

MayaVi: A free tool for CFD data visualization

Prabhu Ramachandran

Graduate Student, Dept. Aerospace Engg. IIT–Madras, Chennai, 600 036.

e–mail: prabhu@aero.iitm.ernet.in

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Abstract:

Visualizing CFD data is extremely important. There are very few freely available tools that allow one to visualize scalar and vector data on rectilinear, structured and unstructured grids. MayaVi is a free tool developed by the author that helps visualize such CFD data. It uses the Visualization Toolkit (VTK) for the actual visualization and provides a useful graphical user interface to make visualizing the data easy. This article describes the tool and the basis for its development.

Introduction:

In the recent past there has been a tremendous drop in the cost per unit of computing power and storage. This has led to a large increase in the size and computational complexity of CFD computations. This results in the production of a large volume of data that is difficult to process by traditional means. It is obvious that the graphical visualization of such CFD data is a necessity for both the developer of CFD code and also for the user of CFD programs. Visualizing three–dimensional CFD data is not an easy task. Researchers can either develop their own tools to visualize data or download free tools or buy commercial visualization tools.

It takes time and effort for a researcher to develop a good CFD visualization tool. This is because three–dimensional data visualization is non–trivial. Also, developing the tool such that it works across different operating systems and hardware is not easy and takes experience and effort. CFD researchers are also better served if they can concentrate on their CFD related work and not have to worry about visualization tasks.

There are very few freely available tools that are simple to use and designed for CFD data. OpenDX[1] is available for free and was originally developed by IBM but is a more generalized visualizer. OpenDX also has a fairly steep learning curve. Commercial tools cost considerably and it is not possible for all CFD developers to have access to them.

Such being the case, a free, easy to use data visualizer for CFD data would be very useful. MayaVi is one such free tool that helps visualize CFD data.

MayaVi:

MayaVi provides an easy to use graphical user interface so that data can be quickly visualized. MayaVi uses the Visualization Toolkit (VTK)[2] in order to do the actual visualization. VTK is an open source visualization library and is written in C++. VTK also has bindings for other programming languages such as Tcl[3], Python[4] and Java[5]. The following are some of the features of VTK:

1. VTK provides over 650 powerful classes that ease the task of visualizing data. Some of the features relevant to CFD include, support for rectilinear grids, structured grids, unstructured grids and polygonal data. Scalar, vector and tensor data can be visualized using various types of algorithms.
2. A very large number of visualization algorithms are supported.
3. VTK also provides powerful image manipulation algorithms and is used frequently for medical imaging.
4. VTK is object oriented and uses a "pipeline" based architecture in order to construct "visualization networks". This makes it easy to use VTK. For more details the interested reader is referred to [6].
5. VTK is open sourced[7] and the source code is available freely and users can adapt the available classes to suit their needs. People can also take part in the development and improvement of VTK.
6. Since VTK has language bindings for scripting languages like Python and Tcl it is easy to develop powerful applications that use VTK.
7. VTK runs on both the Unix family of operating systems and also on the Windows™ family. VTK also runs on the Mac OS X platform.

It is important to note that VTK is a library and provides the functionality necessary to visualize data. It does not provide an easy to use application that can be directly used to visualize data. The user has to learn how to use the library and write programs in C++ or one of the supported scripting languages, viz. Tcl, Python and Java in order to perform the visualization. Scripting languages are described in Ousterhout's excellent article on scripting languages[8].

MayaVi is written in Python. The Python programming language [4] has been chosen because of the following features:

1. It is free, easy to learn and has an elegant syntax.
2. Python is an interpreted, object-oriented, dynamically typed language and provides exceptions and high-level data structures. This makes it a very powerful language.
3. Python is highly modular and has a very large number of useful modules that enable one to perform a variety of tasks. These tasks include scientific computation, creation of graphical applications, etc.
4. Python is a full fledged programming language.
5. It is relatively easy to interface C/C++ programs with Python.
6. Python is available for a variety of operating systems including Unix and Windows™.

These features make Python an ideal choice for rapid application development. The VTK-Python bindings are also very mature.

There are several freely available modules that enable one to build graphical user interfaces (GUI's) using Python. One of these is an interface to the Tk library, called Tkinter. This is relatively easy to use and is cross-platform. Currently there are other, more advanced modules for the GUI. However, MayaVi uses Tkinter. This seems to be satisfactory so far. It is possible that a more advanced module might be used in the future.

Features of MayaVi:

MayaVi is under development and currently provides the following features:

- An easy to use GUI.

- Support for any VTK dataset. For information on the the VTK data format see [9] or [6].
- Support for binary, structured, PLOT3D data. Simple support for multi-block data is also incorporated.
- A lookup table editor to customize lookup tables easily while visualizing data.
- Around 10–15 useful modules to do grid, scalar and vector visualization. This includes a streamline module that can create streamlines, stream-ribbons and stream-tubes.
- Multiple datasets can be loaded simultaneously. Multiple visualization modules can be used simultaneously.
- A pipeline browser that allows one to view and configure the objects in the VTK pipeline. This is a feature that is specially useful for developers who know a bit of VTK.
- Support for importing a simple VRML scene. Texturing is not yet supported due to limitations the corresponding VTK class.
- The visualization (or a part of it) can be saved and reloaded in the future.
- Ability to save the visualization to Post Script files, BMP/PPM/TIFF images and Open Inventor or VRML files.
- MayaVi is known to run on Linux/Unix and Windows™ machines.

MayaVi can visualize the following:

- 3D/2D structured grid planes. This is useful to verify the correctness of the computational grid.
- Unstructured surfaces and polygonal data.
- 3D/2D scalar data in the following manner:
 - Visualize the scalar field using a cut plane on which the scalar is displayed either as a colour map or as contour lines. The cut plane can be moved through the data easily and this works for all kinds of data – rectilinear, structured and unstructured.
 - Visualize iso-surfaces of data. This also works for all kinds of data – rectilinear, structured and unstructured.
 - Show structured grid planes with scalar data either as contours or as colour gradients. This is useful to check data generated on structured grids.

- Vector field data using the following modules:
 - Arrows or cones scaled, coloured and sized as per the vector data.
 - Simple lines scaled as per vector data.
 - Arrows or cones scaled and coloured as per vector data along a cut plane that can be moved through the data.
 - Streamlines, stream–tubes and stream–ribbons using a source of tracer points along the data that can be introduced anywhere in the data.

MayaVi is free and is distributed under the GNU General Public License (GPL)[10]. The GPL license has been used in order that MayaVi may always remain free for all. It also ensures that no commercial interests can deprive the users of MayaVi of any additional features that they may choose to add. It is important to note that such a license encourages that future enhancements to MayaVi will remain available to the users. The MayaVi sources and web pages are hosted by the remarkable SourceForge project[11]. This free service can be obtained for any open source project and provides its users with a host of excellent web hosting and development related facilities free of charge. The MayaVi home page can be found here:

<http://mayavi.sourceforge.net/>

The source can be downloaded from the above mentioned site. Instructions for installation are also provided. A users guide is also provided with the package. This can also be viewed online. Several pictures of the program in action are also available at the site. There are a couple of mailing lists that users can subscribe to. There is an announcement list where information on new releases will be announced and there is a more general users mailing list where both support and discussions on development take place. Information on all these are available at the web site.

MayaVi is currently being used all over the world with more than 1000 people having downloaded the latest version.

The included figures. 1 and 2 show MayaVi in action running several different visualization modules.

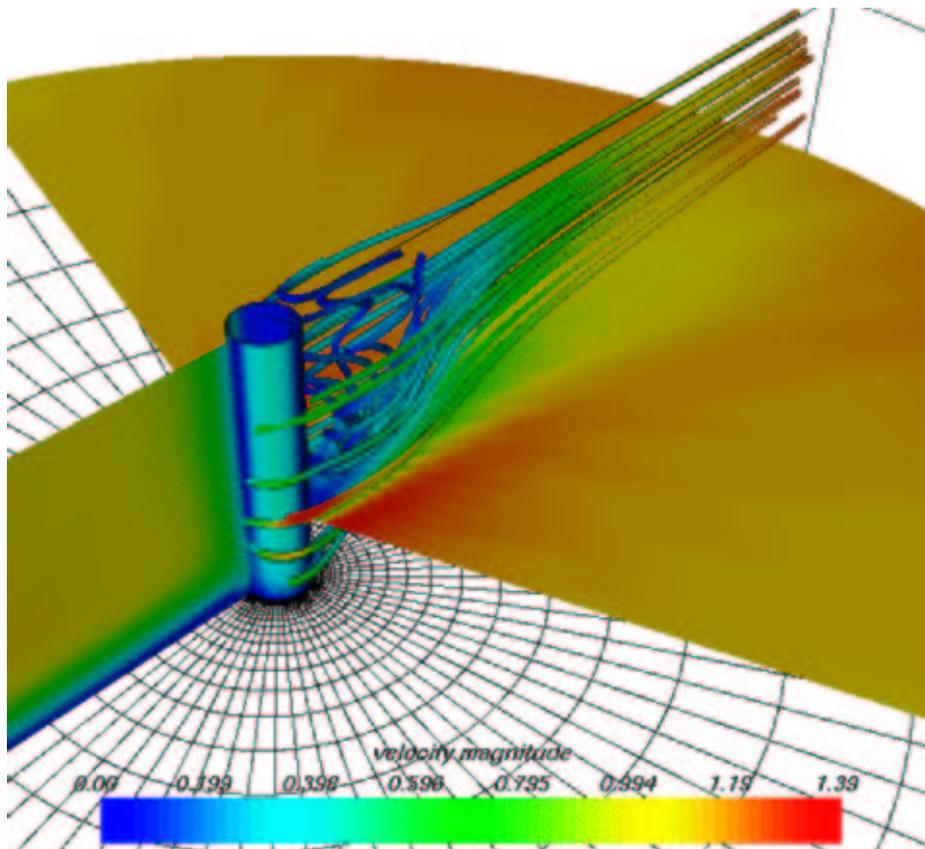


Figure 1: This figure shows stream-tubes for flow past a cylinder placed on a flat plate. Also shown are various cut planes that are colour mapped as per the velocity magnitude. One of them is a little away from the cylinder surface. The grid being used on the floor is also seen. The data used is courtesy NASA and is distributed along with VTK.

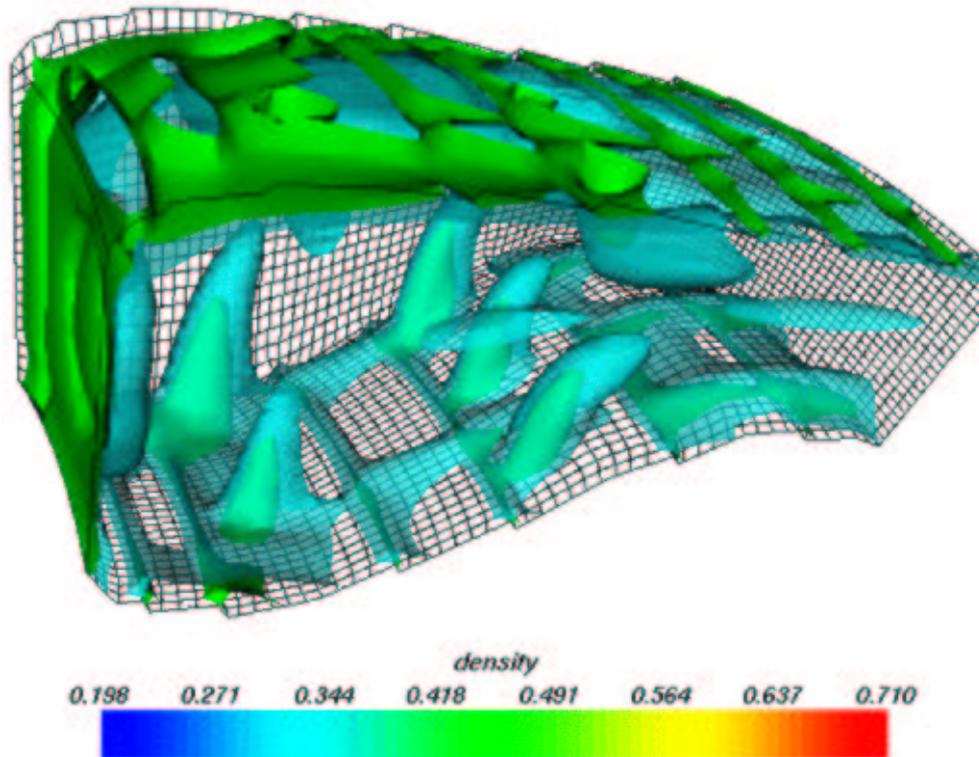


Figure 2: This shows a pair of iso-surfaces of density for flow inside a combustion chamber. Also shown are the structured grid planes that are used for the computation. This data is also courtesy NASA and is distributed along with VTK.

As mentioned earlier, MayaVi is under development and new features will be added when required. It is also possible for users to help in the development of MayaVi by sending their improvements and new modules. The MayaVi-users mailing list is ideal for support questions and for discussions on the future development directions of MayaVi.

Conclusion:

In this article a new, free tool for CFD data visualization called MayaVi has been discussed. The importance of the tool from the perspective of the CFD community has been mentioned. Various features of the tool have been presented. The reasons

for using the Visualization Toolkit and the Python programming language have also been highlighted. It is the authors belief that this tool will be useful to users of CFD programs and also to developers of CFD code.

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References:

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