of points that make up the volume of the annulus.
            They are organized in planes starting with the first value
            of z and with the inside "ring" of the plane as the first
            set of points.  The default point array will be 1331x3.
    """
    # Default values for the annular grid.
    if r is None: r = np.linspace(1.0, 2.0, 11)
    if theta is None: theta = np.linspace(0, 2*pi, 11)
    if z is None: z = np.linspace(0.0, 1.0, 11)

    # Find the x values and y values for each plane.
    x_plane = (cos(theta)*r[:,None]).ravel()
    y_plane = (sin(theta)*r[:,None]).ravel()
```

```
    # Allocate an array for all the points.  We'll have len(x_plane)
    # points on each plane, and we have a plane for each z value, so
    # we need len(x_plane)*len(z) points.
    points = np.empty([len(x_plane)*len(z),3])

    # Loop through the points for each plane and fill them with the
    # correct x,y,z values.
    start = 0
    for z_plane in z:
        end = start + len(x_plane)
        # slice out a plane of the output points and fill it
        # with the x,y, and z values for this plane.  The x,y
        # values are the same for every plane.  The z value
        # is set to the current z
        plane_points = points[start:end]
        plane_points[:,0] = x_plane
        plane_points[:,1] = y_plane
        plane_points[:,2] = z_plane
        start = end

    return points

# Make the data.
dims = (51, 25, 25)
# Note here that the 'x' axis corresponds to 'theta'
theta = np.linspace(0, 2*np.pi, dims[0])
# 'y' corresponds to varying 'r'
r = np.linspace(1, 10, dims[1])
z = np.linspace(0, 5, dims[2])
pts = generate_annulus(r, theta, z)
# Uncomment the following if you want to add some noise to the data.
#pts += np.random.randn(dims[0]*dims[1]*dims[2], 3)*0.04
sgrid = tvtk.StructuredGrid(dimensions=dims)
sgrid.points = pts
s = np.sqrt(pts[:,0]**2 + pts[:,1]**2 + pts[:,2]**2)
sgrid.point_data.scalars = np.ravel(s.copy())
sgrid.point_data.scalars.name = 'scalars'

# Uncomment the next two lines to save the dataset to a VTK XML file.
#w = tvtk.XMLStructuredGridWriter(input=sgrid, file_name='sgrid.vts')
#w.write()

# View the data.
@mayavi2.standalone
def view():
    from enthought.mayavi.sources.vtk_data_source import VTKDataSource
    from enthought.mayavi.modules.api import Outline, GridPlane

    mayavi.new_scene()
    src = VTKDataSource(data=sgrid)
    mayavi.add_source(src)
    mayavi.add_module(Outline())
    g = GridPlane()
    g.grid_plane.axis = 'x'
    mayavi.add_module(g)
    g = GridPlane()
    g.grid_plane.axis = 'y'
    mayavi.add_module(g)
```

```
    g = GridPlane()
    g.grid_plane.axis = 'z'
    mayavi.add_module(g)

if __name__ == '__main__':
    view()
```

10.4.15 Tvtk segmentation example

Using VTK to assemble a pipeline for segmenting MRI images. This example shows how to insert well-controled custom VTK filters in Mayavi.

This example downloads an MRI scan, turns it into a 3D numpy array, applies a segmentation procedure made of VTK filters to extract the gray-matter/white-matter boundary.

The segmentation algorithm used here is very naive and should, of course, not be used as an example of segmentation.

Source code: tvtk_segmentation.py

```
### Download the data, if not already on disk ##################################
import os
if not os.path.exists('mri_data.tar.gz'):
    # Download the data
    import urllib
    print "Downloading data, Please Wait (7.8MB)"
    opener = urllib.urlopen(
                'http://www-graphics.stanford.edu/data/voldata/MRbrain.tar.gz')
    open('mri_data.tar.gz', 'wb').write(opener.read())

# Extract the data
import tarfile
tar_file = tarfile.open('mri_data.tar.gz')
try:
    os.mkdir('mri_data')
except:
    pass
tar_file.extractall('mri_data')
tar_file.close()


### Read the data in a numpy 3D array #########################################
import numpy as np
data = np.array([np.fromfile(os.path.join('mri_data', 'MRbrain.%i' % i),
                                        dtype='>u2') for i in range(1, 110)])
data.shape = (109, 256, 256)
data = data.T

###############################################################################
# Heuristic for finding the threshold for the brain

# Exctract the percentile 20 and 80 (without using
# scipy.stats.scoreatpercentile)
sorted_data = np.sort(data.ravel())
l = len(sorted_data)
lower_thr = sorted_data[0.2*l]
upper_thr = sorted_data[0.8*l]
```

```
# The white matter boundary: find the densest part of the upper half
# of histogram, and take a value 10% higher, to cut _in_ the white matter
hist, bins = np.histogram(data[data > np.mean(data)], bins=50)
brain_thr_idx = np.argmax(hist)
brain_thr =  bins[brain_thr_idx + 4]

del hist, bins, brain_thr_idx

# Display the data ############################################################
from enthought.mayavi import mlab
from enthought.tvtk.api import tvtk

fig = mlab.figure(bgcolor=(0, 0, 0), size=(400, 500))
# to speed things up
fig.scene.disable_render = True

src = mlab.pipeline.scalar_field(data)
# Our data is not equally spaced in all directions:
src.spacing = [1, 1, 1.5]
src.update_image_data = True

#-----------------------------------------------------------------------------
# Brain extraction pipeline

# In the following, we create a Mayavi pipeline that strongly
# relies on VTK filters. For this, we make heavy use of the
# mlab.pipeline.user_defined function, to include VTK filters in
# the Mayavi pipeline.

# Apply image-based filters to clean up noise
thresh_filter = tvtk.ImageThreshold()
thresh_filter.threshold_between(lower_thr, upper_thr)
thresh = mlab.pipeline.user_defined(src, filter=thresh_filter)

median_filter = tvtk.ImageMedian3D()
median_filter.set_kernel_size(3, 3, 3)
median = mlab.pipeline.user_defined(thresh, filter=median_filter)

diffuse_filter = tvtk.ImageAnisotropicDiffusion3D(
                                    diffusion_factor=1.0,
                                    diffusion_threshold=100.0,
                                    number_of_iterations=5, )

diffuse = mlab.pipeline.user_defined(median, filter=diffuse_filter)

# Extract brain surface
contour = mlab.pipeline.contour(diffuse, )
contour.filter.contours = [brain_thr, ]

# Apply mesh filter to clean up the mesh (decimation and smoothing)
dec = mlab.pipeline.decimate_pro(contour)
dec.filter.feature_angle = 60.
dec.filter.target_reduction = 0.7

smooth_ = tvtk.SmoothPolyDataFilter(
                    number_of_iterations=10,
                    relaxation_factor=0.1,
                    feature_angle=60,
```

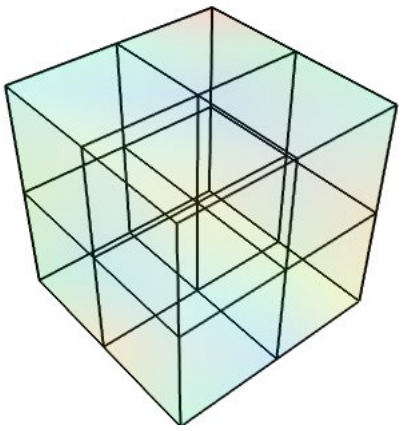
```
                    feature_edge_smoothing=False,
                    boundary_smoothing=False,
                    convergence=0.,
                )
smooth = mlab.pipeline.user_defined(dec, filter=smooth_)

# Get the largest connected region
connect_ = tvtk.PolyDataConnectivityFilter(extraction_mode=4)
connect = mlab.pipeline.user_defined(smooth, filter=connect_)

# Compute normals for shading the surface
compute_normals = mlab.pipeline.poly_data_normals(connect)
compute_normals.filter.feature_angle = 80

surf = mlab.pipeline.surface(compute_normals,
                                        color=(0.9, 0.72, 0.62))

#----------------------------------------------------------------------
# Display a cut plane of the raw data
ipw = mlab.pipeline.image_plane_widget(src, colormap='bone',
                plane_orientation='z_axes',
                slice_index=55)

mlab.view(-165, 32, 350, [143, 133, 73])
mlab.roll(180)

fig.scene.disable_render = False

mlab.show()
```

10.4.16 Datasets example

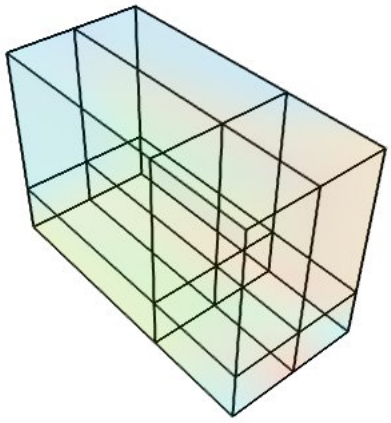
A Mayavi example to show the different data sets. See *Data representation in Mayavi* for a discussion.

The following images are created:

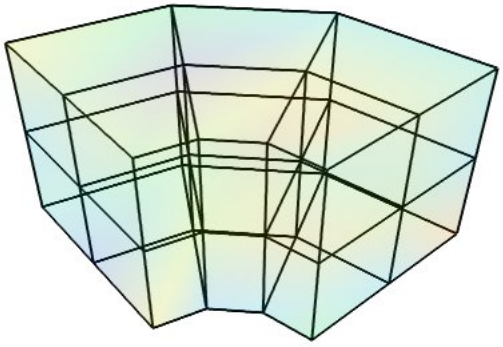
- **ImageData**



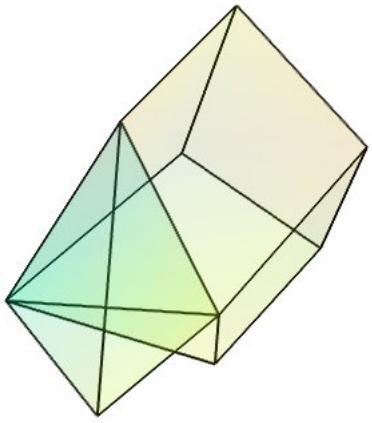
- **RectilinearGrid**



- **StructuredGrid**



- **UnstructuredGrid**



Source code: datasets.py

```
# Author: Gael Varoquaux <gael dot varoquaux at normalesup.org>
# Copyright (c) 2008, Enthought, Inc.
# License: BSD style.

from numpy import array, random, linspace, pi, ravel, cos, sin, empty
from enthought.tvtk.api import tvtk

from enthought.mayavi.scripts import mayavi2
from enthought.mayavi.sources.vtk_data_source import VTKDataSource
```

```
from enthought.mayavi import mlab


def image_data():
    data = random.random((3, 3, 3))
    i = tvtk.ImageData(spacing=(1, 1, 1), origin=(0, 0, 0))
    i.point_data.scalars = data.ravel()
    i.point_data.scalars.name = 'scalars'
    i.dimensions = data.shape
    return i


def rectilinear_grid():
    data = random.random((3, 3, 3))
    r = tvtk.RectilinearGrid()
    r.point_data.scalars = data.ravel()
    r.point_data.scalars.name = 'scalars'
    r.dimensions = data.shape
    r.x_coordinates = array((0, 0.7, 1.4))
    r.y_coordinates = array((0, 1, 3))
    r.z_coordinates = array((0, .5, 2))
    return r


def generate_annulus(r, theta, z):
    """ Generate points for structured grid for a cylindrical annular
        volume.  This method is useful for generating a unstructured
        cylindrical mesh for VTK (and perhaps other tools).
    """
    # Find the x values and y values for each plane.
    x_plane = (cos(theta)*r[:,None]).ravel()
    y_plane = (sin(theta)*r[:,None]).ravel()

    # Allocate an array for all the points.  We'll have len(x_plane)
    # points on each plane, and we have a plane for each z value, so
    # we need len(x_plane)*len(z) points.
    points = empty([len(x_plane)*len(z),3])

    # Loop through the points for each plane and fill them with the
    # correct x,y,z values.
    start = 0
    for z_plane in z:
        end = start+len(x_plane)
        # slice out a plane of the output points and fill it
        # with the x,y, and z values for this plane.  The x,y
        # values are the same for every plane.  The z value
        # is set to the current z
        plane_points = points[start:end]
        plane_points[:,0] = x_plane
        plane_points[:,1] = y_plane
        plane_points[:,2] = z_plane
        start = end

    return points


def structured_grid():
```

```
    # Make the data.
    dims = (3, 4, 3)
    r = linspace(5, 15, dims[0])
    theta = linspace(0, 0.5*pi, dims[1])
    z = linspace(0, 10, dims[2])
    pts = generate_annulus(r, theta, z)
    sgrid = tvtk.StructuredGrid(dimensions=(dims[1], dims[0], dims[2]))
    sgrid.points = pts
    s = random.random((dims[0]*dims[1]*dims[2]))
    sgrid.point_data.scalars = ravel(s.copy())
    sgrid.point_data.scalars.name = 'scalars'
    return sgrid


def unstructured_grid():
    points = array([[0,1.2,0.6], [1,0,0], [0,1,0], [1,1,1], # tetra
                    [1,0,-0.5], [2,0,0], [2,1.5,0], [0,1,0],
                    [1,0,0], [1.5,-0.2,1], [1.6,1,1.5], [1,1,1], # Hex
                    ], 'f')
    # The cells
    cells = array([4, 0, 1, 2, 3, # tetra
                   8, 4, 5, 6, 7, 8, 9, 10, 11 # hex
                   ])
    # The offsets for the cells, i.e. the indices where the cells
    # start.
    offset = array([0, 5])
    tetra_type = tvtk.Tetra().cell_type # VTK_TETRA == 10
    hex_type = tvtk.Hexahedron().cell_type # VTK_HEXAHEDRON == 12
    cell_types = array([tetra_type, hex_type])
    # Create the array of cells unambiguously.
    cell_array = tvtk.CellArray()
    cell_array.set_cells(2, cells)
    # Now create the UG.
    ug = tvtk.UnstructuredGrid(points=points)
    # Now just set the cell types and reuse the ug locations and cells.
    ug.set_cells(cell_types, offset, cell_array)
    scalars = random.random(points.shape[0])
    ug.point_data.scalars = scalars
    ug.point_data.scalars.name = 'scalars'
    return ug


def polydata():
    # The numpy array data.
    points = array([[0,-0.5,0], [1.5,0,0], [0,1,0], [0,0,0.5],
                    [-1,-1.5,0.1], [0,-1, 0.5], [-1, -0.5, 0],
                    [1,0.8,0]], 'f')
    triangles = array([[0,1,3], [1,2,3], [1,0,5],
                       [2,3,4], [3,0,4], [0,5,4], [2, 4, 6],
                        [2, 1, 7]])
    scalars = random.random(points.shape)

    # The TVTK dataset.
    mesh = tvtk.PolyData(points=points, polys=triangles)
    mesh.point_data.scalars = scalars
    mesh.point_data.scalars.name = 'scalars'
    return mesh
```

```
def view(dataset):
    """ Open up a mayavi scene and display the dataset in it.
    """
    engine = mlab.get_engine()
    fig = mlab.figure(bgcolor=(1, 1, 1), fgcolor=(0, 0, 0),
                      figure=dataset.class_name[3:])
    src = VTKDataSource(data=dataset)
    engine.add_source(src)
    mlab.pipeline.surface(src, opacity=0.1)
    mlab.pipeline.surface(mlab.pipeline.extract_edges(src),
                          color=(0, 0, 0), )


@mlab.show
def main():
    view(image_data())
    view(rectilinear_grid())
    view(structured_grid())
    view(unstructured_grid())
    view(polydata())

if __name__ == '__main__':
    main()
```

10.4.17 Delaunay graph example

An example illustrating graph manipulation and display with Mayavi and NetworkX.

This example shows how to use Mayavi in a purely algorithmic way, to compute a Delaunay from data points, extract it and pass it to networkx. It also shows how to plot a graph using quiver.

Starting from points positioned regularly on a sphere, we first use VTK to create the Delaunay graph, and also to plot it. We then create a matching NetworkX graph, calling it's minimum spanning tree function. We display it using Mayavi.

The visualization clearly shows that the minimum spanning tree of the points, considering all possible connections, is included in the Delaunay graph.

The function *compute_delaunay_edges* uses VTK to retrieve the Delaunay graph of a set of points. First a structure of unconnected points is created using *mlab.points3d*. The Delaunay filter applied to it builds an unstructured grid (see *Data representation in Mayavi*). We apply an ExtractEdges filter to it, which returns a structure of points connected by edges: the *PolyData structure*. The dataset structure can be retrieved as the first item of the *outputs* list of the ExtractEdges filter object, returned by the *mlab.pipeline.extract_edges* factory function. Once we have this object, we extract the points and edge list from it. This graph-plotting technique differs from the technique used in the examples *Protein example* and *Flight graph example* where points are created and connected by lines. Unlike these techniques, it enables storing scalar data on each line.

To visualize the graph (function *graph_plot*), we build a list of vectors giving the edges, and use *mlab.quiver3d* to display them. To display an unoriented graph, it is best to use the *2ddash* mode of *quiver3d*.

Source code: delaunay_graph.py

```
# Author: Gary Ruben
#         Gael Varoquaux <gael dot varoquaux at normalesup dot org>
# Copyright (c) 2009, Enthought, Inc.
# License: BSD style.

from enthought.mayavi import mlab
import numpy as np
import networkx as nx

def compute_delaunay_edges(x, y, z, visualize=False):
    """ Given 3-D points, returns the edges of their
        Delaunay triangulation.

        Parameters
        -----------
        x: ndarray
            x coordinates of the points
        y: ndarray
            y coordinates of the points
        z: ndarray
            z coordinates of the points

        Returns
        ---------
        new_x: ndarray
            new x coordinates of the points (same coords but different
            assignment of points)
        new_y: ndarray
            new y coordinates of the points (same coords but different
            assignment of points)
        new_z: ndarray
            new z coordinates of the points (same coords but different
            assignment of points)
        edges: 2D ndarray.
            The indices of the edges of the Delaunay triangulation as a
            (N, 2) array [[pair1_index1, pair1_index2],
                         [pair2_index1, pair2_index2],
                         ...                         ]
    """
    if visualize:
        vtk_source = mlab.points3d(x, y, z, opacity=0.3, mode='2dvertex')
        vtk_source.actor.property.point_size = 3
    else:
        vtk_source = mlab.points3d(x, y, z, figure=False)
    delaunay =  mlab.pipeline.delaunay3d(vtk_source)
    delaunay.filter.offset = 999    # seems more reliable than the default
    edges = mlab.pipeline.extract_edges(delaunay)
    if visualize:
        mlab.pipeline.surface(edges, opacity=0.3, line_width=3)

    # We extract the output array. the 'points' attribute itself
    # is a TVTK array, that we convert to a numpy array using
    # its 'to_array' method.
    new_x, new_y, new_z = edges.outputs[0].points.to_array().T
    lines = edges.outputs[0].lines.to_array()
    return new_x, new_y, new_z, np.array([lines[1::3], lines[2::3]]).T
```

```
def graph_plot(x, y, z, start_idx, end_idx, edge_scalars=None, **kwargs):
    """ Show the graph edges using Mayavi

        Parameters
        -----------
        x: ndarray
            x coordinates of the points
        y: ndarray
            y coordinates of the points
        z: ndarray
            z coordinates of the points
        edge_scalars: ndarray, optional
            optional data to give the color of the edges.
        kwargs:
            extra keyword arguments are passed to quiver3d.
    """
    vec = mlab.quiver3d(x[start_idx],
                        y[start_idx],
                        z[start_idx],
                        x[end_idx] - x[start_idx],
                        y[end_idx] - y[start_idx],
                        z[end_idx] - z[start_idx],
                        scalars=edge_scalars,
                        mode='2ddash',
                        scale_factor=1,
                        **kwargs)
    if edge_scalars is not None:
        vec.glyph.color_mode = 'color_by_scalar'
    return vec


def build_geometric_graph(x, y, z, edges):
    """ Build a NetworkX graph with xyz node coordinates and the node indices
        of the end nodes.

        Parameters
        -----------
        x: ndarray
            x coordinates of the points
        y: ndarray
            y coordinates of the points
        z: ndarray
            z coordinates of the points
        edges: the (2, N) array returned by compute_delaunay_edges()
            containing node indices of the end nodes. Weights are applied to
            the edges based on their euclidean length for use by the MST
            algorithm.

        Returns
        ---------
        g: A NetworkX undirected graph

        Notes
        ------
        We don't bother putting the coordinates into the NX graph.
        Instead the graph node is an index to the column.
    """
```

```
    xyz = np.array((x, y, z))
    def euclidean_dist(i, j):
        d = xyz[:,i] - xyz[:,j]
        return np.sqrt(np.dot(d, d))

    g = nx.Graph()
    for i, j in edges:
        if nx.__version__.split('.')[0] > '0':
            g.add_edge(i, j, weight=euclidean_dist(i, j))
        else:
            g.add_edge(i, j, euclidean_dist(i, j))
    return g


def points_on_sphere(N):
    """ Generate N evenly distributed points on the unit sphere centered at
        the origin. Uses the 'Golden Spiral'.
        Code by Chris Colbert from the numpy-discussion list.
    """
    phi = (1 + np.sqrt(5)) / 2  # the golden ratio
    long_incr = 2*np.pi / phi   # how much to increment the longitude

    dz = 2.0 / float(N)         # a unit sphere has diameter 2
    bands = np.arange(N)        # each band will have one point placed on it
    z = bands * dz - 1 + (dz/2) # the height z of each band/point
    r = np.sqrt(1 - z*z)        # project onto xy-plane
    az = bands * long_incr      # azimuthal angle of point modulo 2 pi
    x = r * np.cos(az)
    y = r * np.sin(az)
    return x, y, z


################################################################################
if __name__ == '__main__':
    # generate some points
    x, y, z = points_on_sphere(50)
    # Avoid triangulation problems on the sphere
    z *= 1.01

    mlab.figure(1, bgcolor=(0,0,0))
    mlab.clf()

    # Now get the Delaunay Triangulation from vtk via mayavi mlab. Vtk stores
    # its points in a different order so overwrite ours to match the edges
    new_x, new_y, new_z, edges = compute_delaunay_edges(x, y, z, visualize=True)
    assert(x.shape == new_x.shape)   # check triangulation got everything
    x, y, z = new_x, new_y, new_z

    if nx.__version__ < '0.99':
        raise ImportError('The version of NetworkX must be at least '
                    '0.99 to run this example')

    # Make a NetworkX graph out of our point and edge data
    g = build_geometric_graph(x, y, z, edges)

    # Compute minimum spanning tree using networkx
    # nx.mst returns an edge generator
    start_idx, end_idx, _ = np.array(list(nx.mst(g))).T
```

```
start_idx = start_idx.astype(np.int)
end_idx   = end_idx.astype(np.int)

# Plot this with Mayavi
graph_plot(x, y, z, start_idx, end_idx,
            edge_scalars=z[start_idx],
            opacity=0.8,
            colormap='summer',
            line_width=4,
            )

mlab.view(60, 46, 4)
mlab.show()
```

10.4.18 Mlab 3D to 2D example

A script to calculate the projection of 3D world coordinates to 2D display coordinates (pixel coordinates) for a given scene.

The 2D pixel locations of objects in the image plane are related to their 3D world coordinates by a series of linear transformations. The specific transformations fall under the group known as projective transformations. This set includes pure projectivities, affine transformations, perspective transformations, and euclidean transformations. In the case of mlab (and most other computer visualization software), we deal with only the perspective and euclidean cases. An overview of Projective space can be found here: http://en.wikipedia.org/wiki/Projective_space and a thorough treatment of projective geometry can be had in the book "Multiple View Geometry in Computer Vision" by Richard Hartley.

The essential thing to know for this example is that points in 3-space are related to points in 2-space through a series of multiplications of 4x4 matrices which are the perspective and euclidean transformations. The 4x4 matrices predicate the use of length 4 vectors to represent points. This representation is known as homogeneous coordinates, and while they appear foriegn at first, they truly simplify all the mathematics involved. In short, homogeneous coordinates are your friend, and you should read about them here: http://en.wikipedia.org/wiki/Homogeneous_coordinates

In the normal pinhole camera model (the ideal real world model), 3D world points are related to 2D image points by the matrix termed the 'essential' matrix which is a combination of a perspective transformation and a euclidean transformation. The perspective transformation is defined by the camera intrinsics (focal length, imaging sensor offset, etc...) and the euclidean transformation is defined by the cameras position and orientation. In computer graphics, things are not so simple. This is because computer graphics have the benefit of being able to do things which are not possible in the real world: adding clipping planes, offset projection centers, arbitrary distortions, etc... Thus, a slightly different model is used.

What follows is the camera/view model for OpenGL and thus, VTK. I can not guarantee that other packages follow this model.

There are 4 different transformations that are applied 3D world coordinates to map them to 2D pixel coordinates. They are: the model transform, the view transform, the perspective transform, and the viewport or display transform.

In OpenGL the first two transformations are concatenated to yield the modelview transform (called simply the view transform in VTK). The modelview transformation applies arbitrary scaling and distortions to the model (if they are specified) and transforms them so that the orientation is the equivalent of looking down the negative Z axis. Imagine its as if you relocate your camera to look down the negative Z axis, and then move everything in the world so that you see it now as you did before you moved the camera. The resulting coordinates are termed "eye" coordinates in OpenGL (I don't know that they have a name in VTK).

The perspective transformation applies the camera perspective to the eye coordinates. This transform is what makes objects in the foreground look bigger than equivalent objects in the background. In the pinhole camera model, this transform is determined uniquely by the focal length of the camera and its position in 3-space. In Vtk/OpenGL it

is determined by the frustum. A frustum is simply a pyramid with the top lopped off. The top of the pyramid (a point) is the camera location, the base of the pyramid is a plane (the far clipping plane) defined as normal to principle camera ray at distance termed the far clipping distance, the top of the frustum (where it's lopped off) is the near clipping plane, with a definition similar to that of the far clipping plane. The sides of the frustum are determined by the aspect ratio of the camera (width/height) and its field-of-view. Any points not lying within the frustum are not mapped to the screen (as they would lie outside the viewable area). The perpspective transformation has the effect of scaling everything within the frustum to fit within a cube defined in the range (-1,1)(-1,1)(-1,1) as represented by homogeneous coordinates. The last phrase there is important, the first 3 coordinates will not, in general, be within the unity range until we divide through by the last coordinate (See the wikipedia on homogeneous coordinates if this is confusing). The resulting coordinates are termed (appropriately enough) normalized view coordinates.

The last transformation (the viewport transformation) takes us from normalized view coordinates to display coordinates. At this point, you may be asking yourself 'why not just go directly to display coordinates, why need normalized view coordinates at all?', the answer is that we may want to embed more than one view in a particular window, there will therefore be different transformations to take each view to an appropriate position an size in the window. The normalized view coordinates provide a nice common ground so-to-speak. At any rate, the viewport transformation simply scales and translates the X and Y coordinates of the normalized view coordinates to the appropriate pixel coordinates. We don't use the Z value in our example because we don't care about it. It is used for other various things however.

That's all there is to it, pretty simple right? Right. Here is an overview:

Given a set of 3D world coordinates:

- Apply the modelview transformation (view transform in VTK) to get eye coordinates
- Apply the perspective transformation to get normalized view coordinates
- Apply the viewport transformation to get display coordinates

VTK provides a nice method to retrieve a 4x4 matrix that combines the first two operations. As far as I can tell, VTK does not export a method to retrieve the 4x4 matrix representing the viewport transformation, so we are on our there to create one (no worries though, its not hard, as you will see).

Now that the prelimenaries are out of the way, lets get started.

Source code: mlab_3D_to_2D.py

```
# Author: S. Chris Colbert <sccolbert@gmail.com>
# Copyright (c) 2009, S. Chris Colbert
# License: BSD Style

# this import is here because we need to ensure that matplotlib uses the
# wx backend and having regular code outside the main block is PyTaboo.
# It needs to be imported first, so that matplotlib can impose the
# version of Wx it requires.
import matplotlib
matplotlib.use('WXAgg')
import pylab as pl


import numpy as np
from enthought.mayavi import mlab
from enthought.mayavi.core.ui.mayavi_scene import MayaviScene

def get_world_to_view_matrix(mlab_scene):
    """returns the 4x4 matrix that is a concatenation of the modelview transform and
    perspective transform. Takes as input an mlab scene object."""

    if not isinstance(mlab_scene, MayaviScene):
        raise TypeError('argument must be an instance of MayaviScene')
```

```
    # The VTK method needs the aspect ratio and near and far clipping planes
    # in order to return the proper transform. So we query the current scene
    # object to get the parameters we need.
    scene_size = tuple(mlab_scene.get_size())
    clip_range = mlab_scene.camera.clipping_range
    aspect_ratio = float(scene_size[0])/float(scene_size[1])

    # this actually just gets a vtk matrix object, we can't really do anything with it yet
    vtk_comb_trans_mat = mlab_scene.camera.get_composite_perspective_transform_matrix(
                                aspect_ratio, clip_range[0], clip_range[1])

     # get the vtk mat as a numpy array
    np_comb_trans_mat = vtk_comb_trans_mat.to_array()

    return np_comb_trans_mat


def get_view_to_display_matrix(mlab_scene):
    """ this function returns a 4x4 matrix that will convert normalized
        view coordinates to display coordinates. It's assumed that the view should
        take up the entire window and that the origin of the window is in the
        upper left corner"""

    if not (isinstance(mlab_scene, MayaviScene)):
        raise TypeError('argument must be an instance of MayaviScene')

    # this gets the client size of the window
    x, y = tuple(mlab_scene.get_size())

    # normalized view coordinates have the origin in the middle of the space
    # so we need to scale by width and height of the display window and shift
    # by half width and half height. The matrix accomplishes that.
    view_to_disp_mat = np.array([[x/2.0,      0.,   0.,   x/2.0],
                                 [   0.,  -y/2.0,   0.,   y/2.0],
                                 [   0.,      0.,   1.,      0.],
                                 [   0.,      0.,   0.,      1.]])

    return view_to_disp_mat


def apply_transform_to_points(points, trans_mat):
    """a function that applies a 4x4 transformation matrix to an of
        homogeneous points. The array of points should have shape Nx4"""

    if not trans_mat.shape == (4, 4):
        raise ValueError('transform matrix must be 4x4')

    if not points.shape[1] == 4:
        raise ValueError('point array must have shape Nx4')

    return np.dot(trans_mat, points.T).T


if __name__ == '__main__':
    f = mlab.figure()
```

```
    N = 4

    # create a few points in 3-space
    X = np.random.random_integers(-3, 3, N)
    Y = np.random.random_integers(-3, 3, N)
    Z = np.random.random_integers(-3, 3, N)

    # plot the points with mlab
    pts = mlab.points3d(X, Y, Z)

    # now were going to create a single N x 4 array of our points
    # adding a fourth column of ones expresses the world points in
    # homogenous coordinates
    W = np.ones(X.shape)
    hmgns_world_coords = np.column_stack((X, Y, Z, W))

    # applying the first transform will give us 'unnormalized' view
    # coordinates we also have to get the transform matrix for the
    # current scene view
    comb_trans_mat = get_world_to_view_matrix(f.scene)
    view_coords = \
            apply_transform_to_points(hmgns_world_coords, comb_trans_mat)

    # to get normalized view coordinates, we divide through by the fourth
    # element
    norm_view_coords = view_coords / (view_coords[:, 3].reshape(-1, 1))

    # the last step is to transform from normalized view coordinates to
    # display coordinates.
    view_to_disp_mat = get_view_to_display_matrix(f.scene)
    disp_coords = apply_transform_to_points(norm_view_coords, view_to_disp_mat)

    # at this point disp_coords is an Nx4 array of homogenous coordinates
    # where X and Y are the pixel coordinates of the X and Y 3D world
    # coordinates, so lets take a screenshot of mlab view and open it
    # with matplotlib so we can check the accuracy
    img = mlab.screenshot()
    pl.imshow(img)

    for i in range(N):
        print  'Point %d:  (x, y) ' % i, disp_coords[:, 0:2][i]
        pl.plot([disp_coords[:, 0][i]], [disp_coords[:, 1][i]], 'ro')

    pl.show()

    # you should check that the printed coordinates correspond to the
    # proper points on the screen

    mlab.show()

#EOF
```

10.4.19 Magnetic field example

An example mixing numerical caculation and 3D visualization of the magnetic field created by an arbitrary number of current loops.

The goal of this example is to show how Mayavi can be used with scipy to debug and understand physics and electromagnetics computation.

The field is caculated for an arbitrary number of current loops using the corresponding exact formula. The coils are plotted in 3D with a synthetic view of the magnetic_field. A VectorCutPlane is used as it enables good inspection of the magnetic field.

This example originated from a real-life case of coil design in Python (Atomic sources for long-time-of-flight interferometric inertial sensors, G. Varoquaux, http://tel.archives-ouvertes.fr/tel-00265714/, page 148).

For another visualization of magnetic field, see the *Magnetic field lines example*.

Source code: magnetic_field.py

```
# Author: Gael Varoquaux <gael.varoquaux@normalesup.org>
# Copyright (c) 2009, Enthought, Inc.
# License: BSD Style.


import numpy as np
from scipy import special
from enthought.mayavi import mlab

################################################################################
# Function to caculate the Magnetic field generated by a current loop

def base_vectors(n):
    """ Returns 3 orthognal base vectors, the first one colinear to n.

        Parameters
        -----------
        n: ndarray, shape (3, )
            A vector giving direction of the basis

        Returns
        -----------
        n: ndarray, shape (3, )
            The first vector of the basis
        l: ndarray, shape (3, )
            The second vector of the basis
        m: ndarray, shape (3, )
            The first vector of the basis

    """
    # normalize n
    n = n / (n**2).sum(axis=-1)

    # choose two vectors perpendicular to n
    # choice is arbitrary since the coil is symetric about n
    if  np.abs(n[0])==1 :
        l = np.r_[n[2], 0, -n[0]]
    else:
        l = np.r_[0, n[2], -n[1]]

    l = l / (l**2).sum(axis=-1)
    m = np.cross(n, l)
    return n, l, m
```

```
def magnetic_field(r, n, r0, R):
    """
    Returns the magnetic field from an arbitrary current loop calculated from
    eqns (1) and (2) in Phys Rev A Vol. 35, N 4, pp. 1535-1546; 1987.

    Arguments
    ----------
        n: ndarray, shape (3, )
            The normal vector to the plane of the loop at the center,
            current is oriented by the right-hand-rule.
        r: ndarray, shape (m, 3)
            A position vector where the magnetic field is evaluated:
            [x1 y2 z3 ; x2 y2 z2 ; ... ]
            r is in units of d
        r0: ndarray, shape (3, )
            The location of the center of the loop in units of d: [x y z]
        R: float
            The radius of the current loop

    Returns
    --------
    B: ndarray, shape (m, 3)
        a vector for the B field at each position specified in r
        in inverse units of (mu I) / (2 pi d)
        for I in amps and d in meters and mu = 4 pi * 10^-7 we get Tesla
    """
    ### Translate the coordinates in the coil's frame
    n, l, m = base_vectors(n)

    # transformation matrix coil frame to lab frame
    trans = np.vstack((l, m, n))
    # transformation matrix to lab frame to coil frame
    inv_trans = np.linalg.inv(trans)

    # point location from center of coil
    r = r - r0
    # transform vector to coil frame
    r = np.dot(r, inv_trans)

    #### calculate field

    # express the coordinates in polar form
    x = r[:, 0]
    y = r[:, 1]
    z = r[:, 2]
    rho = np.sqrt(x**2 + y**2)
    theta = np.arctan(x/y)
    theta[y==0] = 0

    E = special.ellipe((4 * R * rho)/( (R + rho)**2 + z**2))
    K = special.ellipk((4 * R * rho)/( (R + rho)**2 + z**2))
    Bz =  1/np.sqrt((R + rho)**2 + z**2) * (
                K
              + E * (R**2 - rho**2 - z**2)/((R - rho)**2 + z**2)
              )
    Brho = z/(rho*np.sqrt((R + rho)**2 + z**2)) * (
                -K
              + E * (R**2 + rho**2 + z**2)/((R - rho)**2 + z**2)
```

```
                )
    # On the axis of the coil we get a divided by zero here. This returns a
    # NaN, where the field is actually zero :
    Brho[np.isnan(Brho)] = 0
    Brho[np.isinf(Brho)] = 0
    Bz[np.isnan(Bz)]     = 0
    Bz[np.isinf(Bz)]     = 0

    B = np.c_[np.cos(theta)*Brho, np.sin(theta)*Brho, Bz ]

    # Rotate the field back in the lab's frame
    B = np.dot(B, trans)
    return B


def display_coil(n, r0, R, half=False):
    """
    Display a coils in the 3D view.
    If half is True, display only one half of the coil.
    """
    n, l, m = base_vectors(n)
    theta = np.linspace(0, (2-half)*np.pi, 30)
    theta = theta[..., np.newaxis]
    coil = np.atleast_1d(R)*(np.sin(theta)*l + np.cos(theta)*m)
    coil += r0
    coil_x = coil[:, 0]
    coil_y = coil[:, 1]
    coil_z = coil[:, 2]
    mlab.plot3d(coil_x, coil_y, coil_z,
            tube_radius=0.01,
            name='Coil %i' % display_coil.num,
            color=(0, 0, 0))
    display_coil.num += 1
    return coil_x, coil_y, coil_z

display_coil.num = 0

################################################################################
# The grid of points on which we want to evaluate the field
X, Y, Z = np.mgrid[-0.15:0.15:31j, -0.15:0.15:31j, -0.15:0.15:31j]
# Avoid rounding issues :
f = 1e4  # this gives the precision we are interested by :
X = np.round(X * f) / f
Y = np.round(Y * f) / f
Z = np.round(Z * f) / f

r = np.c_[X.ravel(), Y.ravel(), Z.ravel()]

################################################################################
# The coil positions

# The center of the coil
r0 = np.r_[0, 0, 0.1]
# The normal to the coils
n  = np.r_[0, 0, 1]
# The radius
R  = 0.1
```

```
# Add the mirror image of this coils relatively to the xy plane :
r0 = np.vstack((r0, -r0 ))
R  = np.r_[R, R]
n  = np.vstack((n, n))            # Helmoltz like configuration

################################################################################
# Calculate field
# First initialize a container matrix for the field vector :
B = np.empty_like(r)
# Then loop through the different coils and sum the fields :
for this_n, this_r0, this_R in zip(n, r0, R):
  this_n    = np.array(this_n)
  this_r0   = np.array(this_r0)
  this_R    = np.array(this_R)
  B += magnetic_field(r, this_n, this_r0, this_R)


Bx = B[:, 0]
By = B[:, 1]
Bz = B[:, 2]
Bx.shape = X.shape
By.shape = Y.shape
Bz.shape = Z.shape

Bnorm = np.sqrt(Bx**2 + By**2 + Bz**2)

################################################################################
# Visualization

# We threshold the data ourselves, as the threshold filter produce a
# data structure inefficient with IsoSurface
Bmax = 100

Bx[Bnorm > Bmax] = 0
By[Bnorm > Bmax] = 0
Bz[Bnorm > Bmax] = 0
Bnorm[Bnorm > Bmax] = Bmax

mlab.figure(1, bgcolor=(1, 1, 1), fgcolor=(0.5, 0.5, 0.5),
               size=(480, 480))
mlab.clf()

for this_n, this_r0, this_R in zip(n, r0, R):
  display_coil(this_n, this_r0, this_R)

field = mlab.pipeline.vector_field(X, Y, Z, Bx, By, Bz,
                                   scalars=Bnorm, name='B field')
vectors = mlab.pipeline.vectors(field,
                     scale_factor=(X[1, 0, 0] - X[0, 0, 0]),
                     )
# Mask random points, to have a lighter visualization.
vectors.glyph.mask_input_points = True
vectors.glyph.mask_points.on_ratio = 6

vcp = mlab.pipeline.vector_cut_plane(field)
vcp.glyph.glyph.scale_factor=5*(X[1, 0, 0] - X[0, 0, 0])
# For prettier picture:
#vcp.implicit_plane.widget.enabled = False
```

```
iso = mlab.pipeline.iso_surface(field,
                                contours=[0.1*Bmax, 0.4*Bmax],
                                opacity=0.6,
                                colormap='YlOrRd')

# A trick to make transparency look better: cull the front face
iso.actor.property.frontface_culling = True

mlab.view(39, 74, 0.59, [.008, .0007, -.005])

mlab.show()
```

- ***Polydata example*** An example of how to generate a polydata dataset using numpy arrays.
- ***Offscreen example*** A simple example of how you can use Mayavi without using Envisage or the Mayavi Envisage application and do off screen rendering.
- ***Surf regular mlab example*** Shows how to view data created by *enthought.tvtk.tools.mlab* with mayavi2.
- ***Structured points2d example*** An example of how to generate a 2D structured points dataset using numpy arrays. Also shown is a way to visualize this data with the mayavi2 application.
- ***Glyph example*** This script demonstrates using the Mayavi core API to add a VectorCutPlane, split the pipeline using a MaskPoints filter and then view the filtered data with the Glyph module.
- ***Contour contour example*** This example shows how you can produce contours on an IsoSurface.
- ***Scatter plot example*** An example of plotting scatter points with Mayavi's core API.
- ***Structured points3d example*** An example of how to generate a 3D structured points dataset using numpy arrays. Also shown is a way to visualize this data with the mayavi2 application.
- ***Streamline example*** This script demonstrates how one can script Mayavi's core API to display streamlines and an iso surface.
- ***Numeric source example*** This script demonstrates how to create a numpy array data and visualize it as image data using a few modules.
- ***Image cursor filter example*** Excample using the UserDefined filter to paint a cross-shaped cursor on data, in order to point out a special position.
- ***Contour example*** This script demonstrates how one can script Mayavi and use its contour related modules.
- ***Unstructured grid example*** A MayaVi example of how to generate an unstructured grid dataset using numpy arrays. Also shown is a way to visualize this data with mayavi2. The script can be run like so:
- ***Structured grid example*** An example of how to generate a structured grid dataset using numpy arrays. Also shown is a way to visualize this data with the mayavi2 application.
- ***Tvtk segmentation example*** Using VTK to assemble a pipeline for segmenting MRI images. This example shows how to insert well-controled custom VTK filters in Mayavi.
- ***Datasets example*** A Mayavi example to show the different data sets. See *Data representation in Mayavi* for a discussion.
- ***Delaunay graph example*** An example illustrating graph manipulation and display with Mayavi and NetworkX.
- ***Mlab 3D to 2D example*** A script to calculate the projection of 3D world coordinates to 2D display coordinates (pixel coordinates) for a given scene.
- ***Magnetic field example*** An example mixing numerical caculation and 3D visualization of the magnetic field created by an arbitrary number of current loops.

10.5 Misc examples

10.5.1 Standalone example

A simple example of how you can use Mayavi without using Envisage or the Mayavi Envisage application.

Source code: standalone.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2007, Enthought, Inc.
# License: BSD Style.

from os.path import join, abspath

from enthought.pyface.api import GUI
# The core Engine.
from enthought.mayavi.core.api import Engine
from enthought.mayavi.core.ui.engine_view import EngineView
# Usual MayaVi imports
from enthought.mayavi.scripts.util import get_data_dir
from enthought.mayavi.sources.api import VTKXMLFileReader
from enthought.mayavi.modules.api import Outline, ScalarCutPlane, Streamline


def main():
    # Create the MayaVi engine and start it.
    e = Engine()
    # Starting the engine registers the engine with the registry and
    # notifies others that the engine is ready.
    e.start()

    # Do this if you need to see the MayaVi tree view UI.
    ev = EngineView(engine=e)
    ui = ev.edit_traits()

    # Create a new scene.
    scene = e.new_scene()
    # Now create a new scene just for kicks.
    scene1 = e.new_scene()

    # Now setup a normal MayaVi pipeline.
    src = VTKXMLFileReader()
    src.initialize(join(get_data_dir(abspath(__file__)),
                        'fire_ug.vtu'))
    e.add_source(src)
    e.add_module(Outline())
    e.add_module(ScalarCutPlane())
    e.add_module(Streamline())
    return e, ui

if __name__ == '__main__':
    # When main returns the ui to go out of scope and be gc'd causing the view
    # to disappear with qt4.
    e, ui = main()
    # Create a GUI instance and start the event loop.  We do this here so that
    # main can be run from IPython -wthread if needed.
```

```
    gui = GUI()
    gui.start_event_loop()
```

10.5.2 Zzz reader example

This is a simple example that shows how to create a reader factory and register that reader with mayavi.

To use this:

- put this in ~/.mayavi2/
- then import this module in your ~/.mayavi2/user_mayavi.py.

that's it.

What you should get:

- Options to open .zzz files from the file->open menu.
- Open .zzz files via right click.
- Open .zzz files from the engine or mlab (via open)
- do mayavi2 -d foo.zzz.

Source code: zzz_reader.py

```
from enthought.mayavi.core.api import registry, SourceMetadata, PipelineInfo

def zzz_reader(fname, engine):
    """Reader for .zzz files.

    Parameters:
    -----------

    fname -- Filename to be read.

    engine -- The engine the source will be associated with.
    """
    from enthought.tvtk.api import tvtk
    from enthought.mayavi.sources.vtk_data_source import VTKDataSource
    # Do your own reader stuff here, I'm just reading a VTK file with a
    # different extension here.
    r = tvtk.StructuredPointsReader(file_name=fname)
    r.update()

    src = VTKDataSource(data=r.output)
    return src

zzz_reader_info = SourceMetadata(
    id            = "ZZZReader",
    factory = 'zzz_reader.zzz_reader',
    tooltip       = "Load a ZZZ file",
    desc    = "Load a ZZZ file",
    help    = "Load a ZZZ file",
    menu_name        = "&ZZZ file",
    extensions = ['zzz'],
    wildcard = 'ZZZ files (*.zzz)|*.zzz',
    output_info = PipelineInfo(datasets=['unstructured_grid'],
                               attribute_types=['any'],
```

```
                                attributes=['any'])
)
# Inject this information in the mayavi registry
registry.sources.append(zzz_reader_info)

if __name__ == '__main__':
    import sys
    print "*"*80
    print "ERROR: This script isn't supposed to be executed."
    print __doc__
    print "*"*80
    sys.exit(1)
```

10.5.3 Pick on surface example

Example showing how to pick data on a surface, going all the way back

to the index in the numpy arrays.

In this example, two views of the same data are shown. One with the data

The trick is to use an observer on the scene interactor to pick when the mouse is pressed, but no moved (to avoid conflicting with interactor logic). Then we can use conventional picking to see if the object of interest is under the cursor, and with the point picker, go back to the index of the point choosen.

Source code: pick_on_surface.py

```
###############################################################################
# Create some data
import numpy as np
pi  = np.pi
cos = np.cos
sin = np.sin

phi, theta = np.mgrid[0:pi+dphi*1.5:dphi,0:2*pi+dtheta*1.5:dtheta]
m0 = 4; m1 = 3; m2 = 2; m3 = 3; m4 = 6; m5 = 2; m6 = 6; m7 = 4;
r = sin(m0*phi)**m1 + cos(m2*phi)**m3 + sin(m4*theta)**m5 + cos(m6*theta)**m7
x = r*sin(phi)*cos(theta)
y = r*cos(phi)
z = r*sin(phi)*sin(theta)

###############################################################################
# Plot the data
from enthought.mayavi import mlab

# A first plot in 3D
fig = mlab.figure(1)
mlab.clf()
mesh = mlab.mesh(x, y, z, scalars=r)
cursor3d = mlab.points3d(0., 0., 0., mode='sphere',
                                color=(0, 0, 0),
                                scale_factor=0.5)

# A second plot, flat
fig2d = mlab.figure(2)
mlab.clf()
im = mlab.imshow(r)
```

```
cursor = mlab.points3d(0, 0, 0, mode='2dthick_cross',
                               color=(0, 0, 0),
                               scale_factor=10)
mlab.view(90, 0)

######################################################################
# Some logic to select 'mesh' and the data index when picking.
from enthought.tvtk.api import tvtk

def picker_callback(picker_obj, evt):
    picker_obj = tvtk.to_tvtk(picker_obj)
    picked = picker_obj.actors
    if mesh.actor.actor._vtk_obj in [o._vtk_obj for o in picked]:
        # m.mlab_source.points is the points array underlying the vtk
        # dataset. GetPointId return the index in this array.
        x_, y_ = np.lib.index_tricks.unravel_index(picker_obj.point_id,
                                                   r.shape)
        print "Data indices: %i, %i" % (x_, y_)
        n_x, n_y = r.shape
        cursor.mlab_source.set(x=np.atleast_1d(x_) - n_x/2.,
                               y=np.atleast_1d(y_) - n_y/2.)
        cursor3d.mlab_source.set(x=np.atleast_1d(x[x_, y_]),
                                 y=np.atleast_1d(y[x_, y_]),
                                 z=np.atleast_1d(z[x_, y_]))
        #x_, y_, z_ = picker_obj.pick_position
        #cursor3d.mlab_source.set(x=np.atleast_1d(x_),
        #                         y=np.atleast_1d(y_),
        #                         z=np.atleast_1d(z_))

fig.scene.picker.pointpicker.add_observer('EndPickEvent', picker_callback)

######################################################################
# Some logic to pick on click but no move
class MvtPicker(object):
    mouse_mvt = False

    def __init__(self, picker):
        self.picker = picker

    def on_button_press(self, obj, evt):
        self.mouse_mvt = False

    def on_mouse_move(self, obj, evt):
        self.mouse_mvt = True

    def on_button_release(self, obj, evt):
        if not self.mouse_mvt:
            x, y = obj.GetEventPosition()
            self.picker.pick((x, y, 0), fig.scene.renderer)
        self.mouse_mvt = False



mvt_picker = MvtPicker(fig.scene.picker.pointpicker)

fig.scene.interactor.add_observer('LeftButtonPressEvent',
                                  mvt_picker.on_button_press)
fig.scene.interactor.add_observer('MouseMoveEvent',
```

```
                                    mvt_picker.on_mouse_move)
fig.scene.interactor.add_observer('LeftButtonReleaseEvent',
                                    mvt_picker.on_button_release)


mlab.show()
```

10.5.4 Nongui example

This script demonstrates how one can use the Mayavi application framework without displaying Mayavi's UI.

Note: look at the end of this file to see how the non gui plugin is chosen instead of the default gui mayavi plugin.

This should be run as:

```
$ python nongui.py
```

Or:

```
$ mayavi2 script.py
```

Source code: nongui.py

```
# Author: Prabhu Ramachandran <prabhu_r@users.sf.net>
# Copyright (c) 2005, Enthought, Inc.
# License: BSD Style.

# Standard library imports
from os.path import join, abspath

# Enthought library imports
from enthought.mayavi.scripts.util import get_data_dir
from enthought.mayavi.plugins.app import Mayavi, get_non_gui_plugins

class MyApp(Mayavi):
    def run(self):
        """This is executed once the application GUI has started.
        *Make sure all other MayaVi specific imports are made here!*
        """

        # Various imports to do different things.
        from enthought.mayavi.sources.vtk_file_reader import VTKFileReader
        from enthought.mayavi.modules.outline import Outline
        from enthought.mayavi.modules.axes import Axes
        from enthought.mayavi.modules.grid_plane import GridPlane
        from enthought.mayavi.modules.image_plane_widget import ImagePlaneWidget
        from enthought.mayavi.modules.text import Text
        from enthought.mayavi.modules.contour_grid_plane import ContourGridPlane
        from enthought.mayavi.modules.iso_surface import IsoSurface

        script = self.script

        # Create a new scene.
        script.new_scene()

        # Read a VTK (old style) data file.
```

```
        r = VTKFileReader()
        r.initialize(join(get_data_dir(abspath(__file__)),
                          'heart.vtk'))
        script.add_source(r)

        # Put up some text.
        t = Text(text='MayaVi rules!', x_position=0.2, y_position=0.9, width=0.8)
        t.property.color = 1, 1, 0  # Bright yellow, yeah!
        script.add_module(t)

        # Create an outline for the data.
        o = Outline()
        script.add_module(o)

        # Create an axes for the data.
        a = Axes()
        script.add_module(a)

        # Create three simple grid plane modules.
        # First normal to 'x' axis.
        gp = GridPlane()
        script.add_module(gp)
        # Second normal to 'y' axis.
        gp = GridPlane()
        gp.grid_plane.axis = 'y'
        script.add_module(gp)
        # Third normal to 'z' axis.
        gp = GridPlane()
        script.add_module(gp)
        gp.grid_plane.axis = 'z'

        # Create one ImagePlaneWidget.
        ipw = ImagePlaneWidget()
        script.add_module(ipw)
        # Set the position to the middle of the data.
        ipw.ipw.slice_position = 16

        # Create one ContourGridPlane normal to the 'x' axis.
        cgp = ContourGridPlane()
        script.add_module(cgp)
        # Set the position to the middle of the data.
        cgp.grid_plane.axis = 'y'
        cgp.grid_plane.position = 15

        # An isosurface module.
        iso = IsoSurface(compute_normals=True)
        script.add_module(iso)
        iso.contour.contours = [200.0]

        # Set the view.
        s = script.engine.current_scene
        cam = s.scene.camera
        cam.azimuth(45)
        cam.elevation(15)
        s.render()


if __name__ == '__main__':
```

```
    m = MyApp()
    # Get the default non GUI plugins.
    plugins = get_non_gui_plugins()
    # Start the app with these plugins.
    m.main(plugins=plugins)
```

10.5.5 User mayavi example

Sample Mayavi customization file.

This code is not to be executed as *mayavi2 -x user_mayavi.py* or *python user_mayavi.py*.

Put this file in ~/.mayavi2/user_mayavi.py and rerun mayavi2 to see what it does – the worker view may not show up by default so you will have to go to View->Other and in the Show View dialog, activate the "Custom Mayavi2 View".

The added modules should show up in the menus (Look for UserOutline in the Modules)

This module demonstrates how to extend Mayavi. It extends the modules provided by mayavi by adding these to the Mayavi registry. Note that the registry imports customize which in turn imports this file.

It also defines an Envisage plugin that is added to the default list of plugins to extend the running mayavi application. This plugin is returned by the *get_plugins()* function.

This file must be placed inside the *~/.mayavi2* directory and called *user_mayavi.py*. Please note that *~/.mayavi2* is placed in *sys.path* (if the directory exists) so make sure that you choose your module names carefully (so as not to override any common module names).

The file may also be placed anywhere on sys.path and called *site_mayavi.py* for global system level customizations.

Source code: user_mayavi.py

```
# Author: Prabhu Ramachandran <prabhu@aero.iitb.ac.in>
# Copyright (c) 2006-2008, Enthought, Inc.
# License: BSD Style.

from enthought.mayavi.core.registry import registry
from enthought.mayavi.core.pipeline_info import PipelineInfo
from enthought.mayavi.core.metadata import ModuleMetadata

# Metadata for the new module we want to add -- notice that we use a
# factory function here for convenience, we could also use a class but
# the reasons for doing this are documented below.
user_outline = ModuleMetadata(
    id             = "UserOutlineModule",
    menu_name          = "&UserOutline",
    factory = 'user_mayavi.user_outline',
    desc   = "Draw a cornered outline for given input",
    tooltip        = "Draw a cornered outline for given input",
    help       = "Draw a cornered outline for given input",
    input_info = PipelineInfo(datasets=['any'],
                              attribute_types=['any'],
                              attributes=['any'])
)

# Register the module with the mayavi registry.
registry.modules.append(user_outline)
```

```
#######
# The all important function that returns the plugin we wish to add to
# the default mayavi application.
def get_plugins():
    # We simply return a list containing the WorkerPlugin defined below.
    return [WorkerPlugin()]

######################################################################
# Thats it, basically.  The rest of the code should really be in another
# module but is in the same module for convenience here.  There are
# problems with doing any significant non-core module imports in this
# module as documented below.
######################################################################


######################################################################
# THE CODE BELOW SHOULD REALLY BE IN SEPARATE MODULES.
#
# The following can very well be in a separate module but I've kept it
# here to make this a compact demo of how to customize things.
######################################################################


######################################################################
# A new module to expose to mayavi.
#
# WARNING: Do not do other mayavi imports right here like for example:
# 'from enthought.mayavi.modules.outline import Outline' etc.  This is
# because the user_mayavi is imported at a time when many of the imports
# are not complete and this will cause hard-to-debug circular import
# problems.  The registry is given only metadata mostly in the form of
# strings and this will cause no problem.  Therefore to define new
# modules, we strongly recommend that the modules be defined in another
# module or be defined in a factory function as done below.

def user_outline():
    """A Factory function that creates a new module to add to the
    pipeline.  Note that the method safely does any mayavi imports
    inside avoiding any circular imports.
    """
    print "User Outline"
    from enthought.mayavi.modules.outline import Outline
    o = Outline(outline_mode='cornered', name='UserOutline')
    return o


######################################################################
# This code simulates something the user would like to do.  In this case
# we just want to create some data, view it with mayavi and modify the
# data.  We want to add this as a view to the standard mayavi.  The code
# below is simply traits code with a few extra things to be able to grab
# the running mayavi instance and script it.  The object we create we
# offer as an envisage service offer -- this instantiates the worker.
# The WorkerPlugin exposes the service offer and shows the view of this
# worker.

import numpy
```

```
from enthought.traits.api import HasTraits, Range, Button, Instance, List
from enthought.traits.ui.api import Item, View

######################################################################
# `Worker` class
######################################################################
class Worker(HasTraits):
    """This class basically allows you to create a data set, view it
    and modify the dataset.  This is a rather crude example but
    demonstrates how things can be done.
    """

    # Set by envisage when this is contributed as a ServiceOffer.
    window = Instance('enthought.pyface.workbench.api.WorkbenchWindow')

    create_data = Button('Create data')
    reset_data = Button('Reset data')
    view_data = Button('View data')
    scale = Range(0.0, 1.0)
    source = Instance('enthought.mayavi.core.source.Source')

    # Our UI view.
    view = View(Item('create_data', show_label=False),
                Item('view_data', show_label=False),
                Item('reset_data', show_label=False),
                Item('scale'),
                resizable=True
                )

    def get_mayavi(self):
        from enthought.mayavi.plugins.script import Script
        return self.window.get_service(Script)

    def _make_data(self):
        dims = [64, 64, 64]
        np = dims[0]*dims[1]*dims[2]
        x, y, z = numpy.ogrid[-5:5:dims[0]*1j,-5:5:dims[1]*1j,-5:5:dims[2]*1j]
        x = x.astype('f')
        y = y.astype('f')
        z = z.astype('f')
        s = (numpy.sin(x*y*z)/(x*y*z))
        s = s.transpose().copy() # This makes the data contiguous.
        return s

    def _create_data_fired(self):
        mayavi = self.get_mayavi()
        from enthought.mayavi.sources.array_source import ArraySource
        s = self._make_data()
        src = ArraySource(transpose_input_array=False, scalar_data=s)
        self.source = src
        mayavi.add_source(src)

    def _reset_data_fired(self):
        self.source.scalar_data = self._make_data()

    def _view_data_fired(self):
        mayavi = self.get_mayavi()
        from enthought.mayavi.modules.outline import Outline
```

```
        from enthought.mayavi.modules.image_plane_widget import ImagePlaneWidget
        # Visualize the data.
        o = Outline()
        mayavi.add_module(o)
        ipw = ImagePlaneWidget()
        mayavi.add_module(ipw)
        ipw.module_manager.scalar_lut_manager.show_scalar_bar = True

        ipw_y = ImagePlaneWidget()
        mayavi.add_module(ipw_y)
        ipw_y.ipw.plane_orientation = 'y_axes'

    def _scale_changed(self, value):
        src = self.source
        data = src.scalar_data
        data += value*0.01
        numpy.mod(data, 1.0, data)
        src.update()

######################################################################
# The following code is the small amount of envisage code that brings
# the users code (above) and Envisage/Mayavi UI together.
from enthought.envisage.api import Plugin, ServiceOffer

######################################################################
# `WorkerPlugin` class
######################################################################
class WorkerPlugin(Plugin):

    # Extension point Ids.
    SERVICE_OFFERS = 'enthought.envisage.ui.workbench.service_offers'
    VIEWS          = 'enthought.envisage.ui.workbench.views'

    # Services we contribute.
    service_offers = List(contributes_to=SERVICE_OFFERS)
    # Views.
    views = List(contributes_to=VIEWS)

    ######################################################################
    # Private methods.
    def _service_offers_default(self):
        """ Trait initializer. """
        worker_service_offer = ServiceOffer(
            protocol = 'user_mayavi.Worker',
            factory  = 'user_mayavi.Worker'
        )
        return [worker_service_offer]

    def _views_default(self):
        """ Trait initializer. """
        return [self._worker_view_factory]

    def _worker_view_factory(self, window, **traits):
        """ Factory method for the current selection of the engine. """

        from enthought.pyface.workbench.traits_ui_view import \
                TraitsUIView
```

```
        worker = window.get_service(Worker)
        tui_worker_view = TraitsUIView(obj=worker,
                                       view='view',
                                       id='user_mayavi.Worker.view',
                                       name='Custom Mayavi2 View',
                                       window=window,
                                       position='left',
                                       **traits
                                       )
        return tui_worker_view

# END OF CODE THAT SHOULD REALLY BE IN SEPARATE MODULES.
######################################################################

if __name__ == '__main__':
    import sys
    print "*"*80
    print "ERROR: This script isn't supposed to be executed."
    print __doc__
    print "*"*80

    from enthought.util.home_directory import get_home_directory
    print "Your .mayavi2 directory should be in %s"%get_home_directory()
    print "*"*80
    sys.exit(1)
```

- ***Standalone example*** A simple example of how you can use Mayavi without using Envisage or the Mayavi Envisage application.
- ***Zzz reader example*** This is a simple example that shows how to create a reader factory and register that reader with mayavi.
- ***Pick on surface example*** Example showing how to pick data on a surface, going all the way back to the index in the numpy arrays.
- ***Nongui example*** This script demonstrates how one can use the Mayavi application framework without displaying Mayavi's UI.
- ***User mayavi example*** Sample Mayavi customization file.

CHAPTER

ELEVEN

MLAB REFERENCE

Reference list of all the main functions of `enthought.mayavi.mlab` with documentation and examples.

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to run the examples or interact with and assemble the functions of *mlab*.

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.1 Plotting functions

11.1.1 barchart

barchart(**args, **kwargs*)

Plots vertical glyphs (like bars) scaled vertical, to do histogram-like plots.

This functions accepts a wide variety of inputs, with positions given in 2-D or in 3-D.

Function signatures:

```
barchart(s, ...)
barchart(x, y, s, ...)
barchart(x, y, f, ...)
barchart(x, y, z, s, ...)
barchart(x, y, z, f, ...)
```

If only one positional argument is passed, it can be a 1-D, 2-D, or 3-D array giving the length of the vectors. The positions of the data points are deducted from the indices of array, and an uniformly-spaced data set is created.

If 3 positional arguments (x, y, s) are passed the last one must be an array s, or a callable, f, that returns an array. x and y give the 2D coordinates of positions corresponding to the s values.

If 4 positional arguments (x, y, z, s) are passed, the 3 first are arrays giving the 3D coordinates of the data points, and the last one is an array s, or a callable, f, that returns an array giving the data value.

Keyword arguments:

auto_scale whether to compute automaticaly the lateral scaling of the glyphs. This might be computationaly expensive. Must be a boolean. Default: True

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

lateral_scale The lateral scale of the glyph, in units of the distance between nearest points Must be a float. Default: 0.9

line_width The with of the lines, if any used. Must be a float. Default: 2.0

mask_points If supplied, only one out of 'mask_points' data point is displayed. This option is usefull to reduce the number of points displayed on large datasets Must be an integer or None.

mode The glyph used to represent the bars. Must be '2dcircle' or '2dcross' or '2ddiamond' or '2dsquare' or '2dthick_cross' or '2dtriangle' or '2dvertex' or 'cube'. Default: cube

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

resolution The resolution of the glyph created. For spheres, for instance, this is the number of divisions along theta and phi. Must be an integer. Default: 8

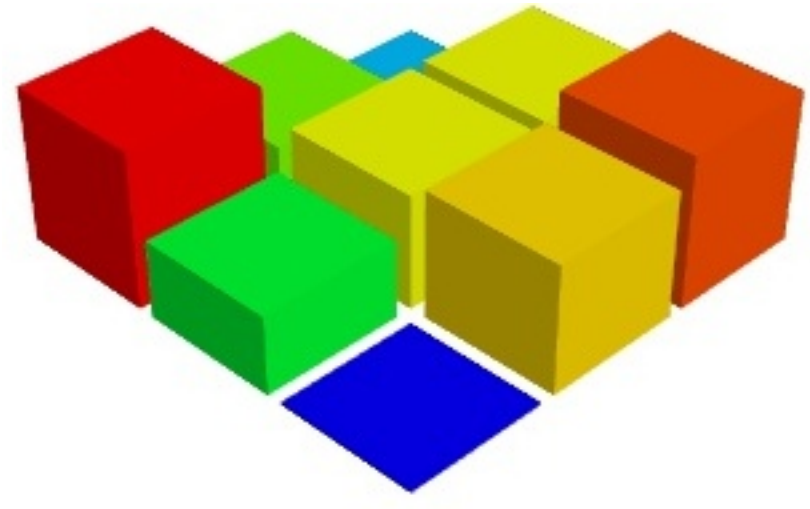
scale_factor the scaling applied to the glyphs. The size of the glyph is by default in drawing units. Must be a float. Default: 1.0

scale_mode the scaling mode for the glyphs ('vector', 'scalar', or 'none').

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *
```

```
def test_barchart():
    """ Demo the bar chart plot with a 2D array.
    """
    s = numpy.abs(numpy.random.random((3, 3)))
    return barchart(s)
```

11.1.2 contour3d

contour3d(**args, **kwargs*)

Plots iso-surfaces for a 3D volume of data suplied as arguments.

Function signatures:

```
contour3d(scalars, ...)
contour3d(x, y, z, scalars, ...)
```

scalars is a 3D numpy arrays giving the data on a grid.

If 4 arrays, (x, y, z, scalars) are passed, the 3 first arrays give the position of the arrows, and the last the scalar value. The x, y and z arrays are then supposed to have been generated by *numpy.mgrid*, in other words, they are 3D arrays, with positions lying on a 3D orthogonal and regularily spaced grid with nearest neighboor in space matching nearest neighboor in the array. The function builds a scalar field assuming the points are regularily spaced.

If 4 positional arguments, (x, y, z, f) are passed, the last one can also be a callable, f, that returns vectors components (u, v, w) given the positions (x, y, z).

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

contours Integer/list specifying number/list of contours. Specifying 0 shows no contours. Specifying a list of values will only give the requested contours asked for.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used

Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_contour3d():
    x, y, z = numpy.ogrid[-5:5:64j, -5:5:64j, -5:5:64j]

    scalars = x*x*0.5 + y*y + z*z*2.0

    obj = contour3d(scalars, contours=4, transparent=True)
    return obj
```

11.1.3 contour_surf

contour_surf(**args, **kwargs*)

Plots a the contours of a surface using grid-spaced data for elevation supplied as a 2D array.

Function signatures:

```
contour_surf(s, ...)
contour_surf(x, y, s, ...)
contour_surf(x, y, f, ...)
```

s is the elevation matrix, a 2D array. The contour lines plotted are lines of equal s value.

x and y can be 1D or 2D arrays (such as returned by numpy.ogrid or numpy.mgrid), but the points should be located on an orthogonal grid (possibly non-uniform). In other words, all the points sharing a same index in the s array need to have the same x or y value. For arbitrary-shaped position arrays (non-orthogonal grids), see the mesh function.

If only 1 array s is passed, the x and y arrays are assumed to be made from the indices of arrays, and an uniformly-spaced data set is created.

If 3 positional arguments are passed the last one must be an array s, or a callable, f, that returns an array. x and y give the coordinnates of positions corresponding to the s values.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

contours Integer/list specifying number/list of contours. Specifying 0 shows no contours. Specifying a list of values will only give the requested contours asked for.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used

warp_scale scale of the warp scalar

Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_contour_surf():
    """Test contour_surf on regularly spaced co-ordinates like MayaVi."""
    def f(x, y):
        sin, cos = numpy.sin, numpy.cos
        return sin(x+y) + sin(2*x - y) + cos(3*x+4*y)

    x, y = numpy.mgrid[-7.:7.05:0.1, -5.:5.05:0.05]
    s = contour_surf(x, y, f)
    return s
```

11.1.4 flow

flow(**args, **kwargs*)

Creates trajectories of particles following the flow of a vector field.

Function signatures:

```
flow(u, v, w, ...)
flow(x, y, z, u, v, w, ...)
flow(x, y, z, f, ...)
```

u, v, w are numpy arrays giving the components of the vectors.

If only 3 arrays, u, v, and w are passed, they must be 3D arrays, and the positions of the arrows are assumed to be the indices of the corresponding points in the (u, v, w) arrays.

If 6 arrays, (x, y, z, u, v, w) are passed, the 3 first arrays give the position of the arrows, and the 3 last the components. The x, y and z arrays are then supposed to have been generated by *numpy.mgrid*, in other words, they are 3D arrays, with positions lying on a 3D orthogonal and regularily spaced grid with nearest neighboor in space matching nearest neighboor in the array. The function builds a vector field assuming the points are regularily spaced.

If 4 positional arguments, (x, y, z, f) are passed, the last one must be a callable, f, that returns vectors components (u, v, w) given the positions (x, y, z).

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

integration_direction The direction of the integration. Must be 'forward' or 'backward' or 'both'. Default: forward

line_width The with of the lines, if any used. Must be a float. Default: 2.0

linetype the type of line-like object used to display the streamline. Must be 'line' or 'ribbon' or 'tube'. Default: line

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

scalars optional scalar data.

seed_resolution The resolution of the seed. Determines the number of seed points Must be an integer or None.

seed_scale Scales the seed around its default center Must be a float. Default: 1.0

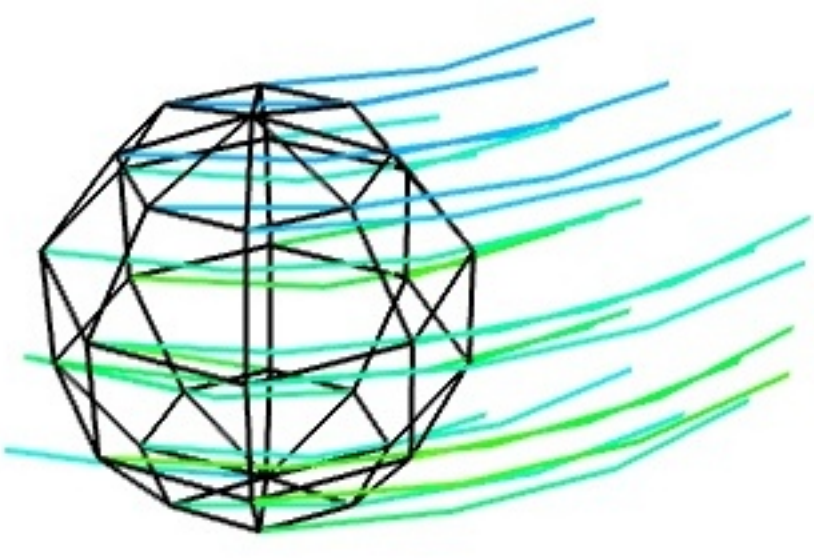
seed_visible Control the visibility of the seed. Must be a boolean. Default: True

seedtype the widget used as a seed for the streamlines. Must be 'line' or 'plane' or 'point' or 'sphere'. Default: sphere

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_flow():
    x, y, z = numpy.mgrid[0:5, 0:5, 0:5]
    r = numpy.sqrt(x**2 + y**2 + z**4)
    u = y*numpy.sin(r)/r
    v = -x*numpy.sin(r)/r
    w = numpy.zeros_like(z)
    obj = flow(u, v, w)
    return obj
```

11.1.5 imshow

imshow(**args, **kwargs*)

View a 2D array as an image.

Function signatures:

```
imshow(s, ...)
```

s is a 2 dimension array. The values of s are mapped to a color using the colormap.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

interpolate if the pixels in the image are to be interpolated or not. Must be a boolean. Default: True

line_width The with of the lines, if any used. Must be a float. Default: 2.0

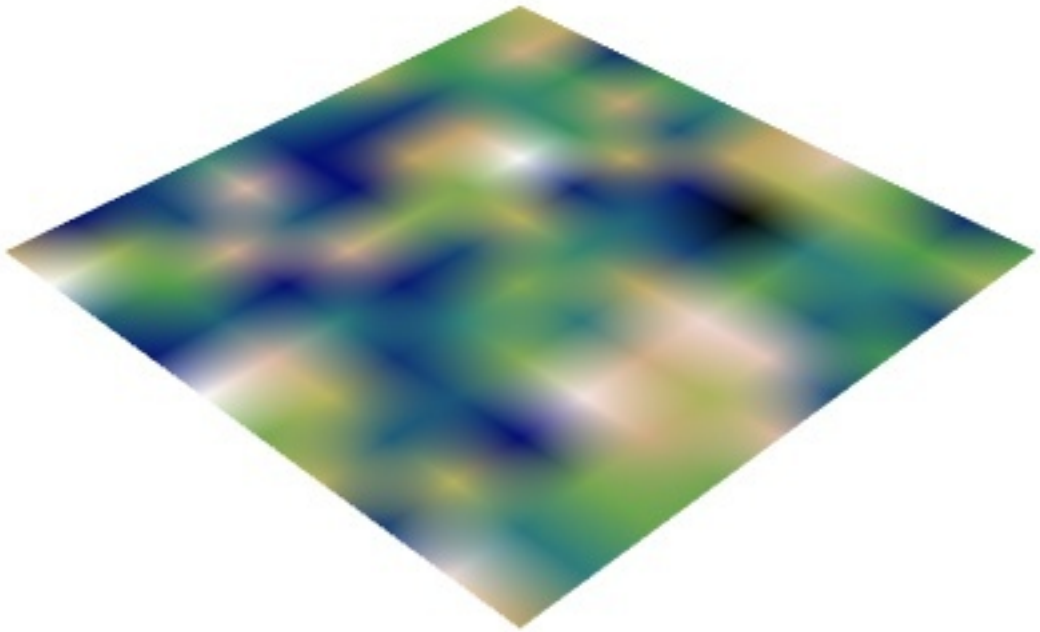
name the name of the vtk object created.

opacity the opacity of the image. Must be a legal value. Default: 1.0

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_imshow():
    """ Use imshow to visualize a 2D 10x10 random array.
    """
    s = numpy.random.random((10,10))
    return imshow(s, colormap='gist_earth')
```

11.1.6 mesh

mesh(**args, **kwargs*)

Plots a surface using grid-spaced data supplied as 2D arrays.

Function signatures:

```
mesh(x, y, z, ...)
```

x, y, z are 2D arrays, all of the same shape, giving the positions of the vertices of the surface. The connectivity between these points is implied by the connectivity on the arrays.

For simple structures (such as orthogonal grids) prefer the *surf* function, as it will create more efficient data structures. For mesh defined by triangles rather than regular implicit connectivity, see the *triangular_mesh* function.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

mask boolean mask array to suppress some data points.

mask_points If supplied, only one out of 'mask_points' data point is displayed. This option is usefull to reduce the number of points displayed on large datasets Must be an integer or None.

mode the mode of the glyphs. Must be '2darrow' or '2dcircle' or '2dcross' or '2ddash' or '2ddiamond' or '2dhooked_arrow' or '2dsquare' or '2dthick_arrow' or '2dthick_cross' or '2dtriangle' or '2dvertex' or 'arrow' or 'axes' or 'cone' or 'cube' or 'cylinder' or 'point' or 'sphere'. Default: sphere

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

representation the representation type used for the surface. Must be 'surface' or 'wireframe' or 'points' or 'mesh' or 'fancymesh'. Default: surface

resolution The resolution of the glyph created. For spheres, for instance, this is the number of divisions along theta and phi. Must be an integer. Default: 8

scalars optional scalar data.

scale_factor scale factor of the glyphs used to represent the vertices, in fancy_mesh mode. Must be a float. Default: 0.05

scale_mode the scaling mode for the glyphs ('vector', 'scalar', or 'none').

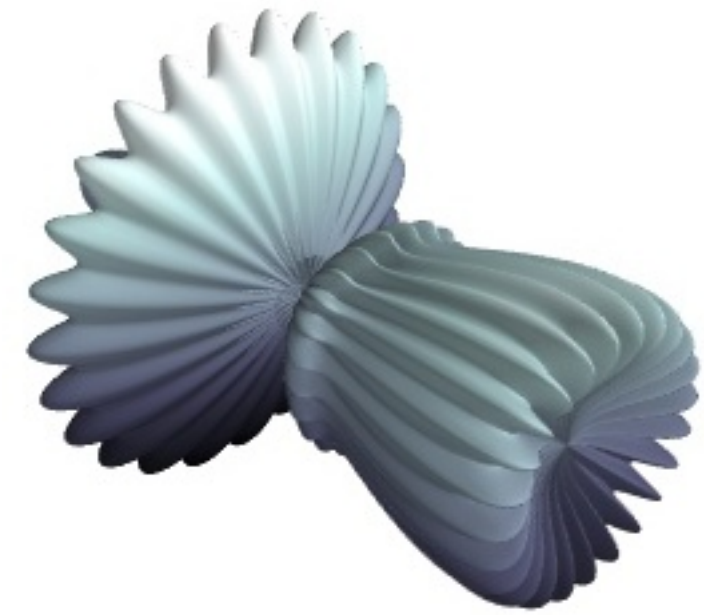
transparent make the opacity of the actor depend on the scalar.

tube_radius radius of the tubes used to represent the lines, in mesh mode. If None, simple lines are used.

tube_sides number of sides of the tubes used to represent the lines. Must be an integer. Default: 6

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_mesh():
    """A very pretty picture of spherical harmonics translated from
    the octaviz example."""
    pi = numpy.pi
    cos = numpy.cos
    sin = numpy.sin
    dphi, dtheta = pi/250.0, pi/250.0
    [phi,theta] = numpy.mgrid[0:pi+dphi*1.5:dphi,0:2*pi+dtheta*1.5:dtheta]
    m0 = 4; m1 = 3; m2 = 2; m3 = 3; m4 = 6; m5 = 2; m6 = 6; m7 = 4;
    r = sin(m0*phi)**m1 + cos(m2*phi)**m3 + sin(m4*theta)**m5 + cos(m6*theta)**m7
    x = r*sin(phi)*cos(theta)
    y = r*cos(phi)
    z = r*sin(phi)*sin(theta);

    return mesh(x, y, z, colormap="bone")
```

11.1.7 plot3d

plot3d(**args, **kwargs*)

Draws lines between points.

Function signatures:

```
plot3d(x, y, z, ...)
plot3d(x, y, z, s, ...)
```

x, y, z and s are numpy arrays or lists of the same shape. x, y and z give the positions of the successive points of the line. s is an optional scalar value associated with each point.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

representation the representation type used for the surface. Must be 'surface' or 'wireframe' or 'points'. Default: surface

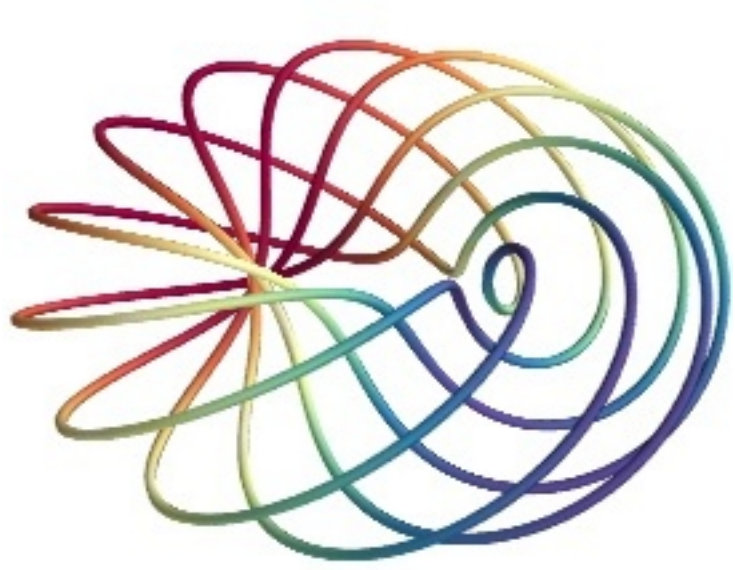
transparent make the opacity of the actor depend on the scalar.

tube_radius radius of the tubes used to represent the lines, If None, simple lines are used.

tube_sides number of sides of the tubes used to represent the lines. Must be an integer. Default: 6

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_plot3d():
    """Generates a pretty set of lines."""
    n_mer, n_long = 6, 11
    pi = numpy.pi
    dphi = pi/1000.0
    phi = numpy.arange(0.0, 2*pi + 0.5*dphi, dphi)
```

```
    mu = phi*n_mer
    x = numpy.cos(mu)*(1+numpy.cos(n_long*mu/n_mer)*0.5)
    y = numpy.sin(mu)*(1+numpy.cos(n_long*mu/n_mer)*0.5)
    z = numpy.sin(n_long*mu/n_mer)*0.5

    l = plot3d(x, y, z, numpy.sin(mu), tube_radius=0.025, colormap='Spectral')
    return l
```

11.1.8 points3d

points3d(**args, **kwargs*)

Plots glyphs (like points) at the position of the supplied data.

Function signatures:

```
points3d(x, y, z...)
points3d(x, y, z, s, ...)
points3d(x, y, z, f, ...)
```

x, y and z are numpy arrays, or lists, all of the same shape, giving the positions of the points.

If only 3 arrays x, y, z are given, all the points are drawn with the same size and color.

In addition, you can pass a fourth array s of the same shape as x, y, and z giving an associated scalar value for each point, or a function f(x, y, z) returning the scalar value. This scalar value can be used to modulate the color and the size of the points.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

mask_points If supplied, only one out of 'mask_points' data point is displayed. This option is usefull to reduce the number of points displayed on large datasets Must be an integer or None.

mode the mode of the glyphs. Must be '2darrow' or '2dcircle' or '2dcross' or '2ddash' or '2ddiamond' or '2dhooked_arrow' or '2dsquare' or '2dthick_arrow' or '2dthick_cross' or '2dtriangle' or '2dvertex' or 'arrow' or 'axes' or 'cone' or 'cube' or 'cylinder' or 'point' or 'sphere'. Default: sphere

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

resolution The resolution of the glyph created. For spheres, for instance, this is the number of divisions along theta and phi. Must be an integer. Default: 8

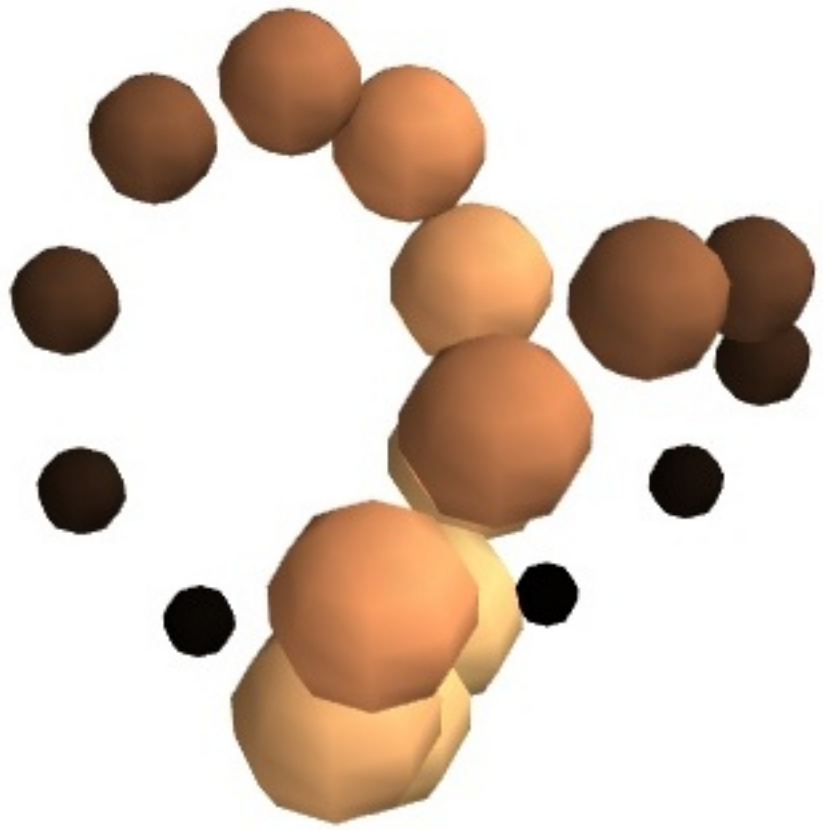
scale_factor The scaling applied to the glyphs. the simple of the glyph is by default calculated from the inter-glyph spacing. Specify a float to give the maximum glyph size in drawing units

scale_mode the scaling mode for the glyphs ('vector', 'scalar', or 'none').

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_points3d():
    t = numpy.linspace(0, 4*numpy.pi, 20)
    cos = numpy.cos
    sin = numpy.sin

    x = sin(2*t)
    y = cos(t)
    z = cos(2*t)
    s = 2+sin(t)

    return points3d(x, y, z, s, colormap="copper", scale_factor=.25)
```

11.1.9 quiver3d

quiver3d(**args, **kwargs*)

Plots glyphs (like arrows) indicating the direction of the vectors at the positions supplied.

Function signatures:

```
quiver3d(u, v, w, ...)
quiver3d(x, y, z, u, v, w, ...)
quiver3d(x, y, z, f, ...)
```

u, v, w are numpy arrays giving the components of the vectors.

If only 3 arrays, u, v, and w are passed, they must be 3D arrays, and the positions of the arrows are assumed to be the indices of the corresponding points in the (u, v, w) arrays.

If 6 arrays, (x, y, z, u, v, w) are passed, the 3 first arrays give the position of the arrows, and the 3 last the components. They can be of any shape.

If 4 positional arguments, (x, y, z, f) are passed, the last one must be a callable, f, that returns vectors components (u, v, w) given the positions (x, y, z).

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

mask_points If supplied, only one out of 'mask_points' data point is displayed. This option is usefull to reduce the number of points displayed on large datasets Must be an integer or None.

mode the mode of the glyphs. Must be '2darrow' or '2dcircle' or '2dcross' or '2ddash' or '2ddiamond' or '2dhooked_arrow' or '2dsquare' or '2dthick_arrow' or '2dthick_cross' or '2dtriangle' or '2dvertex' or 'arrow' or 'axes' or 'cone' or 'cube' or 'cylinder' or 'point' or 'sphere'. Default: 2darrow

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

resolution The resolution of the glyph created. For spheres, for instance, this is the number of divisions along theta and phi. Must be an integer. Default: 8

scalars optional scalar data.

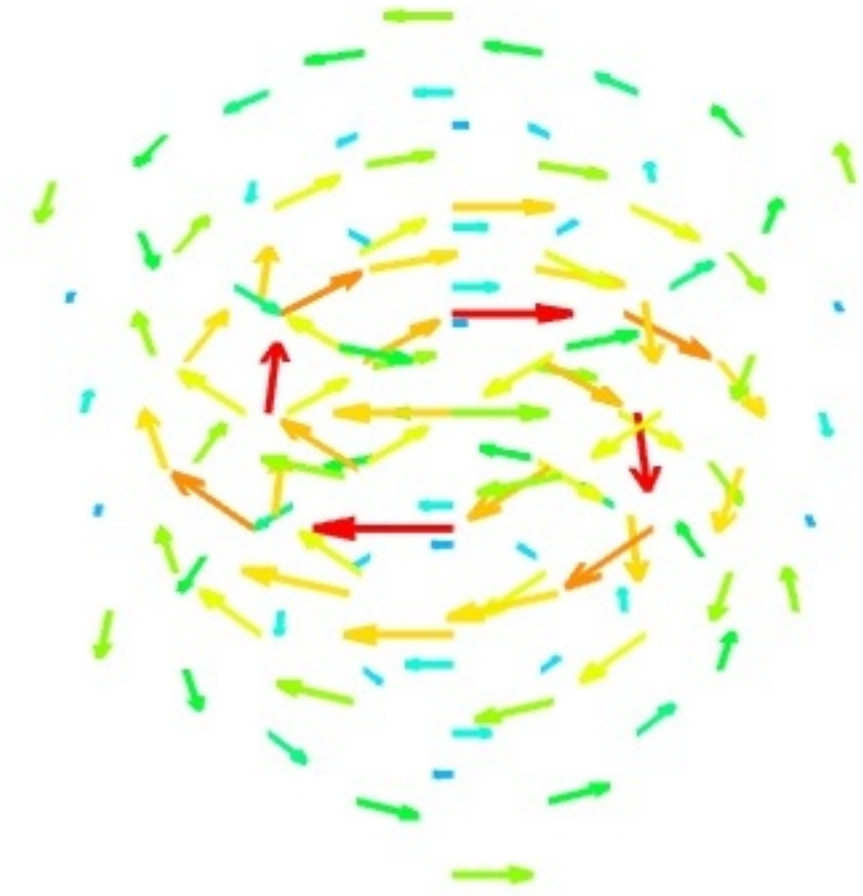
scale_factor The scaling applied to the glyphs. the simple of the glyph is by default calculated from the inter-glyph spacing. Specify a float to give the maximum glyph size in drawing units

scale_mode the scaling mode for the glyphs ('vector', 'scalar', or 'none').

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_quiver3d():
    x, y, z = numpy.mgrid[-2:3, -2:3, -2:3]
    r = numpy.sqrt(x**2 + y**2 + z**4)
    u = y*numpy.sin(r)/(r+0.001)
    v = -x*numpy.sin(r)/(r+0.001)
    w = numpy.zeros_like(z)
    obj = quiver3d(x, y, z, u, v, w, line_width=3, scale_factor=1)
    return obj
```

11.1.10 surf

surf(**args, **kwargs*)

Plots a surface using regularly-spaced elevation data supplied as a 2D array.

Function signatures:

```
surf(s, ...)
surf(x, y, s, ...)
surf(x, y, f, ...)
```

s is the elevation matrix, a 2D array.

x and y can be 1D or 2D arrays (such as returned by numpy.ogrid or numpy.mgrid), but the points should be located on an orthogonal grid (possibly non-uniform). In other words, all the points sharing a same index in the s array need to have the same x or y value. For arbitrary-shaped position arrays (non-orthogonal grids), see the mesh function.

If only 1 array s is passed, the x and y arrays are assumed to be made from the indices of arrays, and an uniformly-spaced data set is created.

If 3 positional arguments are passed the last one must be an array s, or a callable, f, that returns an array. x and y give the coordinnates of positions corresponding to the s values.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

mask boolean mask array to suppress some data points.

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

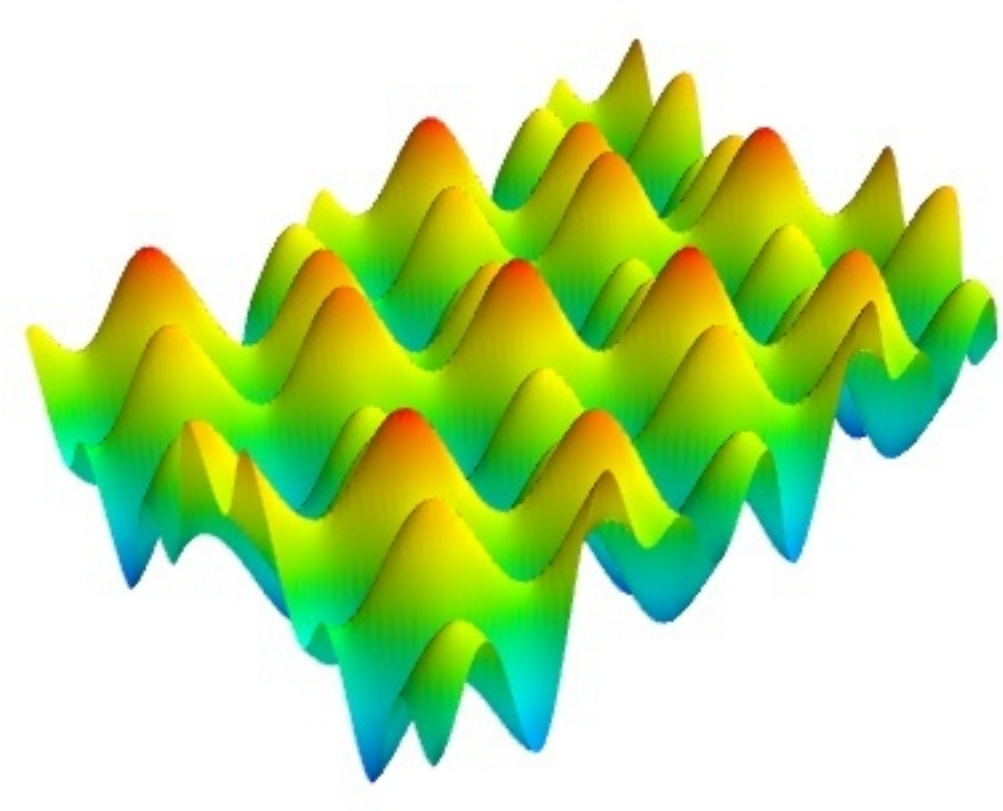
representation the representation type used for the surface. Must be 'surface' or 'wireframe' or 'points'. Default: surface

transparent make the opacity of the actor depend on the scalar.

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used

warp_scale scale of the z axis (warped from the value of the scalar). By default this scale is a float value. If you specify 'auto', the scale is calculated to give a pleasant aspect ratio to the plot, whatever the bounds of the data. If you specify a value for warp_scale in addition to an extent, the warp scale will be determined by the warp_scale, and the plot be positioned along the z axis with the zero of the data centered on the center of the extent. If you are using explicit extents, this is the best way to control the vertical scale of your plots. If you want to control the extent (or range) of the surface object, rather than its scale, see the *extent* keyword argument.



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_surf():
    """Test surf on regularly spaced co-ordinates like MayaVi."""
    def f(x, y):
        sin, cos = numpy.sin, numpy.cos
        return sin(x+y) + sin(2*x - y) + cos(3*x+4*y)

    x, y = numpy.mgrid[-7.:7.05:0.1, -5.:5.05:0.05]
    s = surf(x, y, f)
    #cs = contour_surf(x, y, f, contour_z=0)
    return s
```

11.1.11 triangular_mesh

triangular_mesh(**args, **kwargs*)

Plots a surface using a mesh defined by the position of its vertices and the triangles connecting them.

Function signatures:

```
triangular_mesh(x, y, z, triangles ...)
```

x, y, z are arrays giving the positions of the vertices of the surface. triangles is a list of triplets (or an array) list the vertices in each triangle. Vertices are indexes by their appearance number in the position arrays.

For simple structures (such as rectangular grids) prefer the surf or mesh functions, as they will create more efficient data structures.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Figure to populate.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

mask boolean mask array to suppress some data points.

mask_points If supplied, only one out of 'mask_points' data point is displayed. This option is usefull to reduce the number of points displayed on large datasets Must be an integer or None.

mode the mode of the glyphs. Must be '2darrow' or '2dcircle' or '2dcross' or '2ddash' or '2ddiamond' or '2dhooked_arrow' or '2dsquare' or '2dthick_arrow' or '2dthick_cross' or '2dtriangle' or '2dvertex' or 'arrow' or 'axes' or 'cone' or 'cube' or 'cylinder' or 'point' or 'sphere'. Default: sphere

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

representation the representation type used for the surface. Must be 'surface' or 'wireframe' or 'points' or 'mesh' or 'fancymesh'. Default: surface

resolution The resolution of the glyph created. For spheres, for instance, this is the number of divisions along theta and phi. Must be an integer. Default: 8

scalars optional scalar data.

scale_factor scale factor of the glyphs used to represent the vertices, in fancy_mesh mode. Must be a float. Default: 0.05

scale_mode the scaling mode for the glyphs ('vector', 'scalar', or 'none').

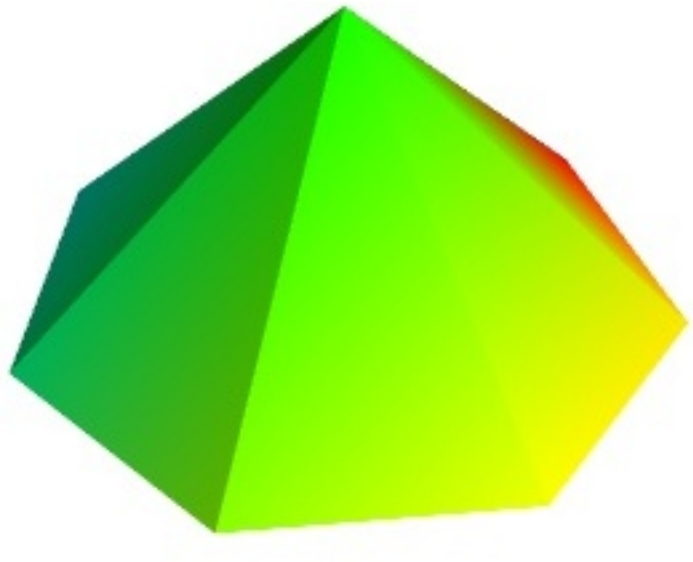
transparent make the opacity of the actor depend on the scalar.

tube_radius radius of the tubes used to represent the lines, in mesh mode. If None, simple lines are used.

tube_sides number of sides of the tubes used to represent the lines. Must be an integer. Default: 6

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used



Example (run in `ipython -wthread` or in the mayavi2 interactive shell, see *Running mlab scripts* for more info):

```
import numpy
from enthought.mayavi.mlab import *

def test_triangular_mesh():
    """An example of a cone, ie a non-regular mesh defined by its
        triangles.
    """
    n = 8
    t = numpy.linspace(-numpy.pi, numpy.pi, n)
    z = numpy.exp(1j*t)
    x = z.real.copy()
    y = z.imag.copy()
    z = numpy.zeros_like(x)

    triangles = [(0, i, i+1) for i in range(n)]
    x = numpy.r_[0, x]
    y = numpy.r_[0, y]
    z = numpy.r_[1, z]
    t = numpy.r_[0, t]

    return triangular_mesh(x, y, z, triangles, scalars=t)
```

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.2 Figure handling functions

11.2.1 clf

clf (*figure=None*)
Clear the current figure.

You can also supply the figure that you want to clear.

11.2.2 close

close(*scene=None, all=False*)

Close a figure window

close() by itself closes the current figure.

close(num) closes figure number num.

close(name) closes figure named name.

close(figure), where figure is a scene instance, closes that figure.

close(all=True) closes all figures controlled by mlab

11.2.3 draw

draw(*figure=None*)

Forces a redraw of the current figure.

11.2.4 figure

figure(*figure=None, bgcolor=None, fgcolor=None, engine=None, size=(400, 350)*)

Creates a new scene or retrieves an existing scene. If the mayavi engine is not running this also starts it.

Keyword arguments

figure The name of the figure, or handle to it.

bgcolor The color of the background (None is default).

fgcolor The color of the foreground, that is the color of all text annotation labels (axes, orientation axes, scalar bar labels). It should be sufficiently far from *bgcolor* to see the annotation texts. (None is default).

engine The mayavi engine that controls the figure.

size The size of the scene created, in pixels. May not apply for certain scene viewer.

11.2.5 gcf

gcf(*engine=None*)

Return a handle to the current figure.

You can supply the engine from which you want to retrieve the current figure, if you have several mayavi engines.

11.2.6 savefig

savefig(*filename, size=None, figure=None, magnification='auto', **kwargs*)

Save the current scene. The output format are deduced by the extension to filename. Possibilities are png, jpg, bmp, tiff, ps, eps, pdf, rib (renderman), oogl (geomview), iv (OpenInventor), vrml, obj (wavefront)

Parameters

Size the size of the image created (unless magnification is set, in which case it is the size of the window used for rendering).

Figure the figure instance to save to a file.

Magnification the magnification is the scaling between the pixels on the screen, and the pixels in the file saved. If you do not specify it, it will be calculated so that the file is saved with the specified size. If you specify a magnification, Mayavi will use the given size as a screen size, and the file size will be 'magnification * size'.

Notes

If the size specified is larger than the window size, and no magnification parameter is passed, the magnification of the scene is changed so that the image created has the requested size. Please note that if you are trying to save images with sizes larger than the window size, there will be additional computation cost.

Any extra keyword arguments are passed along to the respective image format's save method.

11.2.7 screenshot

screenshot(*figure=None, mode='rgb', antialiased=False*)

Return the current figure pixmap as an array.

Parameters

Figure a figure instance or None, optional If specified, the figure instance to capture the view of.

Mode {'rgb', 'rgba'} The color mode of the array captured.

Antialiased {True, False} Use anti-aliasing for rendering the screenshot. Uses the number of aa frames set by figure.scene.anti_aliasing_frames

Notes

On most systems, this works similarly to taking a screenshot of the rendering window. Thus if it is hidden by another window, you will capture the other window. This limitation is due to the heavy use of the hardware graphics system.

Examples

This function can be useful for integrating 3D plotting with Mayavi in a 2D plot created by matplotlib.

```
>>> from enthought.mayavi import mlab
>>> mlab.test_plot3d()
>>> arr = mlab.screenshot()
>>> import pylab as pl
>>> pl.imshow(arr)
>>> pl.axis('off')
>>> pl.show()
```

11.2.8 sync_camera

sync_camera(*reference_figure, target_figure*)

Synchronise the camera of the target_figure on the camera of the reference_figure.

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.3 Figure decoration functions

11.3.1 colorbar

colorbar(*object=None, title=None, orientation=None, nb_labels=None, nb_colors=None, label_fmt=None*)
Adds a colorbar for the color mapping of the given object.

If the object has scalar data, the scalar color mapping is represented. Elsewhere the vector color mapping is represented, if available. If no object is specified, the first object with a color map in the scene is used.

Keyword arguments:

object Optional object to get the color map from

title The title string

orientation Can be 'horizontal' or 'vertical'

nb_labels The number of labels to display on the colorbar.

label_fmt The string formater for the labels. This needs to be a formater for float number, eg '%.1f'.

nb_colors The maximum number of colors displayed on the colorbar.

11.3.2 scalarbar

scalarbar(*object=None, title=None, orientation=None, nb_labels=None, nb_colors=None, label_fmt=None*)
Adds a colorbar for the scalar color mapping of the given object.

If no object is specified, the first object with scalar data in the scene is used.

Keyword arguments:

object Optional object to get the scalar color map from

title The title string

orientation Can be 'horizontal' or 'vertical'

nb_labels The number of labels to display on the colorbar.

label_fmt The string formater for the labels. This needs to be a formater for float number, eg '%.1f'.

nb_colors The maximum number of colors displayed on the colorbar.

11.3.3 vectorbar

vectorbar(*object=None, title=None, orientation=None, nb_labels=None, nb_colors=None, label_fmt=None*)
Adds a colorbar for the vector color mapping of the given object.

If no object is specified, the first object with vector data in the scene is used.

Keyword arguments

object Optional object to get the vector color map from

title The title string

orientation Can be 'horizontal' or 'vertical'

nb_labels The number of labels to display on the colorbar.

label_fmt The string formater for the labels. This needs to be a formater for float number, eg '%.1f'.

nb_colors The maximum number of colors displayed on the colorbar.

11.3.4 xlabel

xlabel(*text, object=None*)

Creates a set of axes if there isn't already one, and sets the x label

Keyword arguments:

object The object to apply the module to, if not the whole scene is searched for a suitable object.

11.3.5 ylabel

ylabel(*text, object=None*)

Creates a set of axes if there isn't already one, and sets the y label

Keyword arguments:

object The object to apply the module to, if not the whole scene is searched for a suitable object.

11.3.6 zlabel

zlabel(*text, object=None*)

Creates a set of axes if there isn't already one, and sets the z label

Keyword arguments

object The object to apply the module to, if not the whole scene is searched for a suitable object.

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.4 Camera handling functions

11.4.1 move

move(*forward=None, right=None, up=None*)

:: Translates the camera and focal point together.

The arguments specify the relative distance to translate the camera and focal point, so as to produce the appearence of moving the camera without changing the effective field of view. If called with no arguments, the function returns the absolute position of the camera and focal pointon a cartesian coordinate system.

Note that the arguments specify relative motion, although the return value with no arguments is in an absolute coordinate system.

Keyword arguments:

forward float, optional. The distance in space to translate the camera forward (if positive) or backward (if negative)

right float, optional. The distance in space to translate the camera to the right (if positive) or left (if negative)

up float, optional. The distance in space to translate the camera up (if positive) or down (if negative)

Returns:

If no arguments are supplied (or all are None), returns a tuple (camera_position, focal_point_position)

otherwise, returns None

Examples:

Get the current camera position:

```
>>> cam,foc = move()
>>> cam
array([-0.06317079, -0.52849738, -1.68316389])
>>> foc
array([ 1.25909623,  0.15692708, -0.37576693])
```

Translate the camera:

```
>>> move(3,-1,-1.2)
>>> move()
(array([ 2.93682921, -1.52849738, -2.88316389]),
 array([ 4.25909623, -0.84307292, -1.57576693]))
```

Return to the starting position::

```
>>> move(-3,1,1.2)
>>> move()
(array([-0.06317079, -0.52849738, -1.68316389]),
 array([ 1.25909623,  0.15692708, -0.37576693]))
```

See also :mlab.yaw: yaw the camera (tilt left-right) :mlab.pitch: pitch the camera (tilt up-down) :mlab.roll: control the absolute roll angle of the camera :mlab.view: set the camera position relative to the focal point instead

of in absolute space

11.4.2 pitch

pitch (*degrees*)

Rotates the camera about the axis corresponding to the "right" direction of the current view. Note that this will change the location of the focal point (although not the camera location).

This angle is relative to the current direction - the angle is NOT an absolute angle in a fixed coordinate system.

See also

Mlab.yaw relative rotation about the "up" direction

Mlab.roll absolute roll angle (i.e. "up" direction)

Mlab.move relative translation of the camera and focal point

11.4.3 roll

roll(*roll=None*)

Sets or returns the absolute roll angle of the camera.

See also

Mlab.view control the position and direction of the camera

11.4.4 view

view(*azimuth=None, elevation=None, distance=None, focalpoint=None, reset_roll=True, figure=None*)

Sets/Gets the view point for the camera.

view(azimuth=None, elevation=None, distance=None, focalpoint=None, figure=None)

If called with no arguments this returns the current view of the camera. To understand how this function works imagine the surface of a sphere centered around the visualization. The *azimuth* argument specifies the angle "phi" on the x-y plane which varies from 0-360 degrees. The *elevation* argument specifies the angle "theta" from the z axis and varies from 0-180 degrees. The *distance* argument is the radius of the sphere and the *focalpoint*, the center of the sphere.

Note that if the *elevation* is close to zero or 180, then the *azimuth* angle refers to the amount of rotation of a standard x-y plot with respect to the x-axis. Thus, specifying `view(0,0)` will give you a typical x-y plot with x varying from left to right and y from bottom to top.

Keyword arguments:

azimuth float, optional. The azimuthal angle (in degrees, 0-360), i.e. the angle subtended by the position vector on a sphere projected on to the x-y plane with the x-axis.

elevation float, optional. The zenith angle (in degrees, 0-180), i.e. the angle subtended by the position vector and the z-axis.

distance float or 'auto', optional. A positive floating point number representing the distance from the focal point to place the camera. New in Mayavi 3.4.0: if 'auto' is passed, the distance is computed to have a best fit of objects in the frame.

focalpoint array_like or 'auto', optional. An array of 3 floating point numbers representing the focal point of the camera. New in Mayavi 3.4.0: if 'auto' is passed, the focal point is positioned at the center of all objects in the scene.

reset_roll boolean, optional. If True, the roll orientation of the camera is reset.

figure The Mayavi figure to operate on. If None is passed, the current one is used.

Returns:

If no arguments are supplied it returns a tuple of 4 values `(azimuth, elevation, distance, focalpoint)`, representing the current view. Note that these can be used later on to set the view.

If arguments are supplied it returns *None*.

Examples:

Get the current view:

```
 >>> v = view()
 >>> v
(45.0, 45.0, 25.02794981, array([ 0.01118028,  0.        ,  4.00558996]))
```

Set the view in different ways:

```
>>> view(45, 45)
>>> view(240, 120)
>>> view(distance=20)
>>> view(focalpoint=(0,0,9))
```

Set the view to that saved in *v* above:

```
>>> view(*v)
```

See also

Mlab.roll control the roll angle of the camera, ie the direction pointing up

11.4.5 yaw

yaw(*degrees*)

Rotates the camera about the axis corresponding to the "up" direction of the current view. Note that this will change the location of the focal point (although not the camera location).

This angle is relative to the current direction - the angle is NOT an absolute angle in a fixed coordinate system.

See also

Mlab.pitch relative rotation about the "right" direction

Mlab.roll absolute roll angle (i.e. "up" direction)

Mlab.move relative translation of the camera and focal point

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.5 Other functions

11.5.1 animate

animate(*func=None, delay=500, ui=True*)

::

A convenient decorator to animate a generator that performs an animation. The *delay* parameter specifies the delay (in milliseconds) between calls to the decorated function. If *ui* is True, then a simple UI for the animator is also popped up. The decorated function will return the *Animator* instance used and a user may call its *Stop* method to stop the animation.

If an ordinary function is decorated a *TypeError* will be raised.

Parameters

delay int specifying the time interval in milliseconds between calls to the function.

ui bool specifying if a UI controlling the animation is to be provided.

Returns

The decorated function returns an *Animator* instance.

Examples

Here is the example provided in the Animator class documentation:

```
>>> from enthought.mayavi import mlab
>>> @mlab.animate
... def anim():
...     f = mlab.gcf()
...     while 1:
...         f.scene.camera.azimuth(10)
...         f.scene.render()
...         yield
...
>>> a = anim() # Starts the animation.
```

For more specialized use you can pass arguments to the decorator:

```
>>> from enthought.mayavi import mlab
>>> @mlab.animate(delay=500, ui=False)
... def anim():
...     f = mlab.gcf()
...     while 1:
...         f.scene.camera.azimuth(10)
...         f.scene.render()
...         yield
...
>>> a = anim() # Starts the animation without a UI.
```

Notes

If you want to modify the data plotted by an *mlab* function call, please refer to the section on: *Animating the data*.

11.5.2 axes

axes(**args, **kwargs*)

Creates axes for the current (or given) object.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the object's extents.

figure Must be a Scene or None.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

nb_labels The number of labels along each direction Must be a legal value. Default: 2

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

ranges [xmin, xmax, ymin, ymax, zmin, zmax] Ranges of the labels displayed on the axes. Default is the object's extents.

x_axis_visibility Whether or not the x axis is visible (boolean)

xlabel the label of the x axis

y_axis_visibility Whether or not the y axis is visible (boolean)

ylabel the label of the y axis

z_axis_visibility Whether or not the z axis is visible (boolean)

zlabel the label of the z axis

11.5.3 get_engine

get_engine(*self*)

Returns an engine in agreement with the options.

11.5.4 orientation_axes

orientation_axes(**args, **kwargs*)

Applies the OrientationAxes mayavi module to the given VTK data object.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

figure Must be a Scene or None.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

xlabel the label of the x axis

ylabel the label of the y axis

zlabel the label of the z axis

11.5.5 outline

outline(**args, **kwargs*)

Creates an outline for the current (or given) object.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the object's extents.

figure Must be a Scene or None.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

11.5.6 set_engine

set_engine (*self, engine*)
Sets the mlab engine.

11.5.7 show

show (*func=None, stop=False*)
Start interacting with the figure.

By default, this function simply creates a GUI and starts its event loop if needed.

If it is used as a decorator, then it may be used to decorate a function which requires a UI. If the GUI event loop is already running it simply runs the function. If not the event loop is started and function is run in the toolkit's event loop. The choice of UI is via *ETSConfig.toolkit*.

If the argument stop is set to True then it pops up a UI where the user can stop the event loop. Subsequent calls to *show* will restart the event loop.

Parameters

stop A boolean which specifies if a UI dialog is displayed which allows the event loop to be stopped.

Examples

Here is a simple example demonstrating the use of show:

```
>>> from enthought.mayavi import mlab
>>> mlab.test_contour3d()
>>> mlab.show()
```

You can stop interaction via a simple pop up UI like so:

```
>>> mlab.test_contour3d()
>>> mlab.show(stop=True)
```

The decorator can be used like so:

```
>>> @mlab.show
... def do():
...     mlab.test_contour3d()
...
>>> do()
```

The decorator can also be passed the stop argument:

```
>>> @mlab.show(stop=True)
... def do():
...     mlab.test_contour3d()
...
>>> do()
```

11.5.8 show_engine

show_engine()
This function is deprecated, please use show_pipeline.

11.5.9 show_pipeline

show_pipeline(*self, engine=None, rich_view=True*)
Show a dialog with the mayavi pipeline. This dialog allows to edit graphicaly the properties of the different objects on the scenes.

11.5.10 start_recording

start_recording(*ui=True*)
Start automatic script recording. If the *ui* parameter is *True*, it creates a recorder with a user interface, if not it creates a vanilla recorder without a UI.

Returns The *Recorder* instance created.

11.5.11 stop_recording

stop_recording(*file=None*)
Stop the automatic script recording.

Parameters

file An open file or a filename or *None*. If this is *None*, nothing is saved.

11.5.12 text

text(**args, **kwargs*)
Adds a text on the figure.

Function signature:

```
text(x, y, text, ...)
```

x, and y are the position of the origin of the text. If no z keyword argument is given, x and y are the 2D projection of the figure, they belong to [0, 1]. If a z keyword argument is given, the text is positionned in 3D, in figure coordinnates.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

figure Must be a Scene or None.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The opacity of the text.

width width of the text.

z Optional z position. When specified, the text is positioned in 3D

11.5.13 text3d

text3d(**args, **kwargs*)

Positions text at a 3D location in the scene.

Function signature:

```
text3d(x, y, z, text, ...)
```

x, y, and z are the position of the origin of the text. The text is positionned in 3D, in figure coordinnates.

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

figure Must be a Scene or None.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

orient_to_camera if the text is kept oriented to the camera, or is pointing in a specific direction, regardless of the camera position. Must be a boolean. Default: True

orientation the angles giving the orientation of the text. If the text is oriented to the camera, these angles are referenced to the axis of the camera. If not, these angles are referenced to the z axis. Must be an array with shape (3,).

scale The scale of the text, in figure units. Either a float, or 3-tuple of floats.

11.5.14 title

title(**args, **kwargs*)

Creates a title for the figure.

Function signature:

```
title(text, ...)
```

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

figure Must be a Scene or None.

height height of the title, in portion of the figure height

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

size the size of the title

11.6 Mlab pipeline-control reference

Reference list of all the main functions of `pipeline` sub module of `mlab`. You can access these functions using:

```
mlab.pipeline.function(...)
```

These functions can be used for finer control of the Mayavi pipeline than the main mlab interface. For usage examples, see *Assembling pipelines with mlab*.

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.6.1 Sources

array2d_source

array2d_source(**args, **kwargs*)

Creates structured 2D data from a 2D array.

Function signatures:

```
array2d_source(s, ...)
array2d_source(x, y, s, ...)
array2d_source(x, y, f, ...)
```

If 3 positional arguments are passed the last one must be an array s, or a callable, f, that returns an array. x and y give the coordinnates of positions corresponding to the s values.

x and y can be 1D or 2D arrays (such as returned by numpy.ogrid or numpy.mgrid), but the points should be located on an orthogonal grid (possibly non-uniform). In other words, all the points sharing a same index in the s array need to have the same x or y value.

If only 1 array s is passed the x and y arrays are assumed to be made from the indices of arrays, and an uniformly-spaced data set is created.

Keyword arguments:

name the name of the vtk object created.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

mask Mask points specified in a boolean masking array.

builtin_image

builtin_image(*metadata=<enthought.mayavi.core.metadata.SourceMetadata object at 0x9c1029c>*)

Create a vtk image data source

builtin_surface

builtin_surface(*metadata=<enthought.mayavi.core.metadata.SourceMetadata object at 0x9c1020c>*)
Create a vtk poly data source

chaco_file

chaco_file(*metadata=<enthought.mayavi.core.metadata.SourceMetadata object at 0x9c103bc>*)
Open a Chaco file

grid_source

grid_source(*x, y, z, **kwargs*)
Creates 2D grid data.

x, y, z are 2D arrays giving the positions of the vertices of the surface. The connectivity between these points is implied by the connectivity on the arrays.

For simple structures (such as orthogonal grids) prefer the array2dsource function, as it will create more efficient data structures.

Keyword arguments:

name the name of the vtk object created.

scalars optional scalar data.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

line_source

line_source(**args, **kwargs*)
Creates line data.

Function signatures:

```
line_source(x, y, z, ...)
line_source(x, y, z, s, ...)
line_source(x, y, z, f, ...)

If 4 positional arguments are passed the last one must be an array s, or
a callable, f, that returns an array.
```

Keyword arguments:

name the name of the vtk object created.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

open

open(*filename, figure=None*)
Open a supported data file given a filename. Returns the source object if a suitable reader was found for the file.

parametric_surface

parametric_surface(*metadata=<enthought.mayavi.core.metadata.SourceMetadata object at 0x9c100ec>*)
Create a parametric surface source

point_load

point_load(*metadata=<enthought.mayavi.core.metadata.SourceMetadata object at 0x9c1017c>*)
Simulates a point load on a cube of data (for tensors)

scalar_field

scalar_field(**args, **kwargs*)
Creates a scalar field data.

Function signatures:

```
scalar_field(s, ...)
scalar_field(x, y, z, s, ...)
scalar_field(x, y, z, f, ...)
```

If only 1 array s is passed the x, y and z arrays are assumed to be made from the indices of arrays.

If the x, y and z arrays are passed they are supposed to have been generated by *numpy.mgrid*. The function builds a scalar field assuming the points are regularily spaced.

If 4 positional arguments are passed the last one must be an array s, or a callable, f, that returns an array.

Keyword arguments:

name the name of the vtk object created.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

scalar_scatter

scalar_scatter(**args, **kwargs*)
Creates scattered scalar data.

Function signatures:

```
scalar_scatter(s, ...)
scalar_scatter(x, y, z, s, ...)
scalar_scatter(x, y, z, s, ...)
scalar_scatter(x, y, z, f, ...)
```

If only 1 array s is passed the x, y and z arrays are assumed to be made from the indices of vectors.

If 4 positional arguments are passed the last one must be an array s, or a callable, f, that returns an array.

Keyword arguments:

name the name of the vtk object created.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

triangular_mesh_source

triangular_mesh_source(*x, y, z, triangles, **kwargs*)

Creates 2D mesh by specifying points and triangle connectivity.

x, y, z are 2D arrays giving the positions of the vertices of the surface. The connectivity between these points is given by listing triplets of vertices inter-connected. These vertices are designed by there position index.

Keyword arguments:

name the name of the vtk object created.

scalars optional scalar data.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

vector_field

vector_field(**args, **kwargs*)

Creates vector field data.

Function signatures:

```
vector_field(u, v, w, ...)
vector_field(x, y, z, u, v, w, ...)
vector_field(x, y, z, f, ...)
```

If only 3 arrays u, v, w are passed the x, y and z arrays are assumed to be made from the indices of vectors.

If the x, y and z arrays are passed, they should have been generated by *numpy.mgrid* or *numpy.ogrid*. The function builds a scalar field assuming the points are regularily spaced on an orthogonal grid.

If 4 positional arguments are passed the last one must be a callable, f, that returns vectors.

Keyword arguments:

name the name of the vtk object created.

scalars optional scalar data.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

vector_scatter

vector_scatter(**args, **kwargs*)
Creates scattered vector data.

Function signatures:

```
vector_scatter(u, v, w, ...)
vector_scatter(x, y, z, u, v, w, ...)
vector_scatter(x, y, z, f, ...)
```

If only 3 arrays u, v, w are passed the x, y and z arrays are assumed to be made from the indices of vectors.

If 4 positional arguments are passed the last one must be a callable, f, that returns vectors.

Keyword arguments:

name the name of the vtk object created.

scalars optional scalar data.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

vertical_vectors_source

vertical_vectors_source(**args, **kwargs*)
Creates a set of vectors pointing upward, useful eg for bar graphs.

Function signatures:

```
vertical_vectors_source(s, ...)
vertical_vectors_source(x, y, s, ...)
vertical_vectors_source(x, y, f, ...)
vertical_vectors_source(x, y, z, s, ...)
vertical_vectors_source(x, y, z, f, ...)
```

If only one positional argument is passed, it can be a 1D, 2D, or 3D array giving the length of the vectors. The positions of the data points are deducted from the indices of array, and an uniformly-spaced data set is created.

If 3 positional arguments (x, y, s) are passed the last one must be an array s, or a callable, f, that returns an array. x and y give the 2D coordinates of positions corresponding to the s values. The vertical position is assumed to be 0.

If 4 positional arguments (x, y, z, s) are passed, the 3 first are arrays giving the 3D coordinates of the data points, and the last one is an array s, or a callable, f, that returns an array giving the data value.

Keyword arguments:

name the name of the vtk object created.

figure optionally, the figure on which to add the data source. If None, the source is not added to any figure, and will be added automatically by the modules or filters. If False, no figure will be created by modules or filters applied to the source: the source can only be used for testing, or numerical algorithms, not visualization.

volume_file

volume_file(*metadata=<enthought.mayavi.core.metadata.SourceMetadata object at 0x9c1032c>*)
Open a Volume file

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.6.2 Tools

add_dataset

add_dataset(*dataset, name='', **kwargs*)
Add a dataset object to the Mayavi pipeline.

Parameters

Dataset a tvtk dataset, or a Mayavi source. The dataset added to the Mayavi pipeline

Figure a figure identifier number or string, None or False, optionnal.

If no *figure* keyword argument is given, the data is added to the current figure (a new figure if created if necessary).

If a *figure* keyword argument is given, it should either the name the number of the figure the dataset should be added to, or None, in which case the data is not added to the pipeline.

If figure is False, a null engine is created. This null engine does not create figures, and is mainly usefull for tensting, or using the VTK algorithms without visualization.

Returns

The corresponding Mayavi source is returned.

add_module_manager

add_module_manager(*object*)
Add a module-manager, to control colors and legend bars to the given object.

get_vtk_src

get_vtk_src(*mayavi_object, stop_at_filter=True*)
Goes up the Mayavi pipeline to find the data sources of a given object.

Parameters

Object any Mayavi visualization object

Stop_at_filter optional boolean flag: if True, the first object exposing data found going up the pipeline is returned. If False, only the source itself is returned.

Returns

Sources List of vtk data sources (vtk data sources, and not Mayavi source objects).

Notes

This function traverses the Mayavi pipeline. Thus the input object 'mayavi_object' should already be added to the pipeline.

set_extent

set_extent(*module, extents*)
Attempts to set the physical extents of the given module.

The extents are given as (xmin, xmax, ymin, ymax, zmin, zmax). This does not work on an image plane widget, as this module does not have an actor.

Once you use this function on a module, be aware that other modules applied on the same data source will not share the same scale. Thus for instance an outline module will not respect the outline of the actors whose extent you modified. You should pass in the same "extents" parameter for this to work.You can have a look at the wigner.py example for a heavy use of this functionnality.

Note

This function does not work on some specific modules, such as Outline, Axes, or ImagePlaneWidget. For Outline and Axes, use the extent keyword argument of mlab.pipeline.outline and mlab.pipeline.axes.

traverse

traverse(*node*)
Generator to traverse a tree accessing the nodes' children attribute.

Example

Here is a simple example printing the names of all the objects in the pipeline:

```
for obj in mlab.pipeline.traverse(mlab.gcf()):
    print obj.name
```

Note: This section is only a reference describing the function, please see the chapter on *mlab: Python scripting for 3D plotting* for an introduction to mlab and how to interact with and assemble the functions of *mlab*.

Please see the section on *Running mlab scripts* for instructions on running the examples.

11.6.3 Data

probe_data

probe_data(*mayavi_object, x, y, z, type='scalars', location='points'*)
Retrieve the data from a described by Mayavi visualization object at points x, y, z.

Parameters

Viz_obj A Mayavi visualization object, or a VTK dataset The object describing the data you are interested in.

X float or ndarray. The x position where you want to retrieve the data.

Y float or ndarray. The y position where you want to retrieve the data.

Z float or ndarray The z position where you want to retrieve the data.

Type 'scalars', 'vectors' or 'tensors', optional The type of the data to retrieve.

Location 'points' or 'cells', optional The location of the data to retrieve.

Returns

The values of the data at the given point, as an ndarray (or multiple arrays, in the case of vectors or tensors) of the same shape as x, y, and z.

11.6.4 Modules and Filters

For each Mayavi module or filter, there is a corresponding *mlab.pipeline* factory function that takes as an input argument the source on which the new module or filter will be added, and returns the created module object. The name of the function corresponds to the name of the module, but with words separated by underscores _, rather than alternating capitals.

The input object, if it is a data source (Mayavi data source or VTK dataset), does not need to be already present in the figure, it will be automatically added if necessary.

Factory functions take keyword arguments controlling some properties of the object added to the pipeline.

For instance, the *ScalarCutPlane* module can be added with the following function:

scalar_cut_plane(**args, **kwargs*)

Applies the ScalarCutPlane mayavi module to the given data source (Mayavi source, or VTK dataset).

Keyword arguments:

color the color of the vtk object. Overides the colormap, if any, when specified. This is specified as a triplet of float ranging from 0 to 1, eg (1, 1, 1) for white.

colormap type of colormap to use.

extent [xmin, xmax, ymin, ymax, zmin, zmax] Default is the x, y, z arrays extents. Use this to change the extent of the object created.

figure Must be a Scene or None.

line_width The with of the lines, if any used. Must be a float. Default: 2.0

name the name of the vtk object created.

opacity The overall opacity of the vtk object. Must be a float. Default: 1.0

plane_orientation the orientation of the plane Must be a legal value. Default: x_axes

transparent make the opacity of the actor depend on the scalar.

view_controls Whether or not the controls of the cut plane are shown. Must be a boolean. Default: True

vmax vmax is used to scale the colormap If None, the max of the data will be used

vmin vmin is used to scale the colormap If None, the min of the data will be used

As the list is long, we shall not enumerate here all the factory function for adding modules or filters. You are invited to refer to their docstring for information on the keyword arguments they accept.

CHAPTER

TWELVE

KNOWN BUGS AND ISSUES

Here we list several known bugs along with potential solutions when available and also those that are currently unresolved with links to the appropriate tickets.

- **Display bugs:** Mayavi, and VTK, heavily use hardware rendering, as a result are very sensitive to hardware rendering bugs. Common issues include surfaces showing up as black instead of colored (mostly on windows or in virtual machines, I believe), z-ordering bugs where hidden triangles are displayed in front of the triangles that should hide them (a common bug on Linux with intel graphics cards), or the rendering windows becomming grey when the focus is moved out (often seen on Linux, when compiz is enabled). The solution is most often simply to turn off hardware rendering in the system settings (turn off compiz under Linux) or change graphics-card drivers (under Linux, try switching between the open source one, and the proprietary one).
- **Crash when adding list items** https://svn.enthought.com/enthought/ticket/1813 : Crashing list editor on Linux with wx backend when adding or removing list items. In Mayavi this happens for instance when adding or removing contours.

CHAPTER

THIRTEEN

MAYAVI 3.3.1 (NOT YET RELEASED)

13.1 Enhancements

13.2 Fixes

CHAPTER

FOURTEEN

MAYAVI 3.3.0 (JULY 15, 2009)

14.1 Enhancements

(not collated yet, sorry)

14.2 Fixes

(not collated yet, sorry)

CHAPTER

FIFTEEN

MAYAVI 3.2.0 (MARCH 23, 2009)

A log of significant changes made to the package especially API changes. This is only partial and only covers the developments after the 2.x series. The log refers to changesets in the trac format [#revno], for example to view the changeset [18702] use the following URL: https://svn.enthought.com/enthought/changeset/18702

17, 18 March, 2009 (PR):

- NEW: A simple example to show how one can use TVTK's visual module with mlab. [23250]
- BUG: The size trait was being overridden and was different from the parent causing a bug with resizing the viewer. [23243]

15 March, 2009 (GV):

- ENH: Add a volume factory to mlab that knows how to set color, vmin and vmax for the volume module [23221].

14 March, 2009 (PR):

- API/TEST: Added a new testing entry point: 'mayavi -t' now runs tests in separate process, for isolation. Added `enthought.mayavi.api.test` to allow for simple testing from the interpreter [23195]...[23200], [23213], [23214], [23223].
- BUG: The volume module was directly importing the wx_gradient_editor leading to an import error when no wxPython is available. This has been tested and fixed. Thanks to Christoph Bohme for reporting this issue. [23191]

14 March, 2009 (GV):

- BUG: [mlab]: fix positioning for titles [23194], and opacity for titles and text [23193].
- ENH: Add the mlab_source attribute on all objects created by mlab, when possible [23201], [23209].
- ENH: Add a message to help the first-time user, using the new banner feature of the IPython shell view [23208].

13 March, 2009 (PR):

- NEW/API: Adding a powerful TCP/UDP server for scripting mayavi via the network. This is available in `enthought.mayavi.tools.server` and is fully documented. It uses twisted and currently only works with wxPython. It is completely insecure though since it allows a remote user to do practically *anything* from mayavi.

13 March, 2009 (GV)

- API: rename mlab.orientationaxes to mlab.orientation_axes [23184]

11 March, 2009 (GV)

- API: Expose 'traverse' in mlab.pipeline [23181]

10 March, 2009 (PR)

- BUG: Fixed a subtle bug that affected the ImagePlaneWidget. This happened because the scalar_type of the output data from the VTKDataSource was not being set correctly. Getting the range of any input scalars also seems to silence warnings from VTK. This should hopefully fix issues with the use of the IPW with multiple scalars. I've added two tests for this, one is an integration test since those errors really show up only when the display is used. The other is a traditional unittest. [23166]

08 March, 2009 (GV)

- ENH: Raises an error when the user passes to mlab an array with infinite values [23150]

07 March, 2009 (PR)

- BUG: A subtle bug with a really gross error in the GridPlane component, I was using the extents when I should really have been looking at the dimensions. The extract grid filter was also not flushing the data changes downstream leading to errors that are also fixed now. These errors would manifest when you use an ExtractGrid to select a VOI or a sample rate and then used a grid plane down stream causing very wierd and incorrect rendering of the grid plane (thanks to conflation of extents and dimensions). This bug was seen at NAL for a while and also reported by Fred with a nice CME. The CME was then converted to a nice unittest by Suyog and then improved. Thanks to them all. [23146]

28 February, 2009 (PR)

- BUG: Fixed some issues reported by Ondrej Certik regarding the use Of mlab.options.offscreen, mlab.options.backend = 'test', removed cruft from earlier 'null' backend, fixed bug with incorrect imports, add_dataset set no longer adds one new null engine each time figure=False is passed, added test case for the options.backend test. [23088]

23 February, 2009 (PR)

- ENH: Updating show so that it supports a stop keyword argument that pops up a little UI that lets the user stop the mainloop temporarily and continue using Python [23049]

21 February, 2009 (GV)

- ENH: Add a richer view for the pipeline to the MayaviScene [23035]
- ENH: Add safegards to capture wrong triangle array sizes in mlab.triangular_mesh_source. [23037]

21 February, 2009 (PR)

- ENH: Making the transform data filter recordable. [23033]
- NEW: A simple animator class to make it relatively to create animations. [23036] [23039]

20 February, 2009 (PR)

- ENH: Added readers for various image file formats, poly data readers and unstructured grid readers. These include DICOM, GESigna, DEM, MetaImage (mha,mhd) MINC, AVSucd, GAMBIT, Exodus, STL, Points, Particle, PLY, PDB, SLC, OBJ, Facet and BYU files. Also added several tests for most of this functionality along with small data files. These are additions from PR's project staff, Suyog Jain and Sreekanth Ravindran. [23013]
- ENH: We now change the default so the ImagePlaneWidget does not control the LUT. Also made the IPW recordable. [23011]

18 February, 2009 (GV)

- ENH: Add a preference manager view for editing preferences outside envisage [22998]

08 February, 2009 (GV)

- ENH: Center the glyphs created by barchart on the data points, as mentioned by Rauli Ruohonen [22906]

29 January, 2009 (GV)

- ENH: Make it possible to avoid redraws with mlab by using *mlab.gcf().scene.disable_render = True* [22869]

28 January, 2009 (PR and GV)

- ENH: Make the mlab.pipeline.user_defined factory function usable to add arbitrary filters on the pipeline. [22867], [22865]

11 January, 2009 (GV)

- ENH: Make mlab.imshow use the ImageActor. Enhance the ImageActor to map scalars to colors when needed. [22816]

CHAPTER

SIXTEEN

MAYAVI 3.1.0

3 December, 2008 (PR)

- BUG: Fixing bugs with persistence of VTKDataSource objects wrapping a structured grid in VTK-5.2. This resulted in hard to debug test errors. [22624]

1 December, 2008 (GV):

- **API: Promote the TestEngine to a first-class citizen NullEngine and** make mlab use it when a source has a keyword argument "figure=False". [22594]

30 November, 2008 (PR)

- NEW: New sources called BuiltinSurface and BuiltinImage that let users create simple polygonal data and images using basic VTK sources. Thanks to Suyog Jain for this code. [22586], [22597].

27 November, 2008 (GV):

- **ENH: Add control of the seed size and resolution to** mlab.pipeline_basene.streamline [22573].
- **DOC: Documentation work, especially in the scripting parts of the** docs. [22572], [22561], [22560], [22546], [22545]

26 November, 2008 (GV):

- **ENH: Add keyword arguments to the cutplanes in mlab.pipeline. [22567]** Also add masking to glyph-based mlab.pipeline factories [22568]

19 November, 2008 (GV):

- UI: Rename 'Modules' to 'Colors and legends' [22512]
- **API: Change defaults [22513]:**
  - CellToPointData and PointToCellData filters to pass the existing dataset.
  - The ouline of the implicite plane is no longer draggable by default.

15-16 November, 2008 (PR)

- ENH/API: Exposing the glyph source choices via a dictionary rather than having the user remember the index in a list. [22497]
- ENH: Adding a button to the LUT UI so the LUT editor can be launched from the UI. [22498]
- DOC: Updating advanced scripting chapter. [22495].

13 November, 2008 (GV)

- ENH: [mlab] Add keyword arguments to colobars to control label number and format, as well as colors number. [22489]

10 November, 2008 (PR)

- TEST: Adding 43 new mayavi tests. These are based on the integration tests but don't pop up a user interface. Thanks to Suyog Jain for doing bulk of the work. [22465]

27 October, 2008 (GV)

- ENH: [mlab] If a module or filter is added to the pipeline using the mlab.pipeline functions, the source on which it is added onto is automatically added to the scene if not alread present. It is also automatically converted from a tvtk dataset to a mayavi source, if needed. [22375], [22377]
- ENH: [mlab] Make mlab.axes and mlab.outline use the extents of the current object when none specified explicitely. [22372]

24-27 October, 2008 (PR)

- NEW: Adding an ImageChangeInformation filter to let users change the origin, spacing and extents of input image data, [22351].
- API: Adding a *set_viewer* function to *enthought.tvtk.tools.visual* so one may specify a viewer to render into. This lets us use visual with a mayavi scene. [22363]
- BUG: Fix a major bug with TVTK when VTK is built with 64 bit ids (VTK_USE_64BIT_IDS is on). The examples and tests should all run in this case now. [22365]
- ENH: [mlab] Added an *mlab.view* method that actually works [22366].

19 October, 2008 (GV)

- ENH: mlab.text can now take 3D positioning [22331].

17-20 October, 2008 (PR)

- ENH: Modified TVTK and Mayavi UI editors so that text entry boxes are only set when the user hits <enter> or <tab> rather than on each keystroke. [22321], [22323]
- ENH/BUG/WARN: Fixed warnings at TVTK build time, fixed bugs with ImageData's scalar_type trait. [22320], [22321], [22325].
- NEW/API: Adding preference option to ease task of loading contrib packages (via a pkg/user_mayavi.py) in mayavi. Also added a contrib finder that trawls sys.path to find contributions. This can be set from the preferences UI. [22324], [22326], [22327].
- BUG: Fixing problems with the gradient_editor and newer VTK versions. This is required for the Volume module to work correctly. [22329], [22341]

13 October, 2008 (GV):

- ENH: Bind the 'explore' function in the python shell [22307]
- **ENH: mlab: axes and outline now find the extents from the objects** they are given, if any. [22305]

12 October, 2008 (GV):

- API: mlab: Add a barchart function, with the corresponding pipeline source function. [22286]

11 October, 2008 (PR):

- ENH/API: Improving texture map support, you can now generate the texture coords on an arbitrary actor. This adds to the API of the actor component. [22283]
- API: Adding a *enthought.mayavi.preferences.bindings* module that abstracts out setting of preferences for common objects. Currently it exposes a *set_scene_preferences* so the non-envisage and off screen scenes have the right preferences. See [22280] and [22295].

- REFACTOR/API: The script recording code is now in *enthought.scripting*, the *enthought.mayavi.core.recorder* was only a temporary solution. See [22277] and [22279].

10 October, 2008 (GV):

- API: mlab: Expose pipeline.set_extent (former private function tools._set_extent) [22251]

9 October, 2008 (GV):

- ENH: Use the IPython shell plugin only if the ipython, envisage and pyface versions are recent-enough. Mayavi now uses an ipython widget instead of the pyshell one if you have the right components installed, but should fall back to pyshell gracefully. [21678], [22245]

4 October, 2008 (PR):

- TEST: Added a 'test' backend to mlab so you can run mlab tests without a display. Fixing core code so that all the unittests run when the ETS_TOOLKIT env var is set to 'null'. [22198]

30 September, 2008 (GV):

- API: mlab: Expose pipeline.add_dataset (former private function tools._data) [22162].
- API: The mlab source functions can now optionaly work without creating a figure (using figure=None) [22161].
- API: The mlab source functions are more robust to various input-argument shape (they accept lists, and 1D or 2D arrays when possible) [22161].

29 September, 2008 (GV):

- NEW: Add a mlab.triangular_mesh function to create meshes with arbitrary triangular connectivity. Also add a corresponding triangular_mesh_source mlab source. [22155]
- ENH: Make mlab.points3d and other mlab functions accept scalars as coordinnates, in addition to arrays. [22156]

12 September, 2008 (PR)

- NEW: Create a separate OffScreenEngine for use to reduce code duplication. This is also available as part of enthought.mayavi.api. [21880]
- TEST: Creating a common.py that contains a TestEngine mayavi engine subclass for easily testing mayavi. [21881]

8-12 September, 2008 (PR)

- NEW: Adding full support for script recording. With this you can pretty much record all UI actions performed on the Mayavi UI (both standalone and application) to human-readable and runnable Python scripts. It also serves as a nice learning tool since it shows the lines of code as the UI actions are performed. Note that interacting with the camera is also recorded which is very convenient. This has been implemented in a pretty general fashion (using TDD) so is reusable in other traits based applications also. Major checkins [21722], [21728], [21776], [21812], [21865] [21878].

CHAPTER

SEVENTEEN

MAYAVI 3.0.3

7 September, 2008 (PR):

- ENH: The mayavi2 application now ([21713], [21714]) supports command line args like the following:

```
mayavi2 -d ParametricSurface -s "function='dini'" -m Surface \
-s "module_manager.scalar_lut_manager.show_scalar_bar = True" \
-s "scene.isometric_view()" -s "scene.save('snapshot.png')"
```

6 September, 2008 (PR):

- ENH/API: Cleaned up the enthought.mayavi.core.traits to remove buggy, and unused DRange and SimpleDRange traits. [21705]
- BUG/TEST: Added tests for some of the MlabSource subclasses and fixed many bugs in the code. [21708]
- TEST: Modified pipeline_base.py so mayavi objects may be started without creating a scene (and therefore a UI). This allows us to create completely non-interactive tests. [21709]
- ENH: Adding X3D and POVRAY export options. [21711]

23 August, 2008 (PR):

- ENH: Adding an offscreen option for mlab. Now you can set mlab.options.offscreen = True. [21510]
- ENH: Setting the window size to (1,1) if the window is offscreen, this prevents the window from showing up prominently – it still does show up though. [21519]

21 August, 2008 (PR):

- ENH: Adding the logger plugin to the mayavi2 app. [21487]

CHAPTER

EIGHTEEN

MAYAVI 3.0.1 AND 3.0.2

16 August, 2008 (PR):

- BUG: fixed various miscellaneous bugs including a testing error[21304], a long standing Mac bug with picking [21310], a segfault [21453] and a bug in tvtk when wrapping certain methods [21475].

CHAPTER

NINETEEN

MAYAVI 3.0.0

15 August, 2008 (PR):

- NEW: Adding a fully tested data set manager that lets users add/remove/modify attribute arrays to a tvtk dataset. This is fully tested and also does not influence any other code. [21300]

10 August, 2008 (PR):

- ENH/API: [mlab] Added a *MlabSource* class to abstract out the data creation and modification into one object that may be modified. This source object is injected in the form of a *mlab_source* trait on objects returned by any of the helper functions (*surf*, *plot3d* etc.) or the sources. The user can use this to modify the data visualized without recreating the pipeline each time, making animations very easy and smooth. There are several examples of the form *test_blah_anim* showing how this is done. [21098], [21103].

27 July, 2008 (GV):

- ENH: Add an option (on by default) to open the docs in a chromeless window when using firefox. [20451] [20450]
- ENH: Add toolbar to the engine view [20447]
- ENH: Selected item on the tree jumps to newly created objects [20454]
- ENH: Add a button on the viewer using by mayavi in standalone to open up the engine view [20456] [20462]
- ENH: Clean UI for adding sources/filters/modules (Adder nodes) [20461] [20460] [20458] [20452]
- ENH: [mlab] add a resolution argument to glyphs [20465]
- **API: [mlab] API Breakage!** Make mlab source names compatible with ETS standards: grid_source rather than gridsource [20466]
- **NEW: Add image_plane_widget to mlab.pipeline, with helpful keyword** arguments.

23 July, 2008 (GV):

- ENH: The mlab API can now take either engine or figure keyword arguments. This allows to avoid the use of the global sate set in the mlab engine. Mlab also now exposes a set_engine function. [20245]

23 July, 2008 (PR)

- ENH/NEW: The mlab.pipeline sources, modules and filters now feature automatic source/filter/module generation functions from registry information. This means mlab fully supports creating objects on the mayavi pipeline with easy one-liners. [20239]
- API: The API has broken! Sources, filters and modules that mirror an existing mayavi class now are named with underscores. For example, isosurface has become iso_surface, extractedges becomes extract_edges etc.

- NEW: Exposing the engine's open method to mlab so it is easy to open data files from mlab also.
- ENH: Implemented an mlab.show decorator so one can write out a normal function for visualization which will work from ipython, standalone and mayavi completely seamlessly.

18, 19 July, 2008 (PR)

- TEST/API: The mayavi tests are now split into integration and unit tests. Unit tests go into enthought/mayavi/tests. Integration tests are in integrationtests/mayavi. Major changes:
  - Removed most of the image based tests except one (test_streamline.py) for reference.
  - Modified the testing code so the standalone mode is the default.
  - Modified so nose picks up the integrationtests. However, there are problems running the test via nosetests on Linux that need investigating.
- ENH: Creating a new object on the pipeline via envisage or right click now sets the active selection to the created object so it is easy to edit.
- API: Moving enthought/mayavi/view/engine_view.py to enthought/mayavi/core/ui. [20098]
- API: Added method to engine (get_viewer) so it gets the viewer associated with a particular scene. [20101]

12 July, 2008 (PR):

- ENH/API: Adding support for global (system wide) and local customizations via a site_mayavi.py and user_mayavi.py (in ~/.mayavi2/). This allows users to register new modules/filters and sources and also add any envisage plugins to the mayavi2 app easily. [19920]

9 July, 2008 (Judah, PR)

- ENH: Adding the core code for an AdderNode that shows up on the engine view and lets a user easily create new scenes/sources/filters and modules.

8 July, 2008 (PR)

- BUG: Ported various bug fixes from branches for ETS-2.8.0 release.
- ENH/API: Added datatype, attribute type and attribute information to all pipeline objects (both at the object and metadata levels). This lets one query if an object will support a given input and what outputs it will provide (this can be changed dynamically too). This allows us to create context sensitive menus. The traits UI menus for the right click is now modified to use this information. We therefore have context sensitive right click menus depending on the nature of the object we right click on. At this point we don't yet check for the attribute_type and attributes metadata information to enable/disable menus, this may be implemented later – the framework makes this quite easy to do. [19512].
- ENH: Envisage menus are now context sensitive [19520].

5 July, 2008 (PR):

- ENH: One can create objects on the pipeline using right-clicks [19469].
- ENH: All the envisage menus and actions for sources, filters and modules now are autogenerated from the metadata for these.
- **NEW/API: [19458] adds the following features:**
  - A Registry (enthought.mayavi.core.registry.Registry) to register engines, sources, filters and modules. Source, filter and module metadata is registered and this can be used to do various things like generate menus, register data file extension handlers and whatnot. The metadata related classes are in enthought.mayavi.core.metadata.
  - This registry and metadata information is used to generate the envisage menus and actions.
  - The registry can be used by users to register new sources, readers, filters and modules.

  - A method to Engine and Script to easily open any supported data file.
  - Simplify the open file interface so it is just one menu item that supports different file extensions.
  - Changed the command line options for the mayavi2 application so you can open *any* supported data file format with the -d option. This breaks backwards compatibility but makes it very easy to open supported data files – even if the new ones are added by users.
  - Fixed the PLOT3DReader so it opens the q file using the xyz filenames basename.

29 June, 2008 (GV):

- ENH: Updated Sphinx docs [19318].
- ENH: New splash screen [19319].
- ENH: mlab now works with envisage, including in "mayavi2 -x" [19321] [19323]

27 June, 2008 (Vibha):

- API: Remove SimpleScene class [19285].
- API: Moved tvtk-related examples from TraitsGUI to Mayavi [19191] [19197] [19231] [19280]

27 June, 2008 (GV):

- BUG: tvtk: proper handling of non-float numpy arrays. Added test case [19297]

25 June, 2008 (GV):

- ENH: Add autoscale to mlab.surf (scalez keyword argument) [19131]
- ENH: mlab.usrf and mlab.mesh can now take x and y arguments with a more flexible shape [19114].

12 June, 2008 (PR):

- ENH: Adding an offscreen option to the mayavi2 application. This lets you run a normal mayavi Python script in offscreen mode without the full UI. This is very convenient when you want to render a huge number of images from a visualization and don't want the UI to bother you or create a special script for the purpose. See [18951], [18955].

07, 08 June, 2008 (PR):

- API: TVTK: Added two methods *setup_observers* and *teardown_observers* that let one turn on/off the observer for the ModifiedEvent fired on each VTK object that a TVTK object wraps to keep the traits updated. Thus, if you call *teardown_observers* the traits will not be automatically updated if the wrapped VTK object is changed. This can be manually updated by calling the *update_traits* method. It is OK to call the setup/teardown_observers method as often as needed. This is also tested. See [18885].
- API: TVTK: Removed the *__del__* method on all TVTK objects. This should make it much nicer for proper garbage collection. See [18886], [18887].

06 June, 2008 (PR):

- TEST: Added a standalone mode to the tests so you can test without starting up the envisage app. Envisage imports may be required however. To use this run any test with the -s option. [18880]
- TEST: Added a way to run the tests on one application launch instead of starting mayavi each time. To use this execute run.py with the –one-shot command line option. [18880] [18881].
- TEST: The standalone offscreen mode now should work without a single Traits UI showing up with just a dummy blank window being used. This demonstrates how mayavi scripts can work in completely different contexts. [18881].

31 May, 2008 (PR):

- PORT: Backported important additions to the 2.2.0 branch.

- BUG: Added a test case for the hide/show functionality and fixed known bugs.
- API: Adding elementary support for texturing an actor (if it has texture coords). This was thanks to a patch from Chandrashekhar Kaushik. [18827]

30 May, 2008 (PR):

- API: Adding closing, closed lifecycle events to the scene [18806].

27 May, 2008 (PR):

- NEW: Adding a Labels module to label input data. This is like MayaVi1's module and with this checkin all important mayavi1 modules and filters are supported in mayavi2. The only missing one is Locator which hardly anyone uses I think. See [18801].

27 May, 2008 (PR):

- NEW: Adding an ImageDataProbe filter which does the same thing that MayaVi-1.5's StructuredPointsProbe does. [18792]

25 May, 2008 (PR):

- NEW: Adding CellDerivatives and Vorticity filters. [18785]

24 May, 2008 (PR):

- NEW: Adding a tvtk_doc.py module that doubles as a TVTK Class/Filter/Source/Sink chooser and also as a documentation browser (with search!) like Mayavi1.x's vtk_doc.py. tvtk_doc is also installed as a console script now. [18776]
- NEW: Adding a UserDefined filter where the user can wrap around any TVTK filter. [18780]

23 May, 2008 (PR):

- NEW: SetActiveAttribute filter that lets you select the active attribute. This makes it very easy to find the contours of one scalar on the iso-contour of another. The example contour_contour.py shows how this is done. See [18774], [18775].

22 May, 2008 (PR):

- NEW: Adding Contour and CutPlane filters that use the Wrapper filter and respective components. This is very convenient.
- Checked in modified patch from Chandrashekhar Kaushik (CSE IITB), which reimplements hide/show using a visible trait.

21 May, 2008 (PR):

- TEST: Adding an @test decorator to make it easy to create a mayavi test case from a mayavi script. While this is convenient, I still prefer to explicitly use the TestCase class since this makes the code compatible with the 2.2.0 branch.
- The GenericModule is now tested.

20 May, 2008 (PR):

- NEW: Adding a GenericModule to easily put together a bunch of Filters and Components. Using this code it takes 30 simple lines of code for a ScalarCutPlane compared to the 300 complex ones we need for the current implementation! This is because the module takes care of all the dirty work.
- NEW: Adding Wrapper, Optional and Collection filters that make it easy to wrap around existing Components and Filters, make them optional and create collections of them very easily. This gives us a great deal of reuse and makes it very easy to create new filters.

18 May, 2008 (PR):

- ENH: Improved the PLOT3D reader and added a test for it.
- Added a menu item to allow a user to run a Python script from the UI.
- API: Added a close method to *enthought.pyface.tvtk.tvtk_scene.TVTKScene*. This class is inherited by all Scenes (DecoratedScene and Scene). The close method shuts down the scene properly. This should hopefully prevent async errors when closing editors/windows containing scenes. See [18708].
- Updated the scene plugin, scene_editor (TraitsBackend*), actor_editor and the ivtk code to use the close method.
- TEST: All the tests run on the trunk and pass when the offscreen option is used (which was also added).

17 May, 2008 (PR):

- NEW: Adding an SelectOutput filter that should address bug number 478359 in the Debian BTS. See [18700].
- API: enthought.mayavi.plugins.app.Mayavi now defines a setup_logger method so this can be overridden by subclasses, see [18703].

13 May, 2008 (PR):

- NEW: Adding an ExtractVectorComponents filter contributed by Varun Hiremath.

11,12 May 2008 (PR):

- ENH/API: The plugins now start the engine themselves and also do the binding to the shell. Earlier this was done by the application. This makes the plugins reusable. Also added a running trait to the engine to check on its status. [18672], [18678].
- At this point all examples in trunk work save the mayavi_custom_ui plugin stuff.

10 May 2008 (PR):

- API: Moving enthought/mayavi/engine.py -> enthought/mayavi/core/engine.py where it really belongs; see [18667].

7,8 May 2008 (PR):

- API: The plugins_e3 package is now moved into plugins. This breaks the enthought.tvtk.plugins API and also the enthought.mayavi.mayavi_*_definition modules. The older envisage2 plugin code is all removed. See: [18649], [18650], [18651], [18652], [18655], [18657], [18662].

6 May 2008 (PR):

- API: The enthought.mayavi.core.Base.confirm_delete class attribute is gone since it is no longer needed [18635].
- API: Removed config directory, integrated all mlab preferences into the the mayavi preferences framework, see [18632]. To get the preferences just do:

```
from enthought.mayavi.preferences.api import preference_manager
```

  This is the preference manager that manages all prefs. To see the code look in enthought.mayavi.preferences.preference_manager. It is also a good idea to read the enthought.preferences documentation.
- BUG: [18627] Fixed bug number 478844 on the Debian BTS here: http://bugs.debian.org/cgi-bin/bugreport.cgi?bug=478844

4 May 2008 (PR):

- API: Added to api. Added a new preferences framework for mayavi2. This uses enthought.preferences and works well both standalone and with envisage3. It makes it easy to create/define/change preferences at the application and library level.

2 May, 2008 (PR):

- API: Ported the mayavi2 application and plugin to work with Envisage3. See changesets [18595] and [18598]. *This obviously breaks the plugin API completely!*
- Got the mlab envisage_engine_manager working with new changes [18599].

Before this changeset, the code was that of the 2.x series.

- *Index*
- *Search Page*

m2_about.jpg