

INTRODUCTION TO VISUALIZATION WITH VTK AND PARAVIEW

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SIMULATION VISUALIZATION

Simulation visualization referred to a computing method in which a geometric representation is used to gain understanding and insight into numeric data generated by numerical simulation. The data is usually placed into a reference coordinate system to create and extract quantities/qualities of interest.

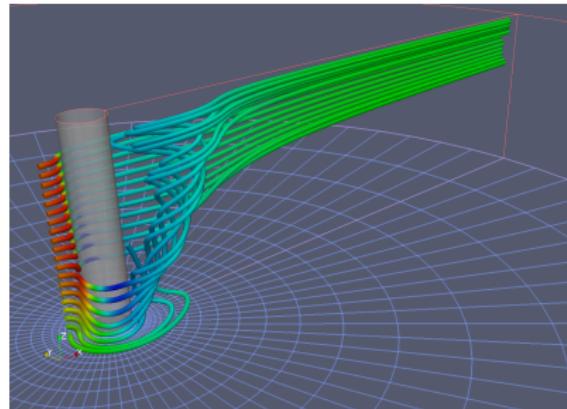


FIGURE 1: Streamlines of flow pass a cylinder (image courtesy of Kitware Inc).

VISUALIZATION PIPELINE

The goal of **visualization pipeline** is to create geometrically constructed images from numeric data. The process can be described step-wise as:

- **Data analysis:** preparing data for visualization
 - **Filtering:** specifying data portion to be visualized
 - **Mapping:** transforming filtered data into geometrical primitive (e.g. points, lines) with attributes (e.g. color, size)
 - **Rendering:** generating image from geometric data

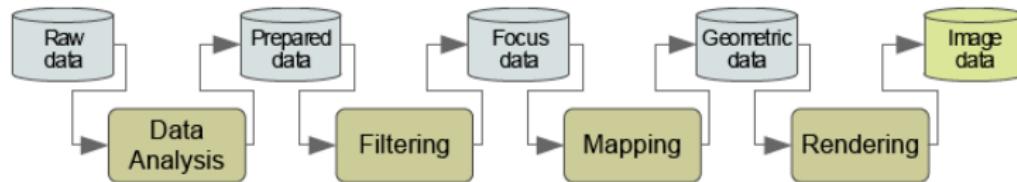


FIGURE 2: Visualization pipeline (image courtesy of www.infovis-wiki.net).

DATA STRUCTURE

Data structure is a way of exporting and organizing simulated data. It also defines applicability of some visualization techniques (e.g. operations on field dimensions are not applicable with unstructured mesh).

Types of grids

- *Structured*: nodes arrayed on a one-, two- or three-dimensional hexagonal grid in which the connectivity between the nodes is implied by dimensions

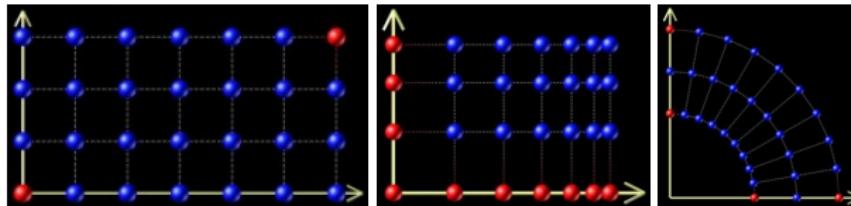


FIGURE 3: Uniform, rectilinear and irregular 2D structured grid (image courtesy of AICT, University of Alberta).

DATA STRUCTURE

Data structure is a way of exporting and organizing simulated data. It also defines applicability of some visualization techniques (e.g. operations on field dimensions are not applicable with unstructured mesh).

Types of grids

- *Structured*: nodes arrayed on a one-, two- or three-dimensional grid in which the connectivity between the nodes is implied by dimensions
- *Unstructured*: nodes exist in space and can be connected together in a certain order of line, triangle, tetrahedral, etc., together they form *Cells*

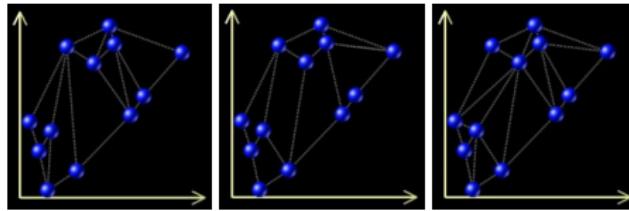


FIGURE 4: Unstructured grids formed by a set points (image courtesy of AICT, University of Alberta).

DATA STRUCTURE

Data structure is a way of exporting and organizing simulated data. It also defines applicability of some visualization techniques (e.g. operations on field dimensions are not applicable with unstructured mesh).

Types of data

- *Point data*: data specified at each grid point
- *Cell data*: data specified per cell

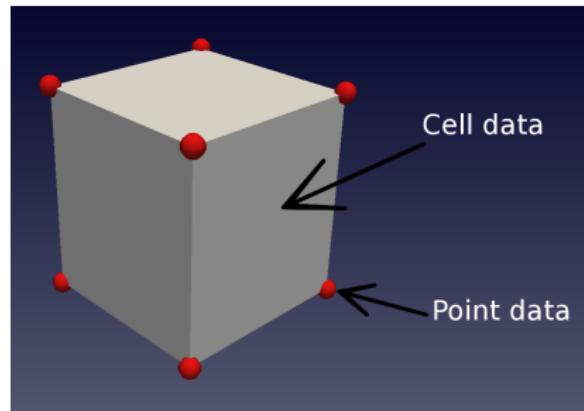


FIGURE 5: Cell and point data.

VISUALIZATION TOOLKIT (VTK) DATA FORMAT

VTK is an open-source, object-oriented software system for computer graphics, visualization and image processing [VTK User's Guide, 2006. Kitware, Inc.]. It provides variety of data representations such as structured, rectilinear, point sets and polygonal data. An overview of file format used in this workshop is given below:

```
# vtk DataFile Version 3.0 ] Header
fluid_state      ] Title
ASCII           ] Data type
DATASET RECTILINEAR_GRID
DIMENSIONS 300 60 1
X_COORDINATES 300 float| } Geometry / Topology
0.5 1.5 2.5 3.5 4.5 ....
Y_COORDINATES 60 float
0.5 1.5 2.5 3.5 4.5 ....
Z_COORDINATES 1 float
0
POINT_DATA 18000
SCALARS density_difference float 1
LOOKUP_TABLE default
0.00110679
0.00101563
0.000917072
0.000839312
0.000733818
.....
VECTORS velocity_vector float
0.00520462 -9.83587e-05 0
0.00550567 -9.90565e-05 0
0.00580871 -9.90717e-05 0
0.00611734 -0.000103073 0
0.00642669 -9.9772e-05 0
.....
} Dataset attributes
```

FIGURE 6: Example of file created from LBM simulation.

Further information can be found in The VTK Users Guide

WHY PARAVIEW?

Paraview is an open-source, multi-platform application for the visualization and analysis of scientific data set. It was developed to analyze large data set on variety of computing resources.

Pros

- *Freely available* (download from www.paraview.org)
 - Design for visualization of large data (in parallel)
 - Available in large variety of platforms
 - Open, flexible and intuitive user interface

Cons

- Data file format is not easy to modify (before today)
 - Frequent upgrades and changes (without fully update online info)
 - No refresh button!!!

PARAVIEW INTERFACE

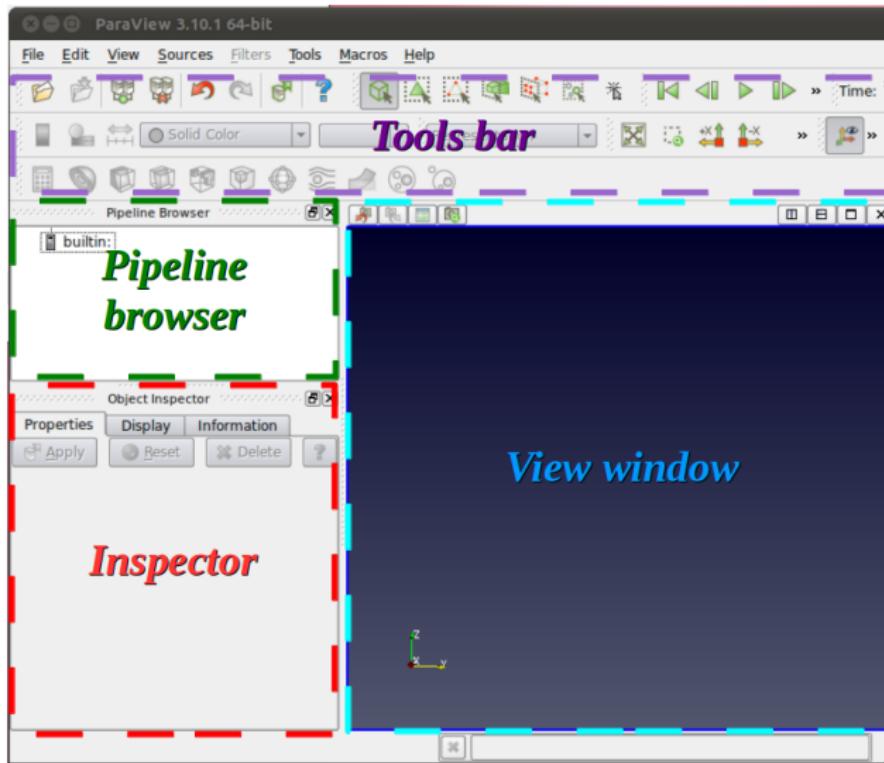


FIGURE 7: ParaView (version 3.10) user interface.

LOADING DATA

ParaView can open *single file*, *multiple files* with time serie indicator as well as *selected files*.

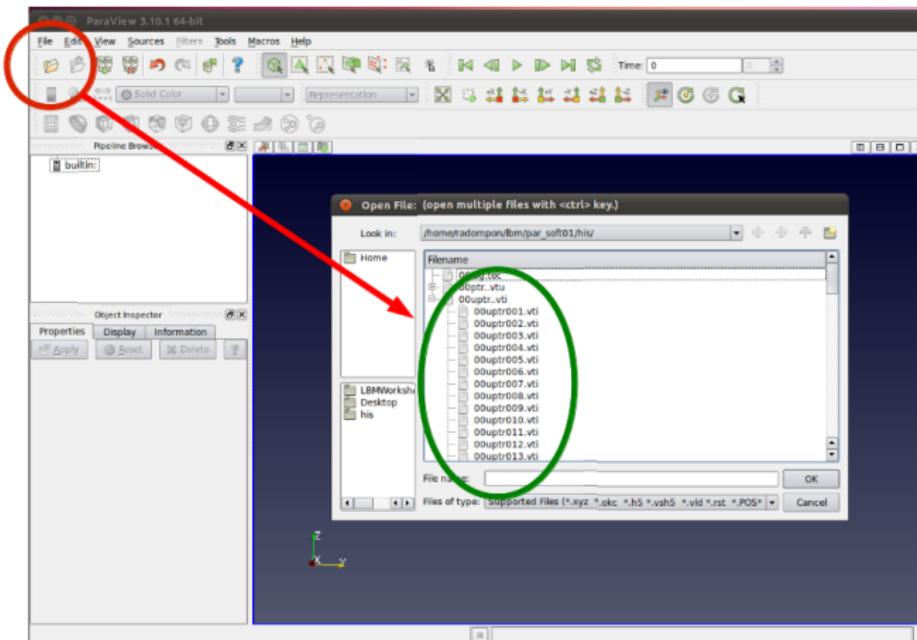


FIGURE 8: Loading file(s).

VIEW CONTROLS

The object in view window can be controlled directly on-screen by the movement of mouse. Additionally, view controls tool can be found on the tools bar.

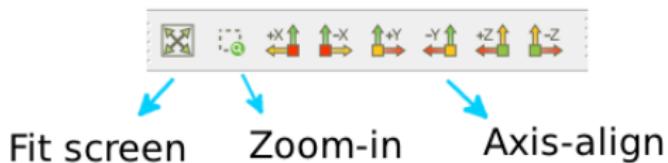


FIGURE 9: View controls.

MESH

A mesh consists cells (elements, zones) generated by connecting a set of vertices (points) together. Cell type and its connection are defined by the topology of the data.

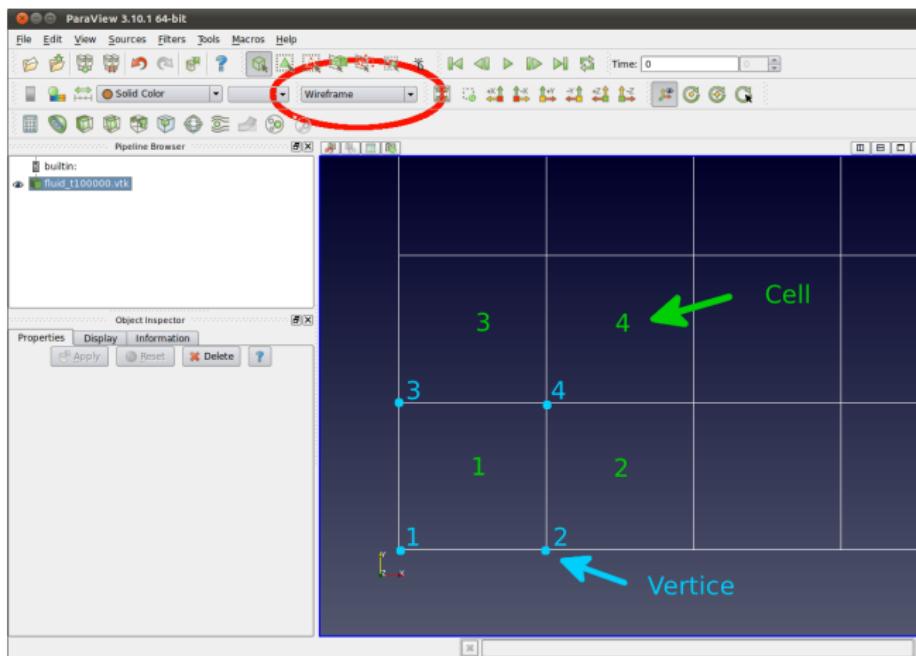


FIGURE 10: Cells and vertices.

ATTRIBUTES

An attribute can be scalar, vector or tensor defined in the raw data. It defines value of a field over the mesh. In the example below, the vertices' attribute (velocity magnitude) is shown.

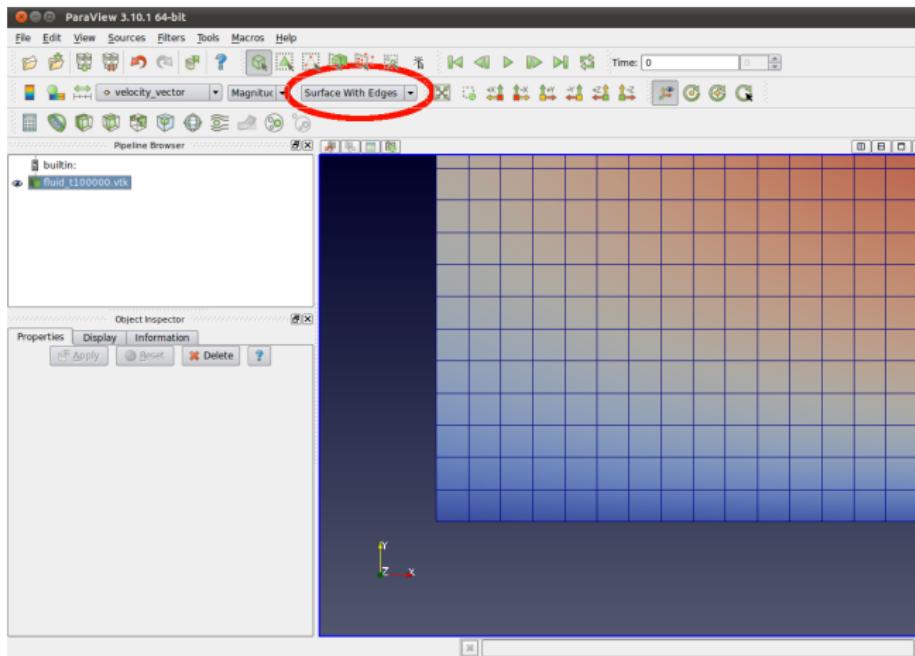


FIGURE 11: Contour plot of velocity fields.

PIPELINE

Navigation of data manipulation in ParaView is shown on the pipeline browser. The pipeline process **does not** modify the raw data. Instead, it copies and operates on unmodified data. Operations will be carried out only with the selected data set.

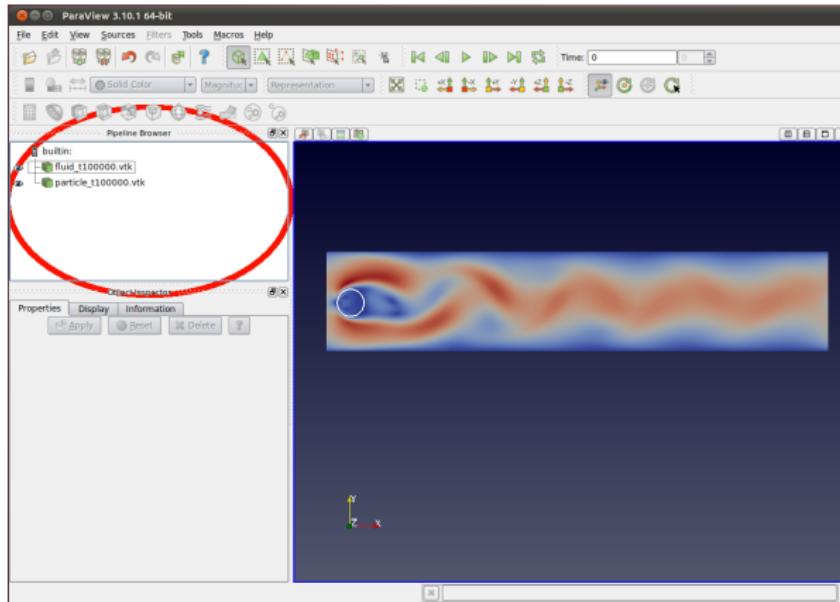


FIGURE 12: Pipeline showing two sets of data.

FILTERS

Filters modify data in particular way to deliver the modified data as output. Various filters available in ParaView. They can be found on the tools bar and in the filters menu. Applicability of some filters may depend on data structure.

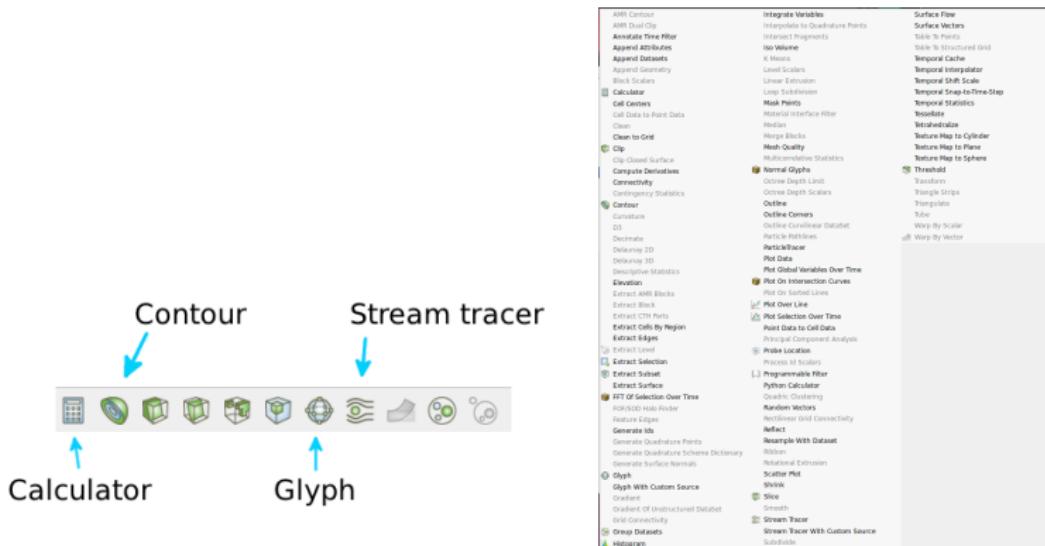


FIGURE 13: Filters toolbar and filters menu.

CONTOUR

A contour plot represents a graphic relation between spatial position (e.g. in x and y) and the quantity of interest. It can be plotted as interpolated color and curves.

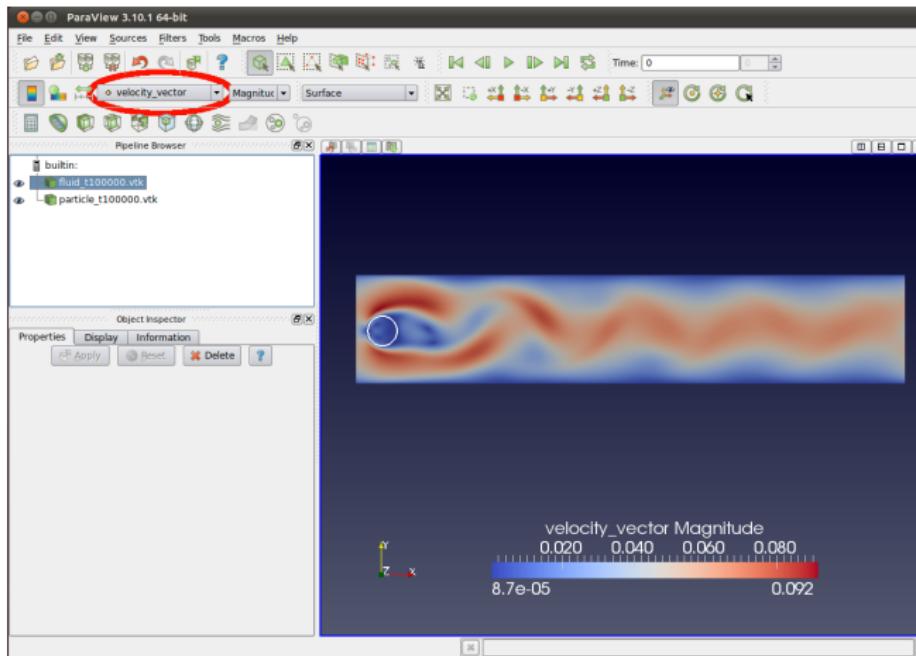


FIGURE 14: Velocity contour plot of flow pass a circle.

COLOR SCALE

Variation of color, i.e. color scale, delivers information for visualization. It provides colorful and *meaningful* graphical representation of the numeric data.

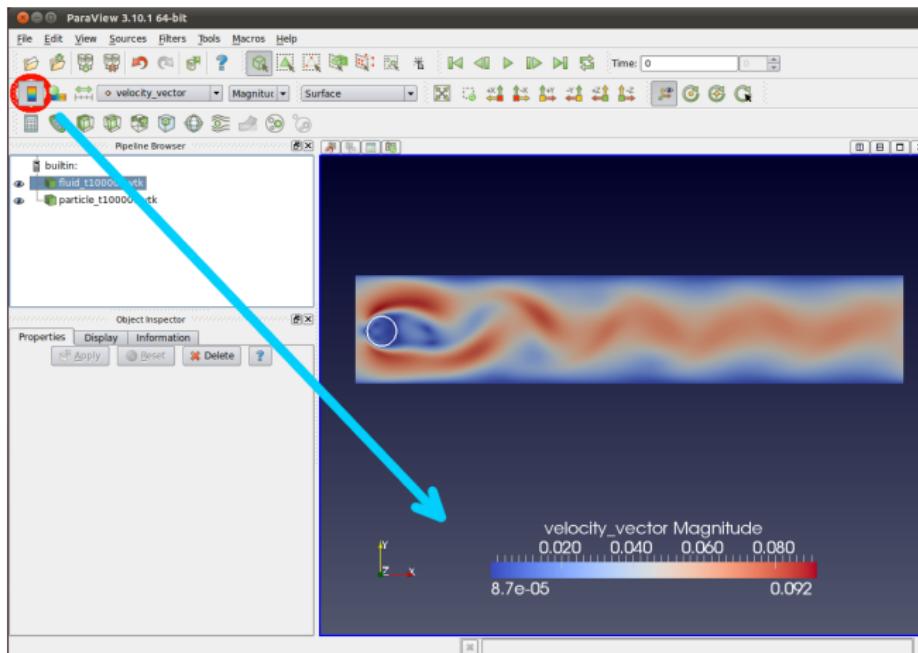


FIGURE 15: Control of color scale on tools bar.

COLOR SCALE EDITOR

ParaView offers controls of color scale via its editor, i.e. the icon next to the color scale on the tools bar.

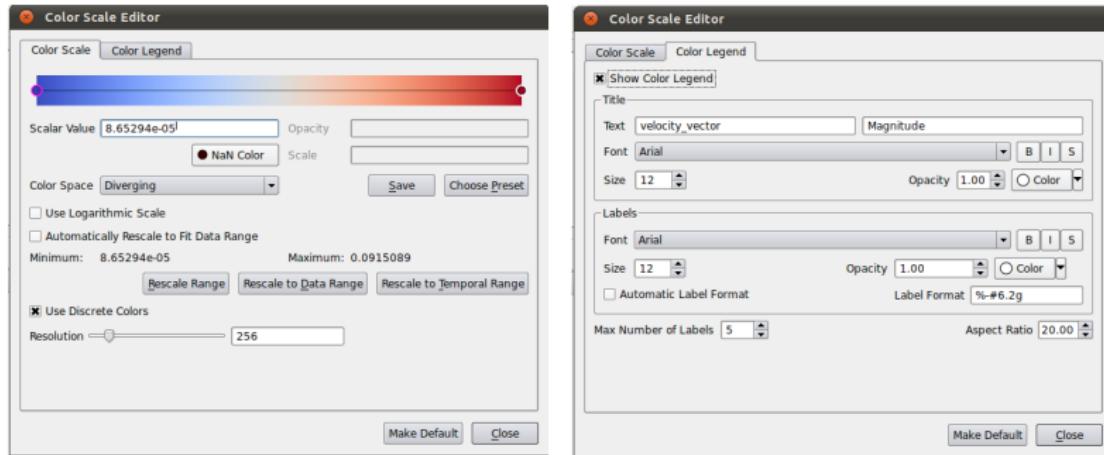


FIGURE 16: Controls of color scale editor.

VECTOR FIELDS

Vector glyph can be used to display additional dimension attached to data. The direction and length (or color) of glyphs (arrows) are provided by the vector field.

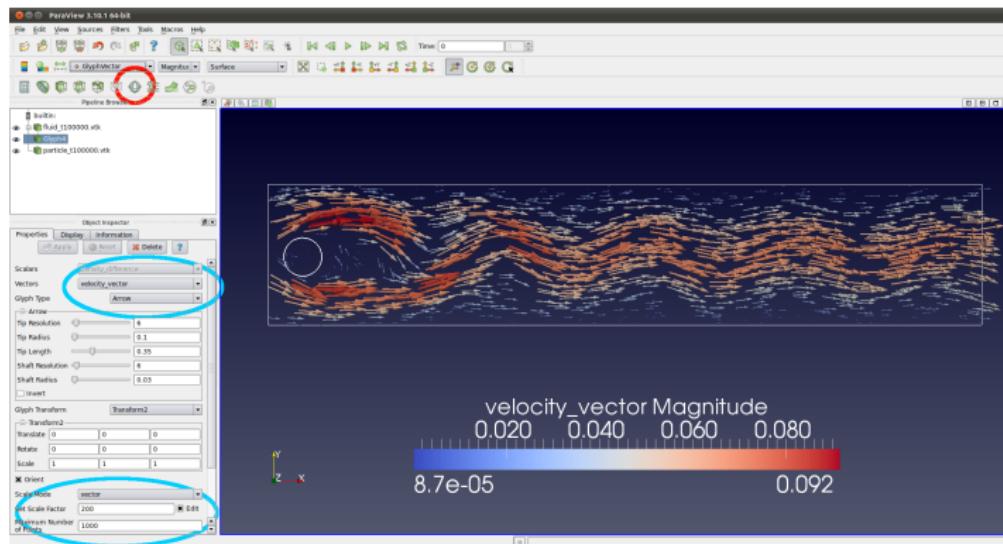


FIGURE 17: Velocity vector field.

STREAMLINES

A stream line is a line in the tangential direction to the vector field at every points along the line. Stream lines show the flow direction that fluid element will travel in time.

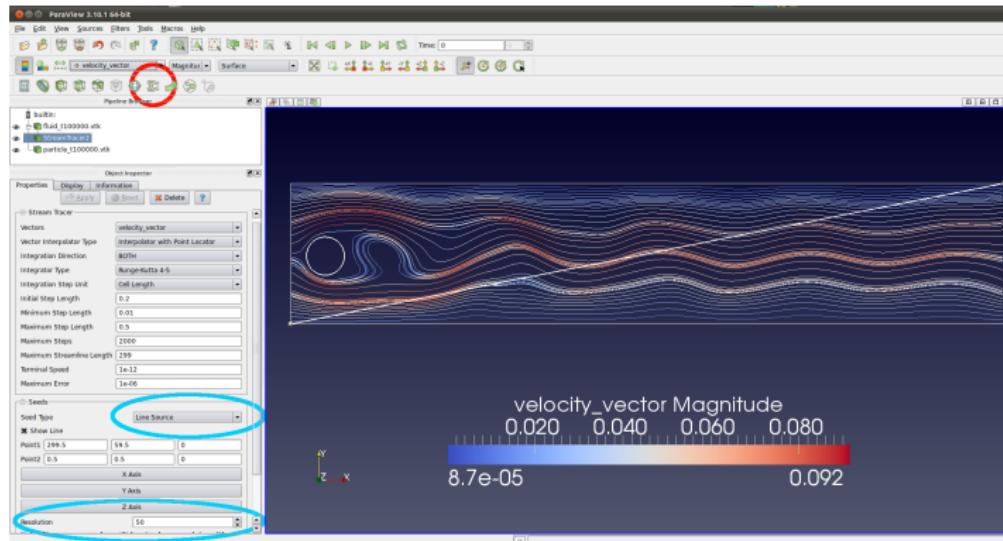


FIGURE 18: Stream lines of fluid velocity.

VORTICITY

Vorticity represents the amount of *rotation* in a fluid. It is defined as the curl of the fluid velocity field. In ParaView, vorticity can be obtained directly from the filter *Compute Derivatives* in filter menu.

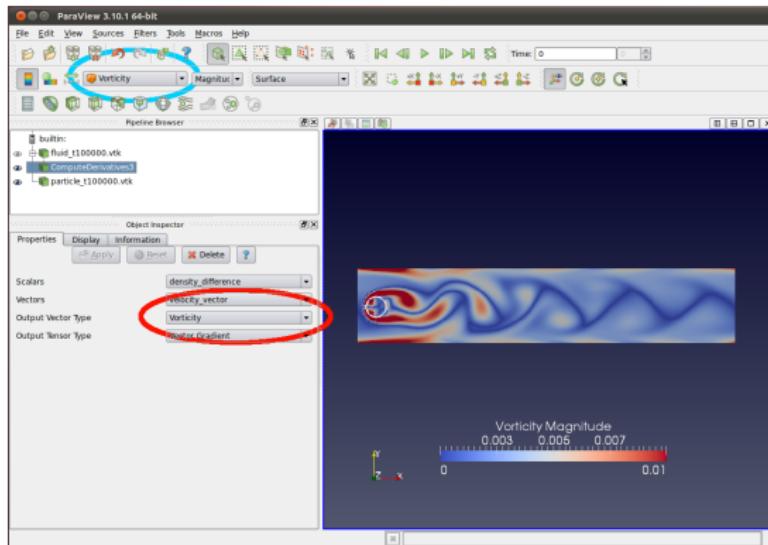


FIGURE 19: Vorticity plot of flow pass a circle.

SAVE DATA AND ANIMATION

ParaView is capable of exporting screenshot of the view window in standard formats (e.g. png, bmp, tiff, jpg, pdf). An animation can be created from a serie of data set.

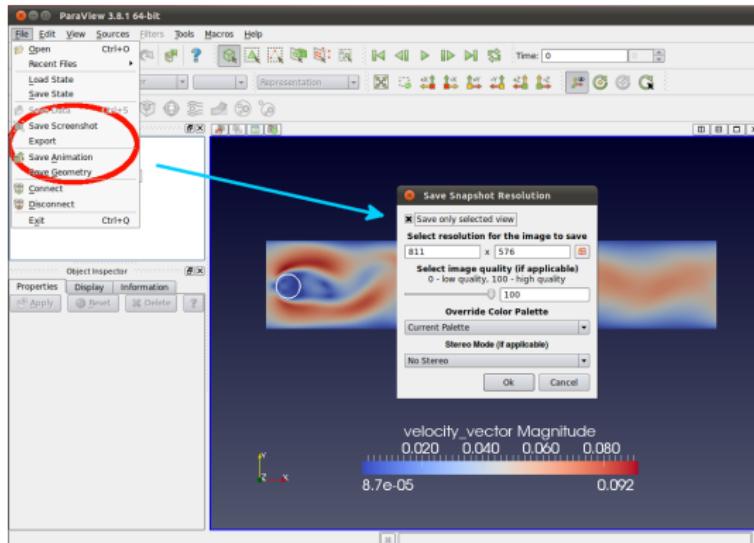


FIGURE 20: Save data and animation.

STREAMLINES OF FLOW IN A CHAMBER

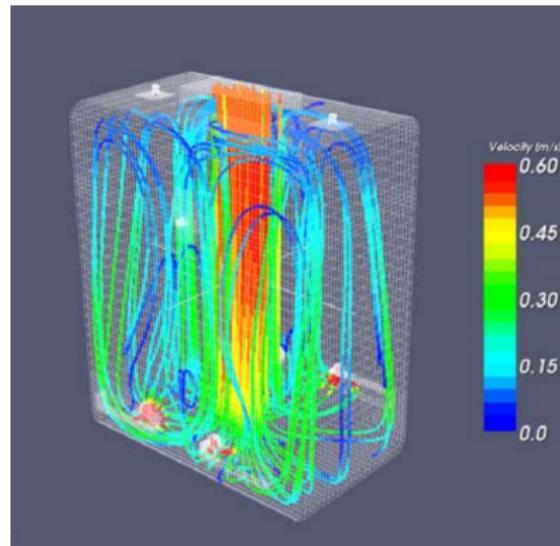


FIGURE 21: Streamlines of flow in a chamber. The streamlines are colored by the velocity magnitude

SIMULATION OF A GAS-LIQUID STIRRED REACTOR

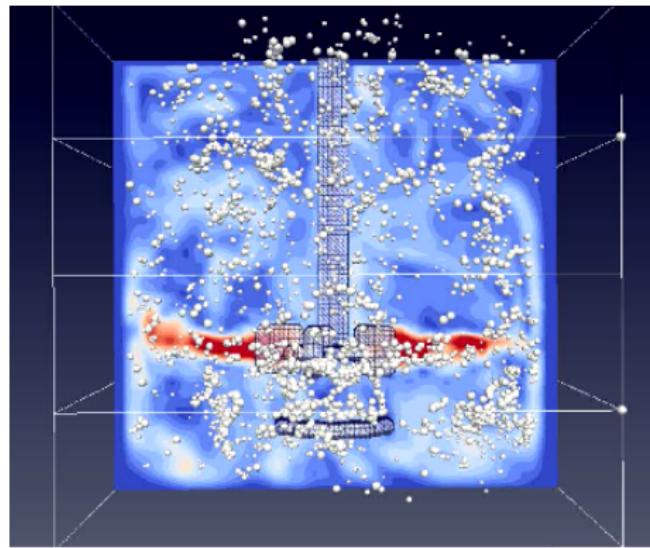


FIGURE 22: Simulation result of a gas-liquid stirred reactor. Bubbles are represented by sphere glyphs and scaled by its diameter. The contour plot shows the liquid velocity contour at the mid-plane between baffles.

3D ANIMATION OF A GAS-LIQUID STIRRED REACTOR (1)



FIGURE 23: 3D (anaglyph) animation of bubble dispersion in a gas-liquid stirred reactor from front.

3D ANIMATION OF A GAS-LIQUID STIRRED REACTOR (2)

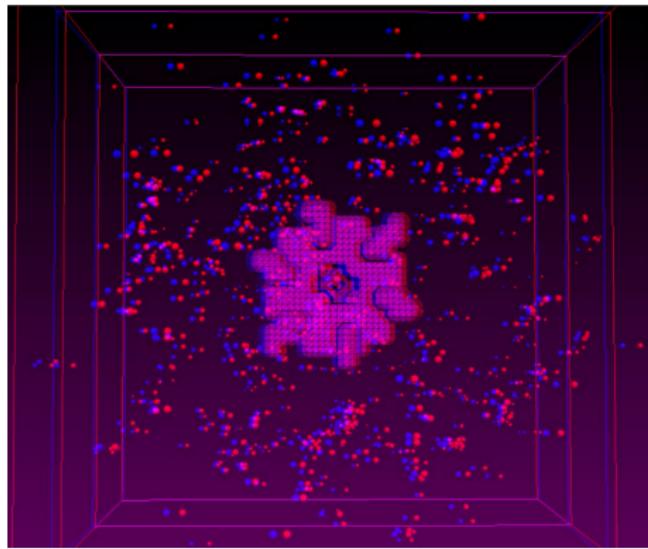


FIGURE 24: 3D (anaglyph) animation of bubble dispersion in a gas-liquid stirred reactor from top.

RESOURCES AND FURTHER READING

- ParaView website (www.paraview.org)
 - ParaView user's guide
 - AICT, University of Alberta website
(<http://sciviz.aict.ualberta.ca/index.php?page=intro>)
 - W.J. Shroeder, L.S. Avila, W. Hoffmann, Visualizing with VTK: A tutorial. Kitware. 2000.
 - Introduction to ParaView by Pittsburgh supercomputer center
(<http://www.psc.edu/general/software/packages/paraview/tutorial/>)
 - The VTK Users Guide (www.kitware.com)