

Mayavi and VTK

Introduction

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Outline

Background and Motivation

Introduction to Mayavi
History

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Visualization?

What is visualization?

Visualization: graphics

Making a visible presentation of numerical data, particularly a graphical one. This might include anything from a simple X-Y graph of one dependent variable against one independent variable to a virtual reality which allows you to fly around the data.

– from the Free On-line Dictionary of Computing

What is visualization?

Visual representation of data

3D visualization

Harder but important

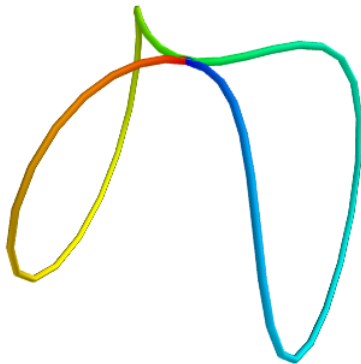
Is this Graphics?

Visualization is about data!

Examples: trajectory in space

```
>>> t = linspace(0, 2*pi, 50)
>>> u = cos(t)*pi
>>> x, y, z = sin(u), cos(u), sin(t)
```

Examples: trajectory in space



Examples: Fire in a room

Demo of data

Motivation and Needs

Scientists: not interested in
graphics

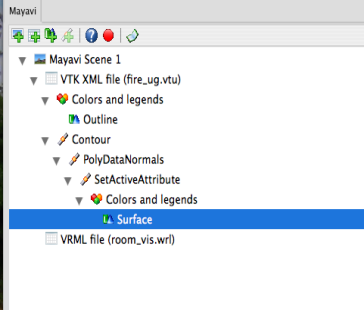
Interactive visualization of data
(think Matlab)

Visualization of data files with a
nice UI

Embedding visualizations in applications

Customization

Flexible library/app
for every one of
these needs!



Mayavi object editor

Contours Actor Texturing

Enable Contours: ☒Filled contours: ☒Auto contours: ☒

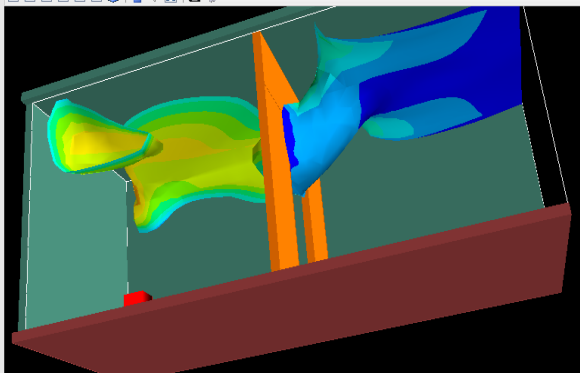
Number of contours: 10

Minimum contour: 307.84 → 631.18

Maximum contour: 307.84 → 631.18

Auto update range: ☒

Mayavi Scene 1



IPython Logger

Welcome to Mayavi, this is the interactive IPython shell.

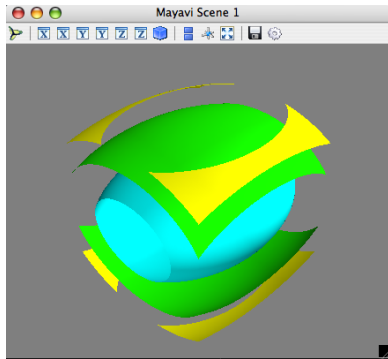
If this is your first time using Mayavi, take a quick look at the tutorial examples section of the user guide, accessible via the help menu.

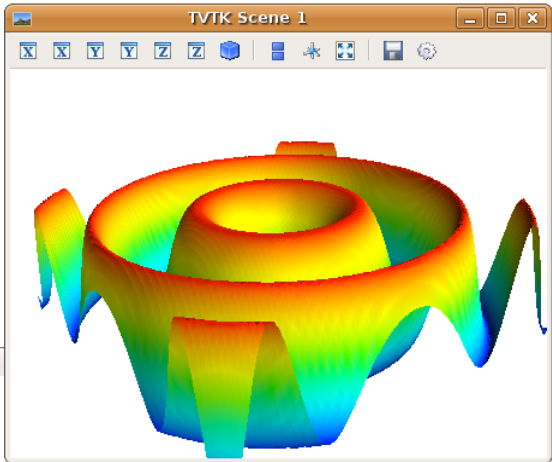
To use Mayavi, you need to load your data in "data sources" and apply "visualization modules" to it.

`In [1]:`

```
from mayavi import mlab
from numpy import ogrid
x, y, z = ogrid[-5:5:64j,
                -5:5:64j,
                -5:5:64j]

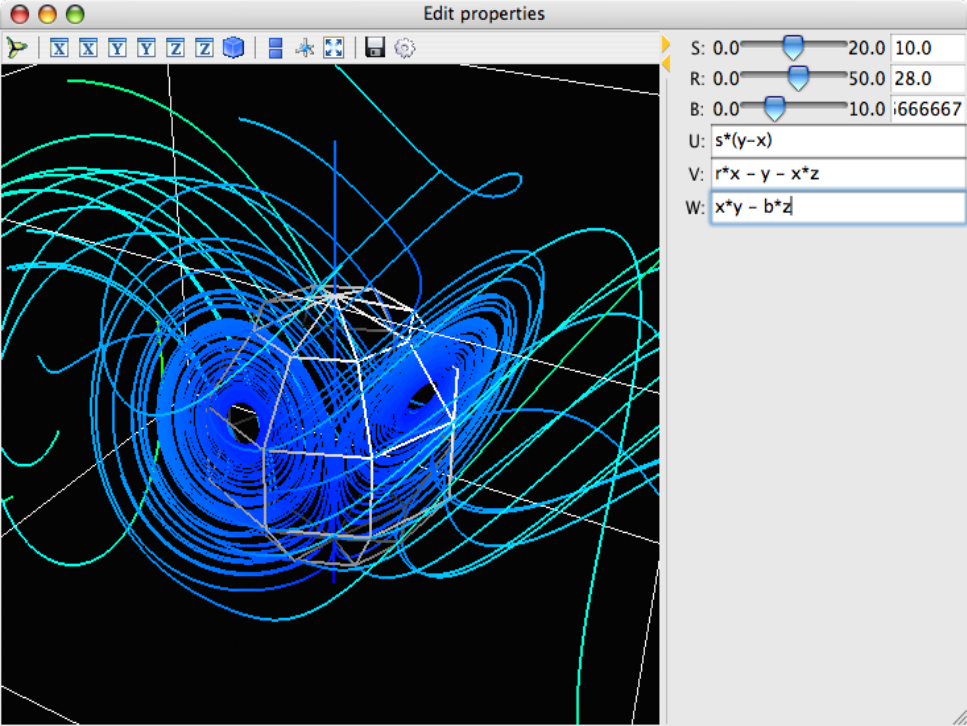
mlab.contour3d(
    x*x*0.5 + y*y + z*z*2
)
mlab.show()
```





Terminal

```
In [1]: from numpy import *  
In [2]: x, y = mgrid[-3:3:100j, -3:3:100j]  
In [3]: z = sin(x**2 + y**2)  
In [4]: from mayavi import mlab  
In [5]: mlab.surf(x, y, z)
```



Explorer3D

Equation: $\sin(x*y*z)/(x*y*z)$

nx: 128

Dimensions: ny: 128

nz: 128

xmin: -5.0

xmax: 5.0

Volume: ymin: -5.0

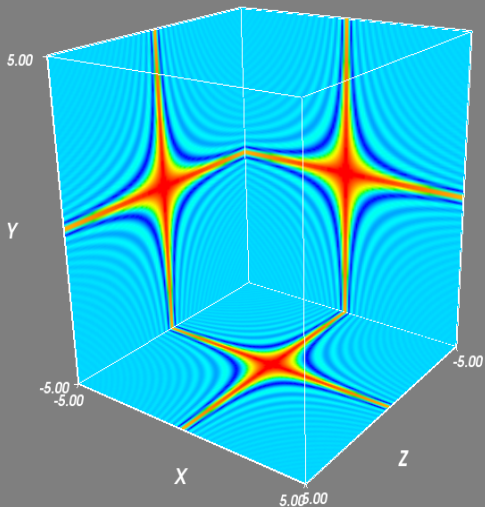
ymax: 5.0

zmin: -5.0

zmax: 5.0

Update data

TVTK Scene 1



mayavi_jupyter x Prabhu

localhost:8891/notebooks/mayavi_jupyter.ipynb

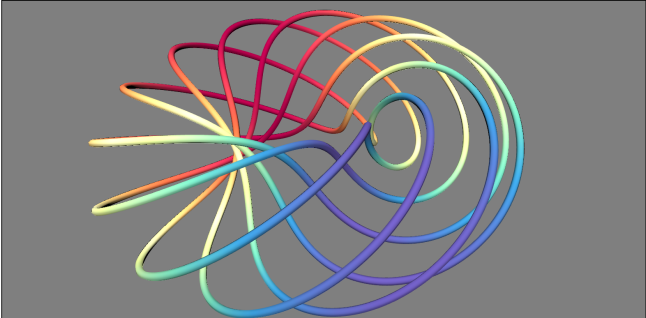
jupyter mayavi_jupyter Last Checkpoint: 2 minutes ago (autosaved)

File Edit View Insert Cell Kernel Help Python 2

In [1]: `from mayavi import mlab`
`mlab.init_notebook()`
Notebook initialized with x3d backend.

In [2]: `s = mlab.test_plot3d()`
`s`

Out[2]:



In [1]:

Other features

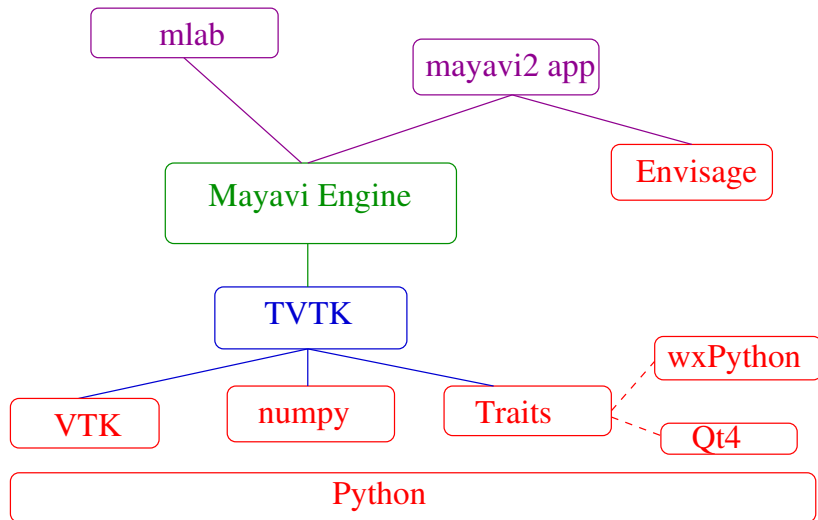
- ▶ Automatic script recording
- ▶ wxPython and Qt support
- ▶ Powerful command line options
- ▶ Off-screen support

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Overview of architecture



Information

- ▶ `http://code.enthought.com/projects/mayavi`
- ▶ `https://github.com/enthought/mayavi`
- ▶ **Uses VTK** (`www.vtk.org`)
- ▶ **BSD license**
- ▶ **Linux, Windows and Mac OS X**
- ▶ **Debian/Ubuntu/Fedora**
- ▶ **Canopy/Anaconda**

Overview of features

- ▶ `mayavi2` application
- ▶ Python library
- ▶ OO design
- ▶ Highly scriptable
- ▶ `mayavi.mlab`: for easy scripting
- ▶ **Pythonic**: Seamless NumPy integration
- ▶ Embed in Traits UIs (wxPython and PyQt4/PySide)
- ▶ Envisage Plugins

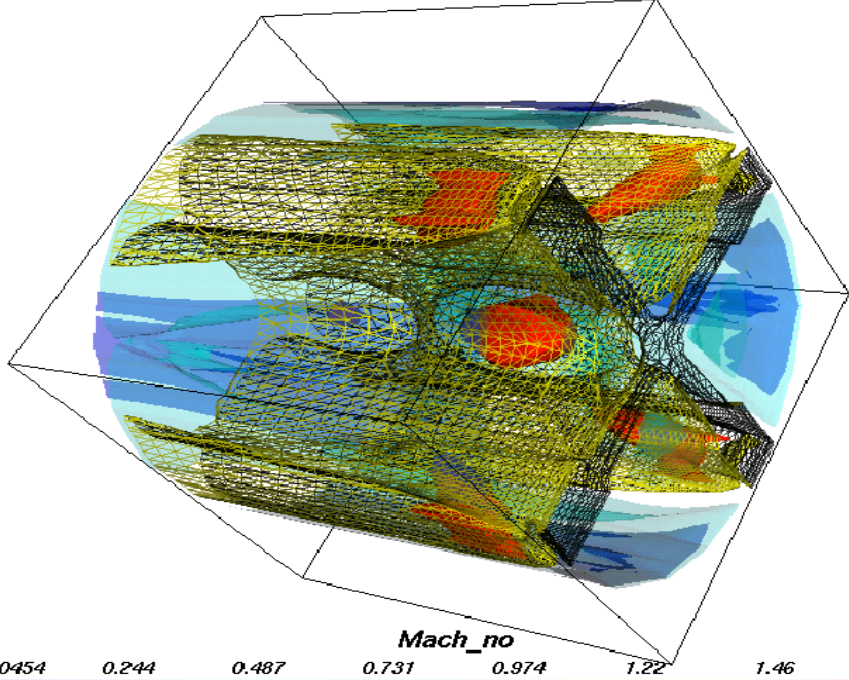
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Requirements

Colleagues at IITM needed 3D
visualization for CFD data (1998)



Mach_no

0.000454 0.244 0.487 0.731 0.974 1.22 1.46 1.70

VTK: Visualization Toolkit

`www.vtk.org`

- ▶ 3D graphics, imaging and visualization
- ▶ C++ wrappers: Python (Tcl, Java)
- ▶ Pipeline architecture
- ▶ Huge: 900+ classes!
- ▶ 2000+ classes now!!

Who wants to learn a graphics
library?

VTK-CFD (2000)

- ▶ Simple UI: Tkinter
- ▶ Free

VTK CFD Visualizer

File Data Visualize Configure

slice1 16

slice2 16

slice3 6

Number of contours: 0

Minimum contour: 0.0

Maximum contour: 255.0

Configure Axis

☒ X-Axis

☒ Y-Axis

☒ Z-Axis

X-Axis label: X

Y-Axis label: Y

Z-Axis label: Z

Number of labels: 2

Font size factor: 1.5

Offset from corner: 0.1000

☐ Fly mode to closest triad

☐ Fly mode to outer edges

Change Color

Color

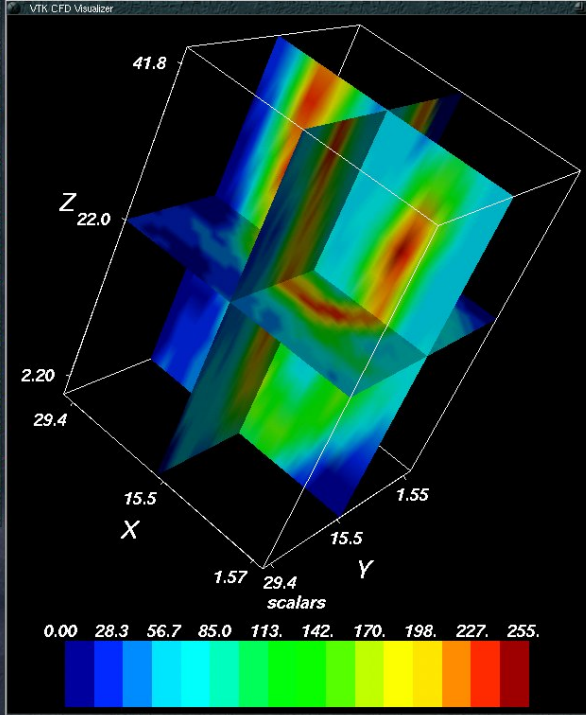
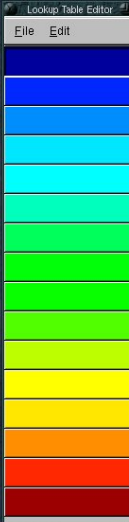
Red: 0

Green: 0

Blue: 158

Selection: #00009e

OK Cancel



VTK CFD Visualizer

File Data Visualize Configure

Vector scale factor: 2.0

Cone resolution: 5

Cone height: 1.0

Cone radius: 0.25

☒ Threshold points using scalars

Minimum threshold: 100

Maximum threshold: 550

Mask on ratio: 10

Mask offset: 0

Maximum number of points: 15000

☐ Randomized masking of points

Configure Axes

Configure Axis

☐ X-Axis

☐ Y-Axis

☐ Z-Axis

X-Axis label: X

Y-Axis label: Y

Z-Axis label: Z

Number of labels: 2

Font size factor: 1.5

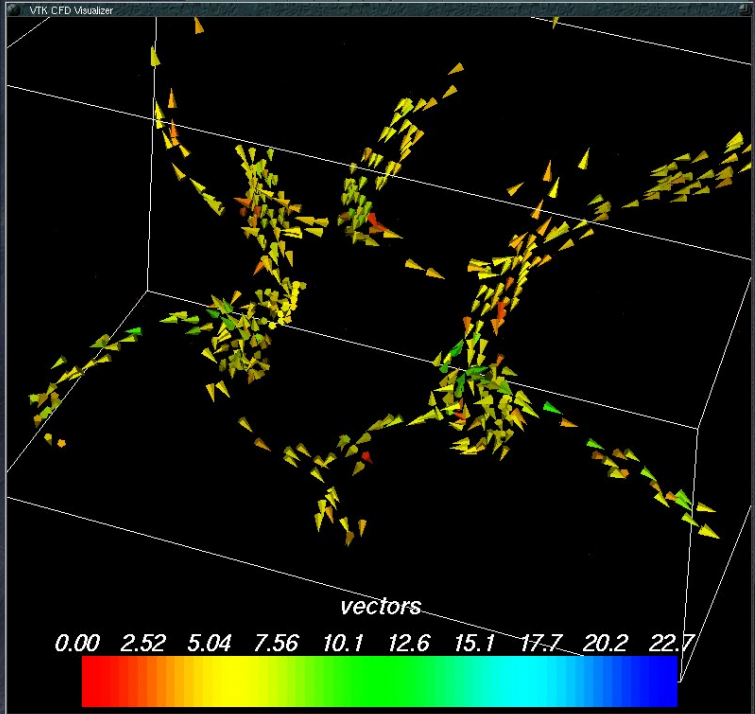
Offset from corner: 0.0500

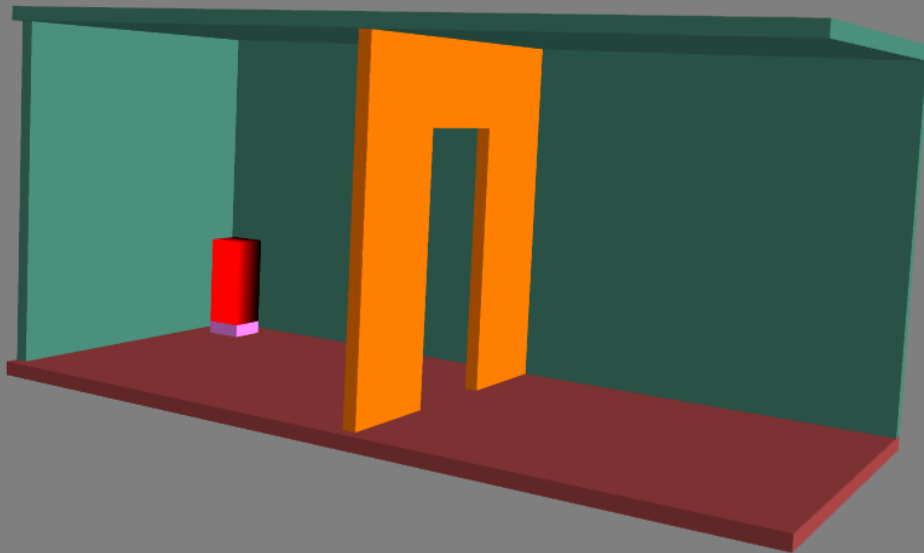
☐ Fly mode to closest triad

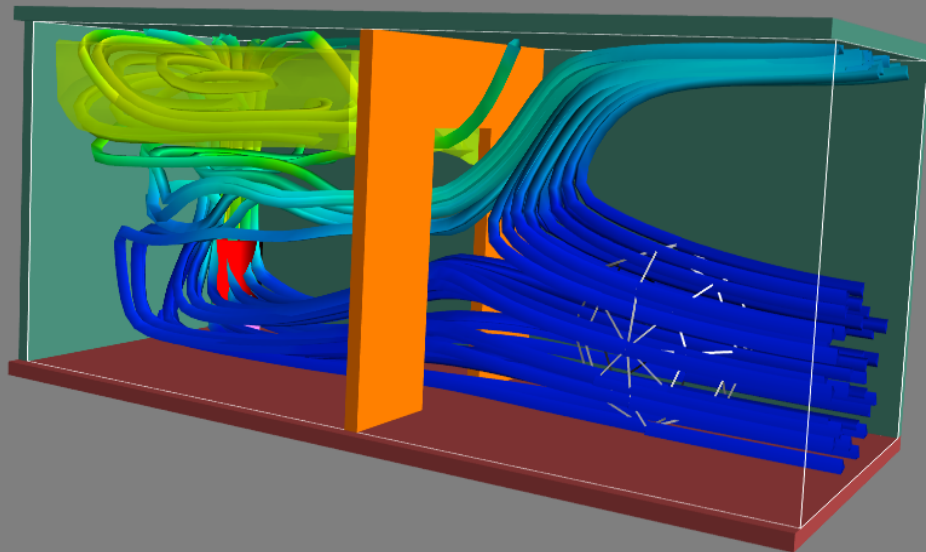
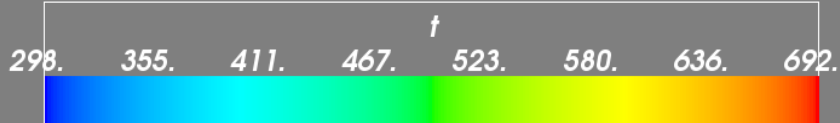
☐ Fly mode to outer edges

Change Color

Close







vtkPipeline

Parse VTK class on the fly
producing automatic UI

vtkPipeline

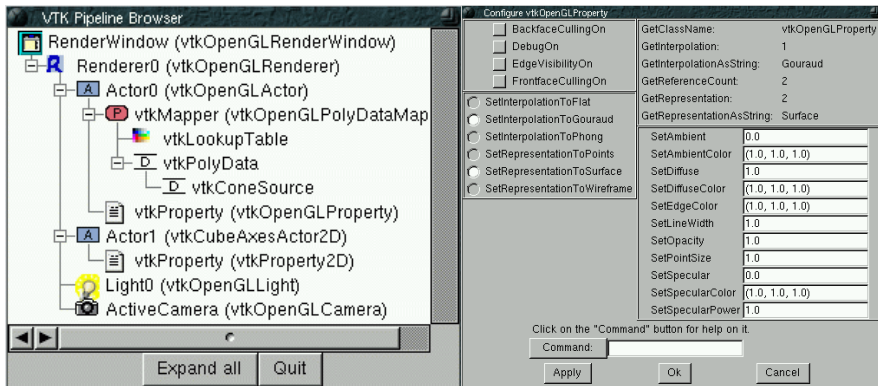
Parse VTK class on the fly
producing automatic UI

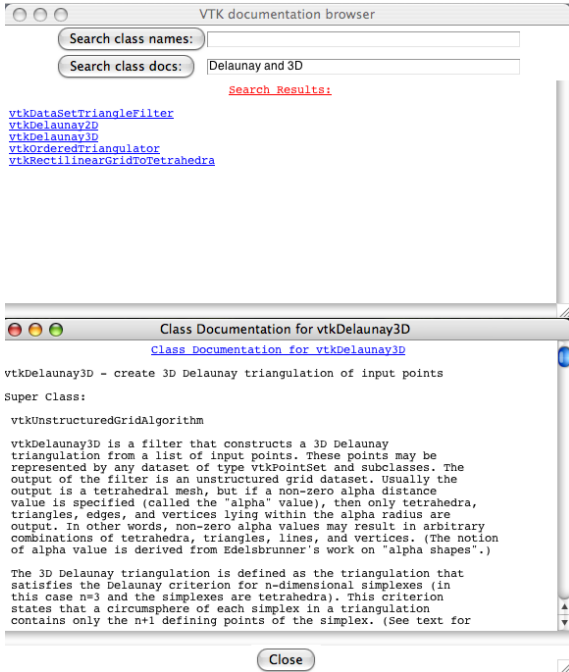
Discover and generate VTK
pipeline

```
from vtkPipeline import \  
vtkPipelineBrowser
```

```
# Create a full VTK-Python script  
# ...
```

```
# renwin is a vtkRenderWindow.  
pipe = vtkPipelineBrowser(root, renwin)  
pipe.browse ()
```





Doc browser: one afternoon!

Lessons

- ▶ Python rocks!
- ▶ VTK is very powerful

Lessons

- ▶ Run-time introspection
- ▶ Dynamic programming
- ▶ Automatic UIs are cool and fun

Issues with VTK-CFD

- ▶ Very specific visualizations
- ▶ Not general enough

MayaVi-1.0

`mayavi.sf.net`

Configure StructuredGridOutline mod

☐ Show Pipeline

Change Object Color

Set Opacity

1.00

Opacity resolution: 0.01

Configure ContourGridPlane module

☒ Show Pipeline

- Actor (vtkOpenGLActor)
 - Mapper (vtkOpenGLPolyDataMapper)
 - LookupTable (vtkLookupTable)
 - vtkPolyData
 - vtkExtentTranslator
 - Source (vtkStructuredGrid)
 - vtkStructuredGrid
 - Property (vtkOpenGLProperty)

Refresh Expand all

☐ X-Axis
☐ Y-Axis
☐ Z-Axis

Position 15

Set Opacity

1.00

Opacity resolution: 0.01

Line width: 4.0

☐ Show Contours

Number of contours: 10

Minimum contour: 0.0

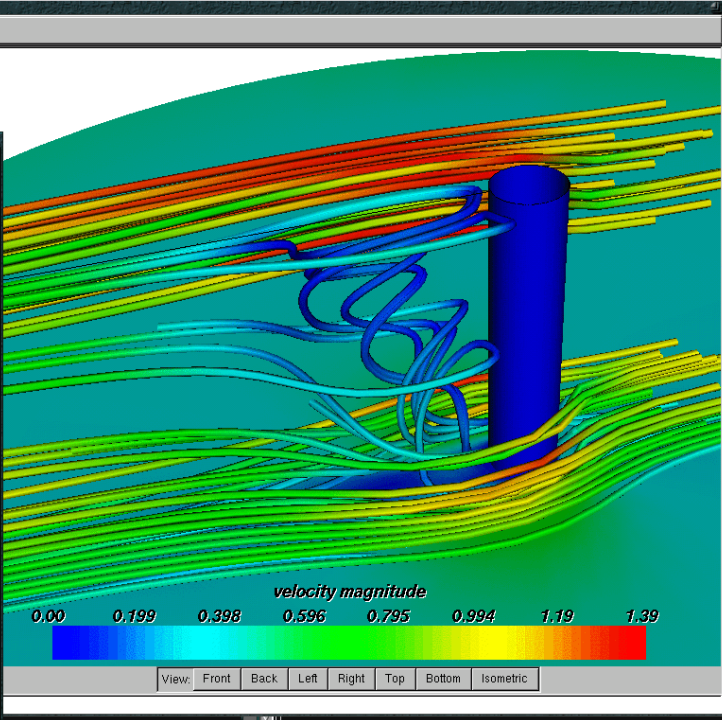
Maximum contour: 1.391444

☐ Auto Sweep

Auto Sweep Step: 1

Auto Sweep Delay: 1.0

Close



Search class names:

Search class docs:

delaunay and triangulation

Search Results:

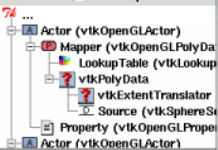
MayaVt Data Visualizer 1

File Visualize Options

1. DataVizManager

Configure Streamlines module

Show Pipeline



Refresh

Expand all

PointSource0
PointSource1
PointSource2

Add streamline source

Delete streamline source

Save streamlines

Load streamlines

Close

Configure LutHandler module

Show Pipeline

Load Lookup Table

Edit Lookup Table

- blue-red colormap
- red-blue colormap
- black-white colormap
- white-black colormap

☐ Use specified data range

Data Range: (0.0, 1.39144)

☐ Use visible range

Visible Range: (0.0, 1.39144)

☒ Show Legend☒ Horizontal☒ Vertical☐ Shadow Legend

Number of Labels: 8

Number of Colors: 256

Legend text: velocity mag

Close

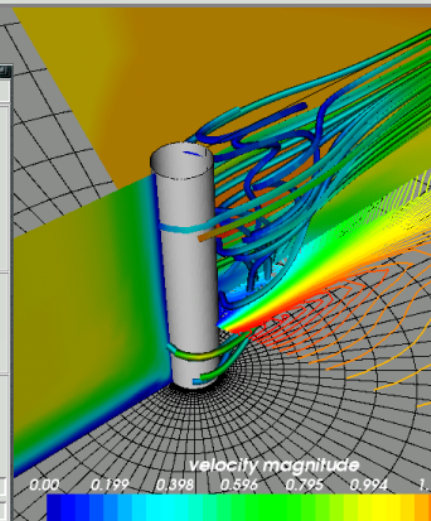
Class Documentation for vtkDelaunay3D

vtkDelaunay3D - create 3D Delaunay triangulation of input points

Super Class:

vtkUnstructuredGridSource

File Edit



View:

+X

-X

+Y

-Y

+Z

-Z

Isometric

- ▶ 2001 May
- ▶ GUI, CLI
- ▶ One month, including docs
- ▶ PhD Procrastination Project!

Issues with MayaVi-1.0

- ▶ No clean scripting API
- ▶ No MVC
- ▶ Clunky Tkinter UI
- ▶ Not easy to embed

Mayavi2

`code.enthought.com/projects/mayavi`

2004 –



Apprentice no longer!

Enthought

TVTK + Mayavi2 (2004)

`www.enthought.com`

The world of Traits

Python object on steroids!

Part of the Enthought Tool Suite
(ETS)

TVTK

TVTK = VTK + Traits + NumPy

The whole is greater than the sum
of the parts!

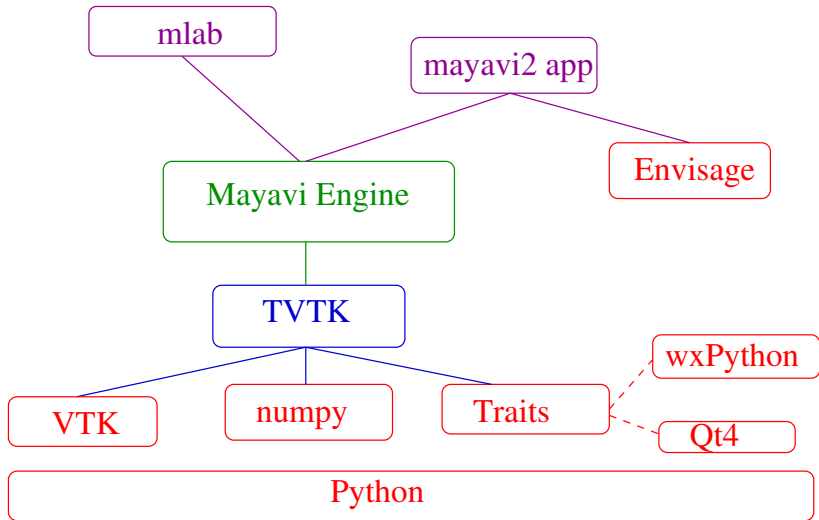
Lessons

- ▶ The API matters a lot
- ▶ TDD is quite a life-saver
- ▶ Be prepared to throw away code!

Mayavi2

- ▶ TVTK + Traits + Envisage

Recap of architecture



Developers and support

Prabhu Ramachandran	Creator and lead, 2001 –
Gaël Varoquaux	Mlab, documentation, usability, 2007 – 2012
Enthought Inc.	ETS, Hosting, support, sprints, initial funding, distribution
Deepak Surti	new pipeline support, 2014 – 2016
Enthought Devs	Bug fixes, support, testing: Kit Choi, Ioannis Tziakos
IITB	Freedom and support for PR