Introduction to VTK and Paraview

Scientific Visualisation
HT 2018
Lecture 2

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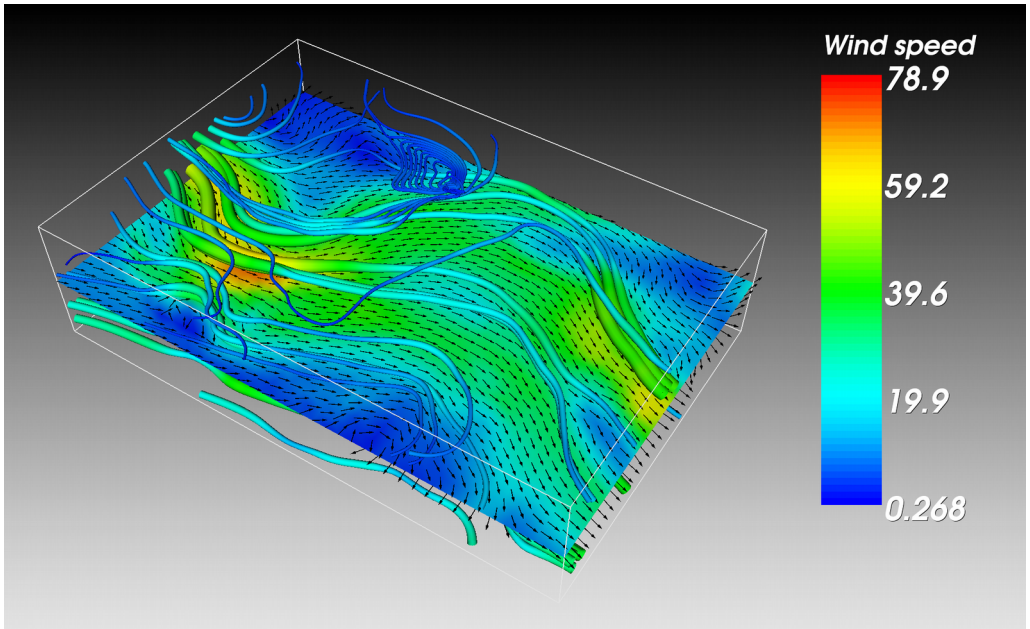
vtk

The Visualization Toolkit (VTK)

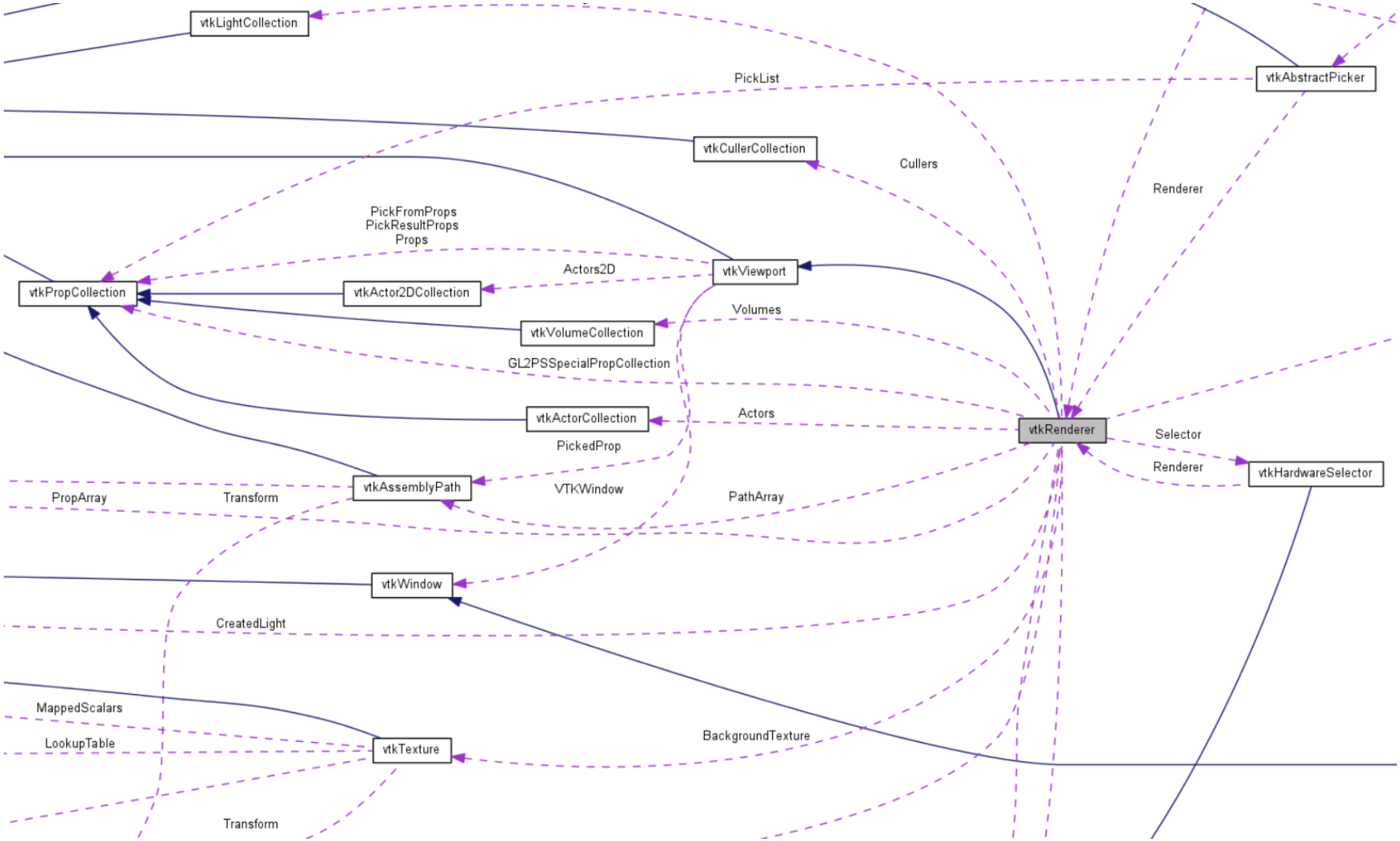
- Open source, freely available C++ toolkit for
  - scientific visualization
  - 3D computer graphics
  - mesh and image processing
- Managed by Kitware Inc.



VTK

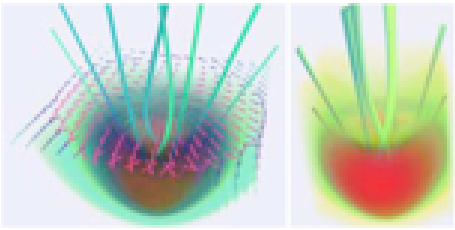
- Object-oriented design
- High level of abstraction (compared to graphics APIs like OpenGL or Direct3D)
- Provides bindings to Tcl/Tk, Python, and Java
- GUI bindings: Qt, wxWidgets, Tkinter, etc

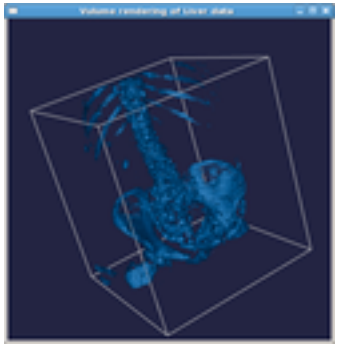
Heavily object-oriented
(and a bit over-designed...)

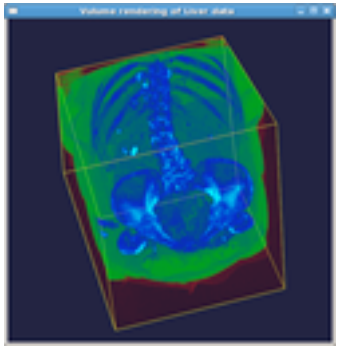


Some examples of what you can do with VTK

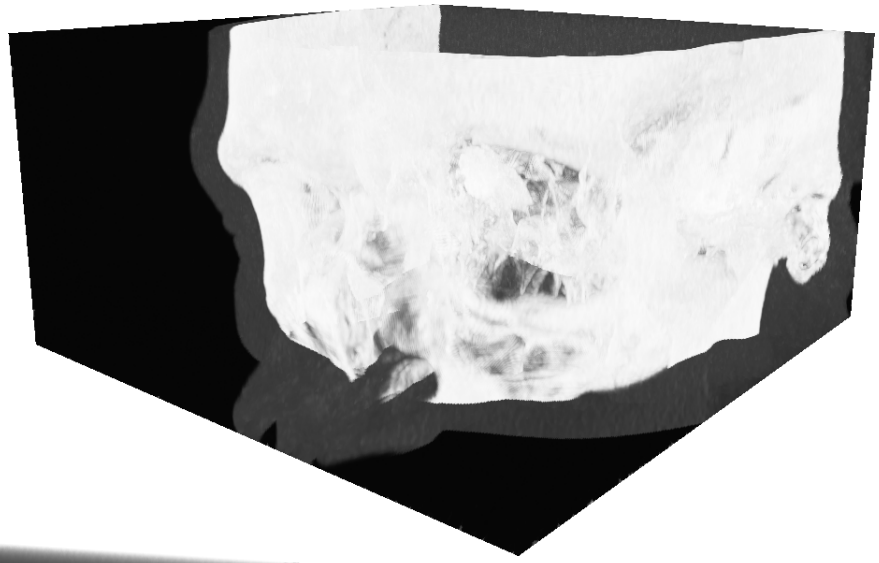
- Create visualizations of
  - scalar, vector, and tensor fields
  - volume data (e.g., 3D CT or MRI scans)
- Mesh and polygon processing
- Image analysis (2D and 3D images)
- Isosurface extraction
- Implement your own algorithms

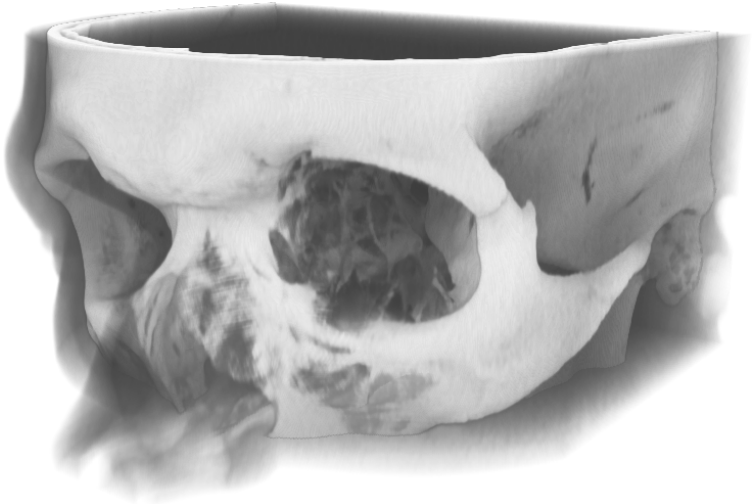


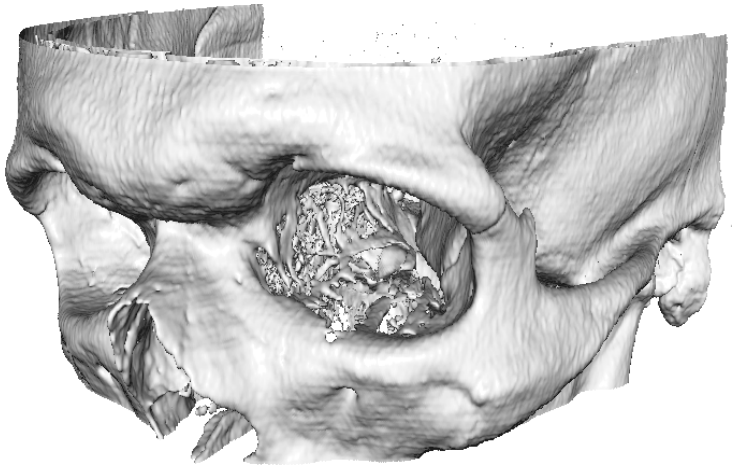




Volume rendering



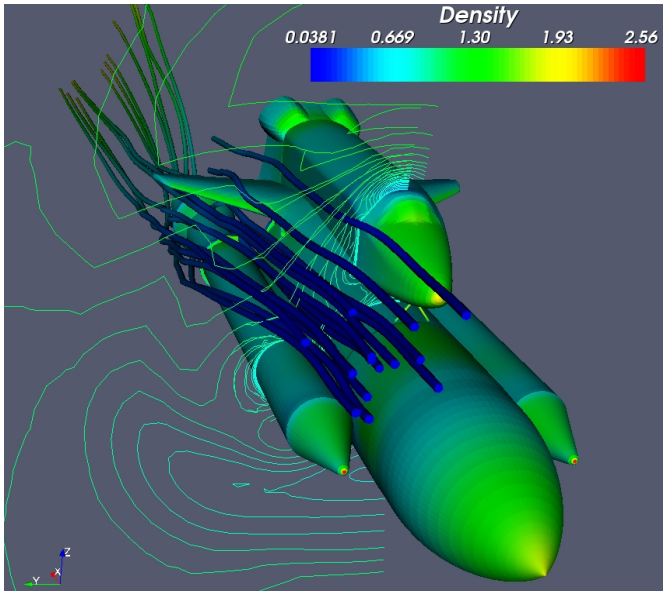




Rendering graphical 3D models (imported from .stl, .ply, .obj, etc)

Rendering performance

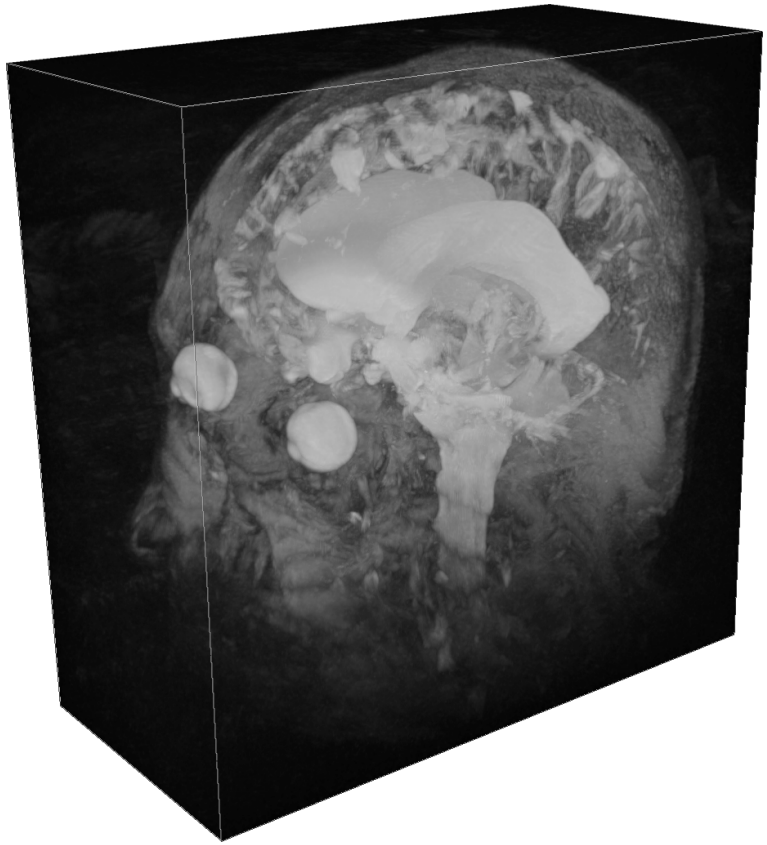
- VTK has decent rendering performance and is good for prototyping 3D visualization tools
- Not suitable for demanding real-time rendering applications (games, VR)



The visualization pipeline

```
# vtk DataFile Version 3.0
vtk output
BINARY
DATASET STRUCTURED_POINTS
DIMENSIONS 256 256 124
SPACING 0.9 0.9 0.9
ORIGIN 0 0 0
CELL_DATA 7998075
POINT_DATA 8126464
COLOR_SCALARS ImageFile 1
^D^E^C^G^D^B^D^B^B^C^D^E^D^E^C^C
^D^C^C^C^C^E^D^C^A^B^B^B^F^A^C^E
^D^D^E^A^A^C^B^B^E^B^A^A^E^B^E^E
^A^C^C^G^C^D^F^B^D^E^@^G^C^D^D^C
^D^C^F^C^B^E^E^E^B^C^C^B^C^B^C^B
^C^C^F^E^F^C^D^A^A^C^F^D^D^E^E^B
```

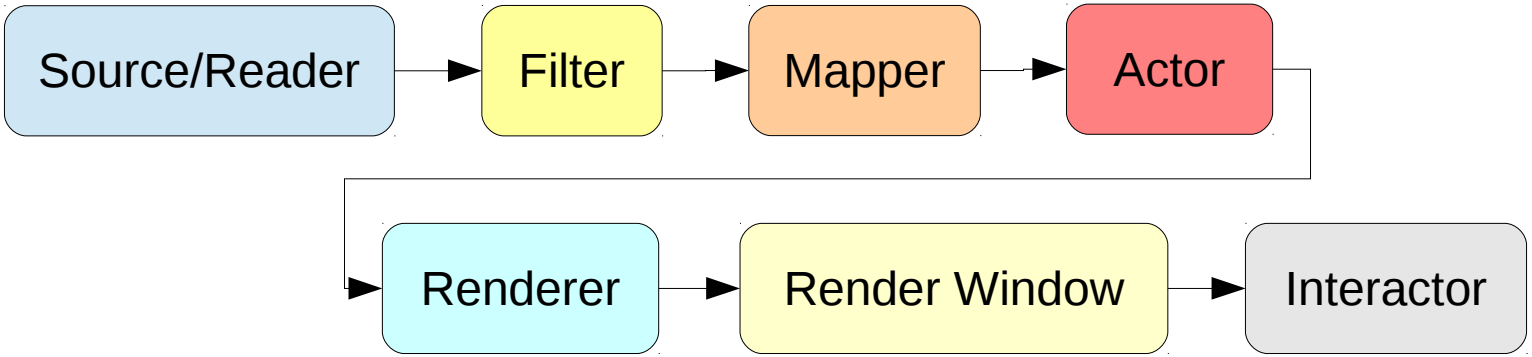
Input data



Visualization

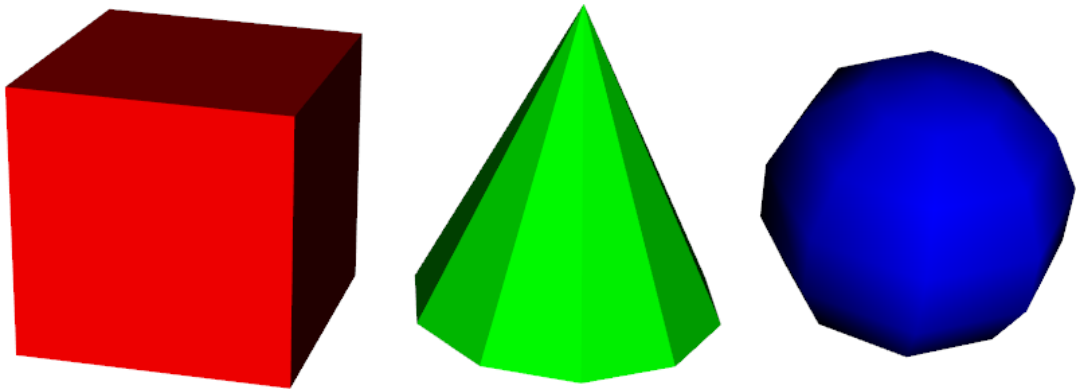
The visualization pipeline

- To visualize your data in VTK, you normally set up a pipeline like this:



Sources

- VTK provides various source classes that can be used to construct simple geometric objects like spheres, cubes, cones, cylinders, etc...
- Examples: **vtkSphereSource**, **vtkCubeSource**, **vtkConeSource**



source/reader → filter → mapper → actor → renderer → renderWindow → interactor

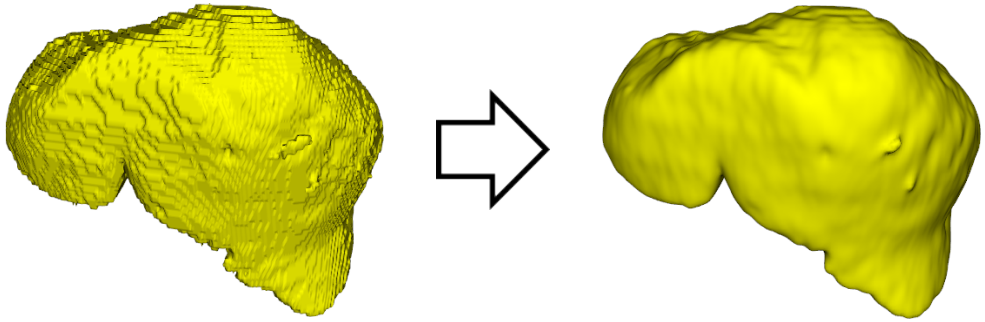
Readers

- Reads data from file
- You can use, e.g., **vtkStructuredPointsReader** to read a volumetric image from a .vtk file
- or **vtkSTLReader** to load a 3D polygon model from a .stl file
- If VTK cannot read your data, write your own reader!

source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Filters

- Takes data as input, modifies it in some way, and returns the modified data
- Can be used to (for example)
  - select data of a particular size, strength, intensity, etc
  - process 2D/3D images or polygon meshes
  - generate geometric objects from data



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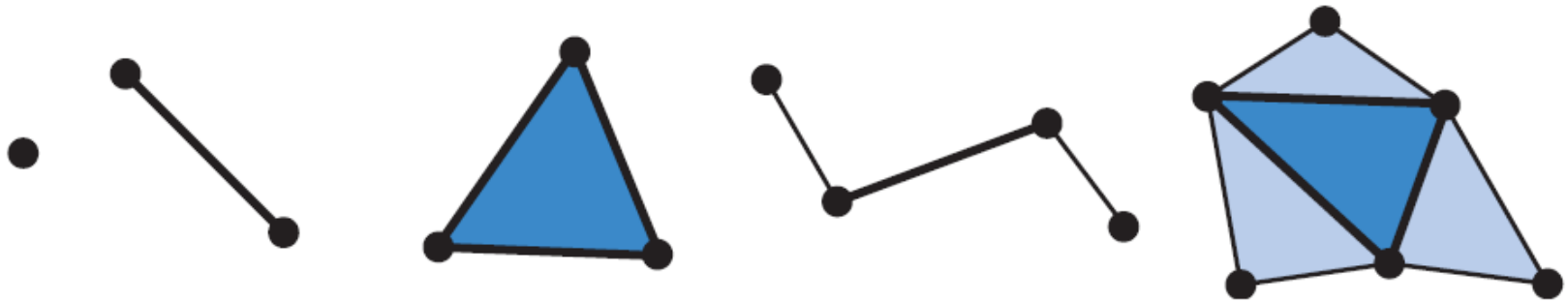
Mappers

- Maps data to graphics primitives (points, lines, or triangles) that can be displayed by the renderer
- Example: **vtkPolyDataMapper** maps polygonal data (**vtkPolyData**) to graphics primitives

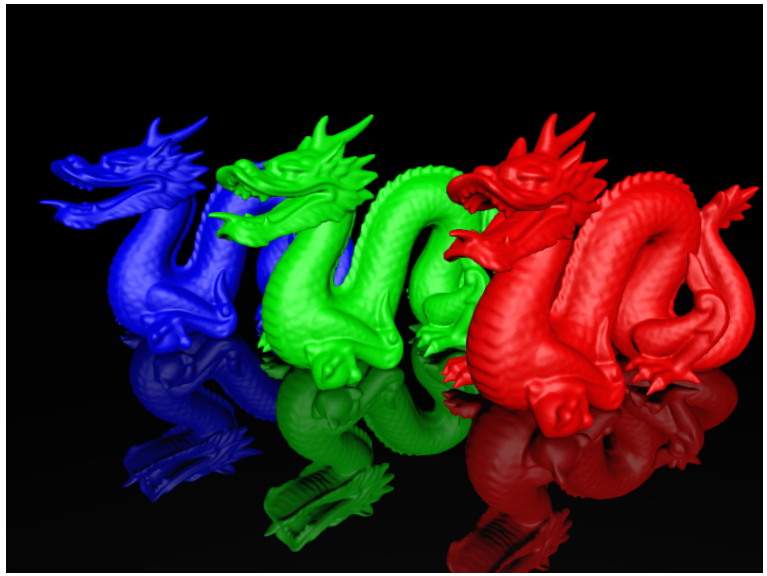


source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Image source: http://www.realtimerendering.com

Actors

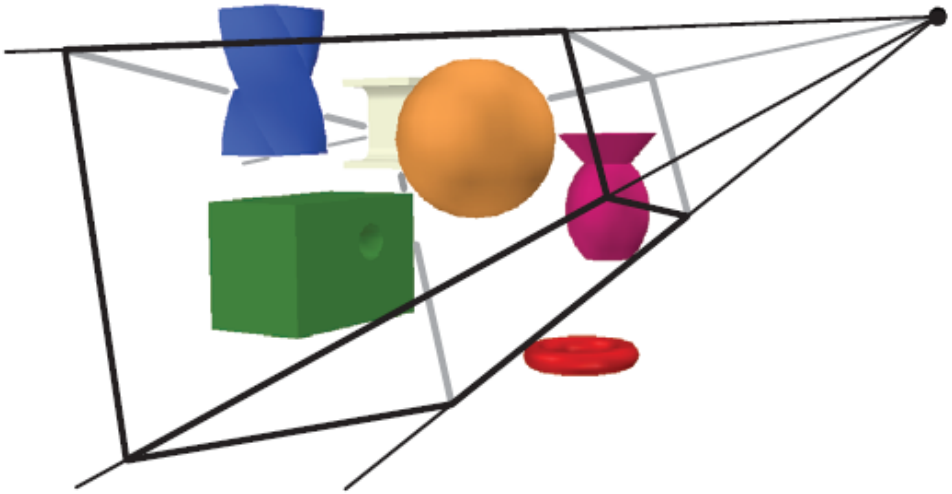
- **vtkActor** represents an object (geometry and properties) in a rendering scene
- Has position, scale, orientation, various rendering properties, textures, etc. Keeps a reference to the mapper.

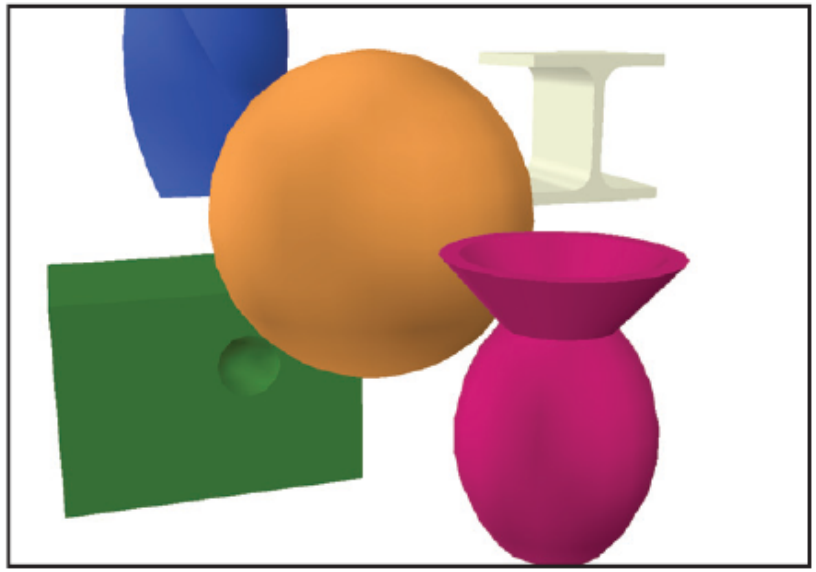


source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Renderer

- **vtkRenderer** controls the rendering process for actors and scenes
- Under the hood, VTK uses OpenGL for rendering



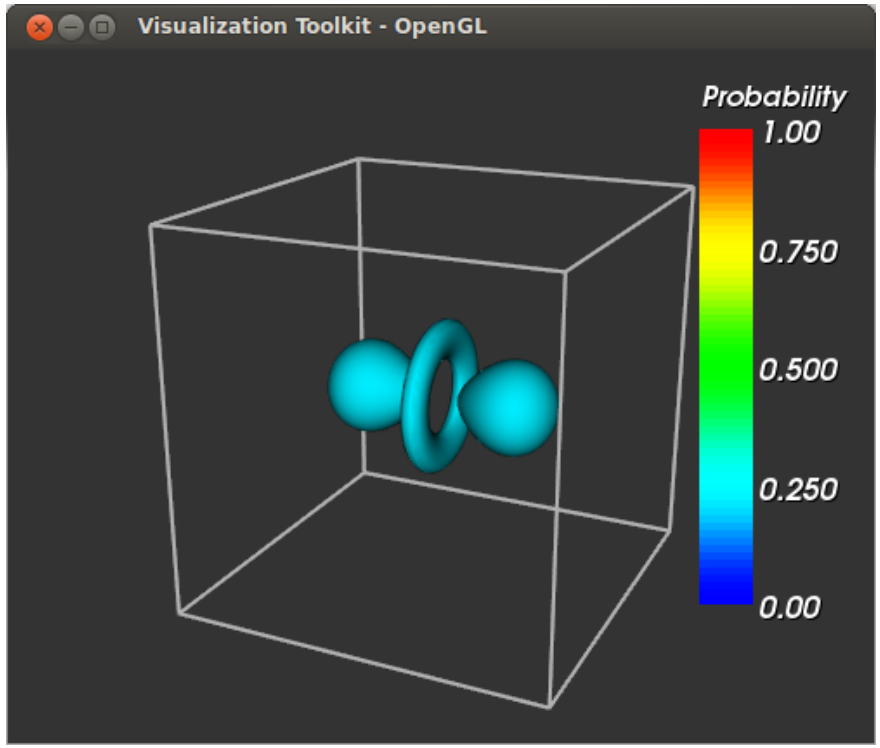


source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Image source: http://www.realtimerendering.com

Render window

- The **vtkRenderWindow** class creates a window for renderers to draw into



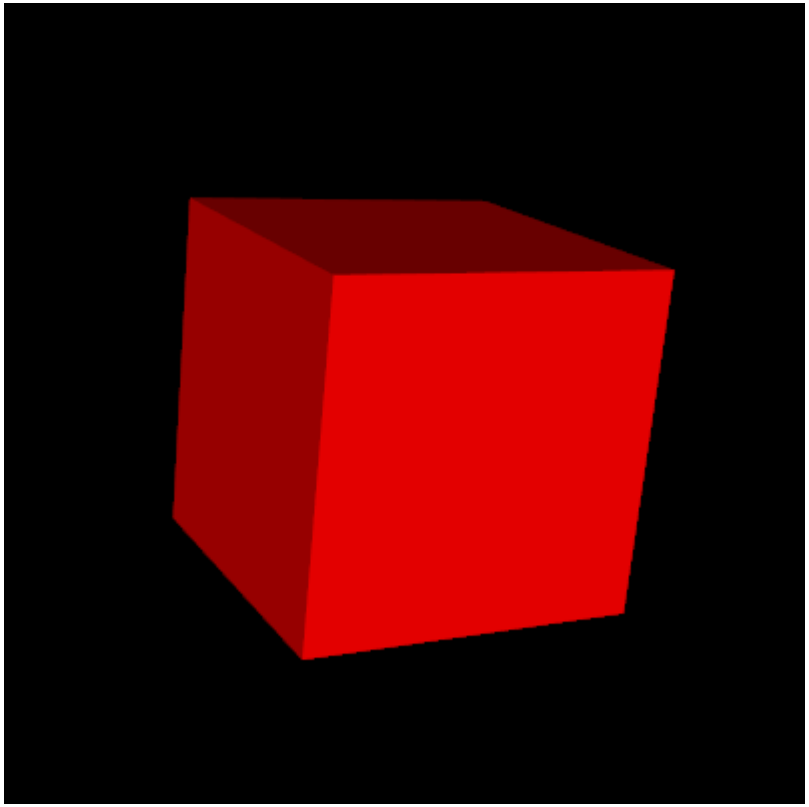
source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Interactors

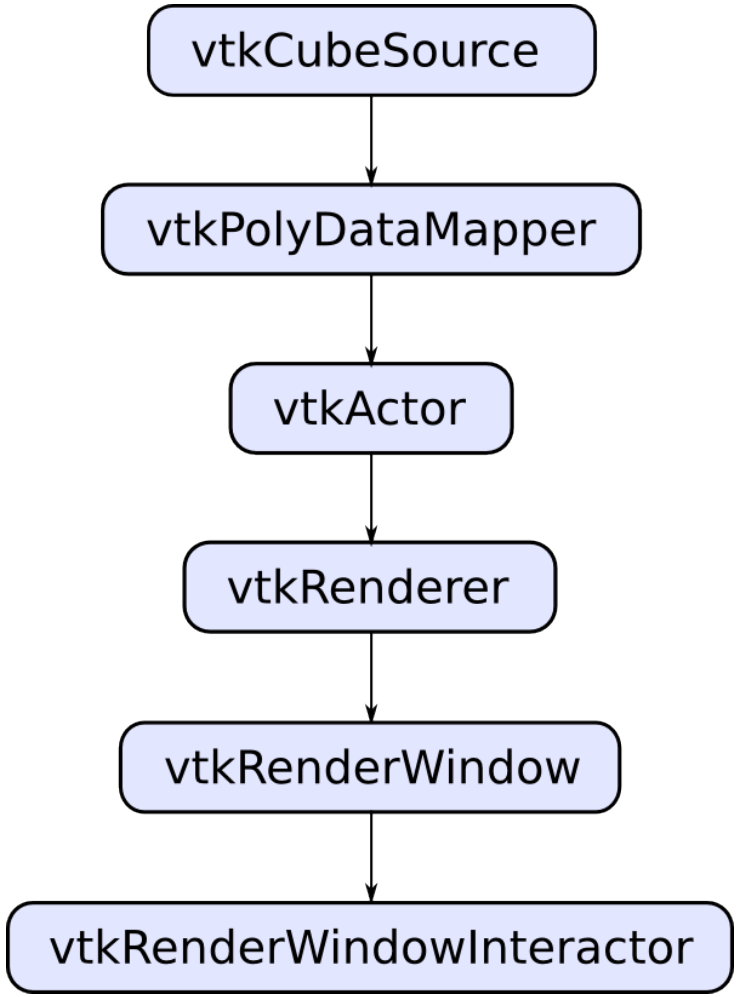
- The **vtkRenderWindowInteractor** class provides platform-independent window interaction via the mouse and keyboard
- Allows you to rotate/zoom/pan the camera, select and manipulate actors, etc
- Also handles time events

source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Example 1:
Rendering a cube



Pipeline for the cube example



Source

```
import vtk

# Generate polygon data for a cube
cube = vtk.vtkCubeSource()
```

source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Mapper

```
# Create a mapper for the cube data
cube_mapper = vtk.vtkPolyDataMapper()
cube_mapper.SetInputConnection(
   cube.GetOutputPort())

# This will not work in VTK 6!
#cube_mapper.SetInput(cube.GetOutput())
```

source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Actor

```
# Connect the mapper to an actor
cube_actor = vtk.vtkActor()
cube_actor.SetMapper(cube_mapper)
cube_actor.GetProperty().SetColor(1.0, 0.0, 0.0)
```

source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Renderer

```
# Create a renderer and add the cube actor to it
renderer = vtk.vtkRenderer()
renderer.SetBackground(0.0, 0.0, 0.0)
renderer.AddActor(cube_actor)
```

source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Render window

```
# Create a render window
render_window = vtk.vtkRenderWindow()
render_window.SetWindowName("Simple VTK scene")
render_window.SetSize(400, 400)
render_window.AddRenderer(renderer)
```

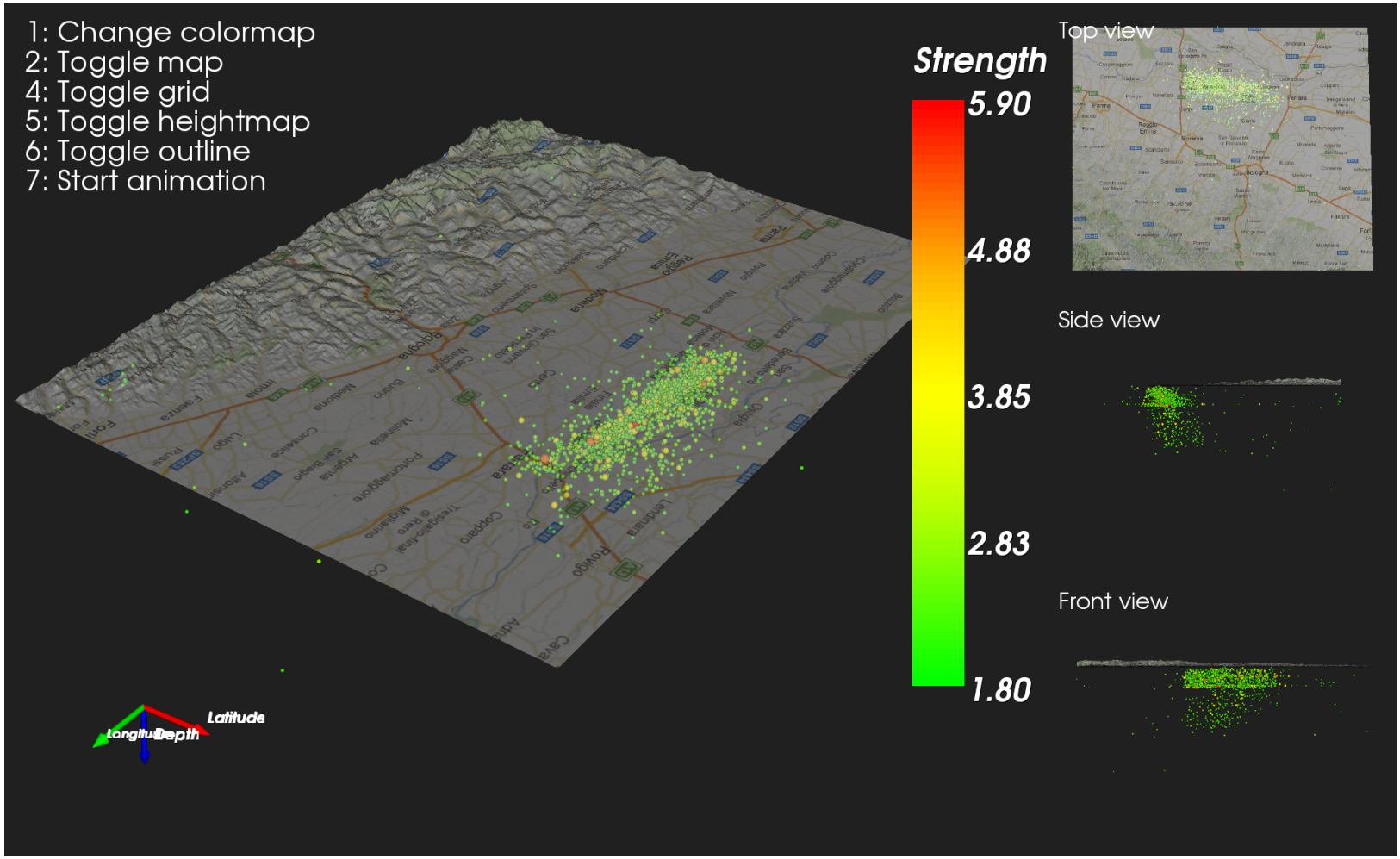
source/reader → filter → mapper → actor → renderer → renderWindow → interactor

Interactor

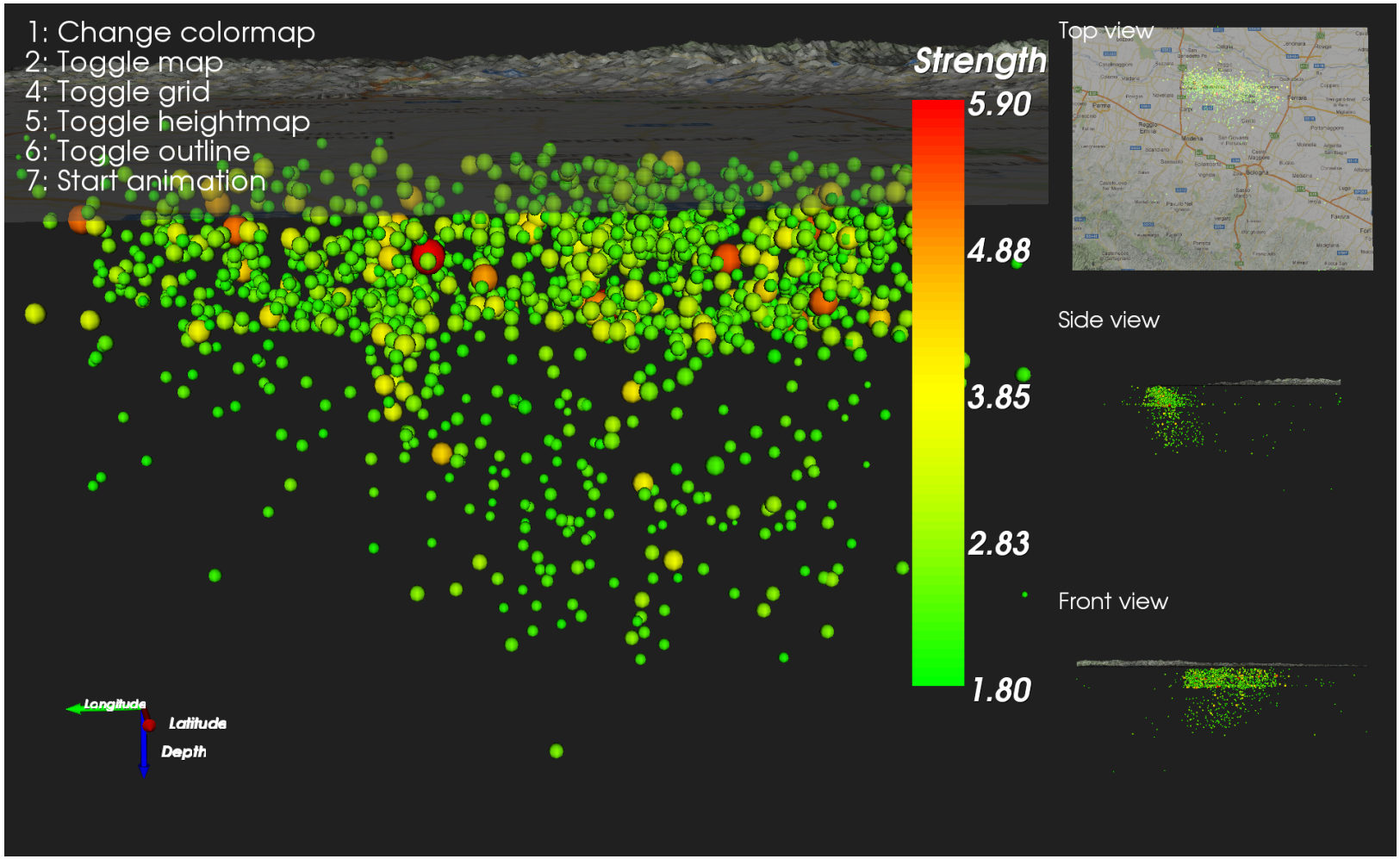
```
# Create an interactor
interactor = vtk.vtkRenderWindowInteractor()
interactor.SetRenderWindow(render_window)

# Initialize the interactor and start the
# rendering loop
interactor.Initialize()
render_window.Render()
interactor.Start()
```

source/reader → filter → mapper → actor → renderer → renderWindow → interactor

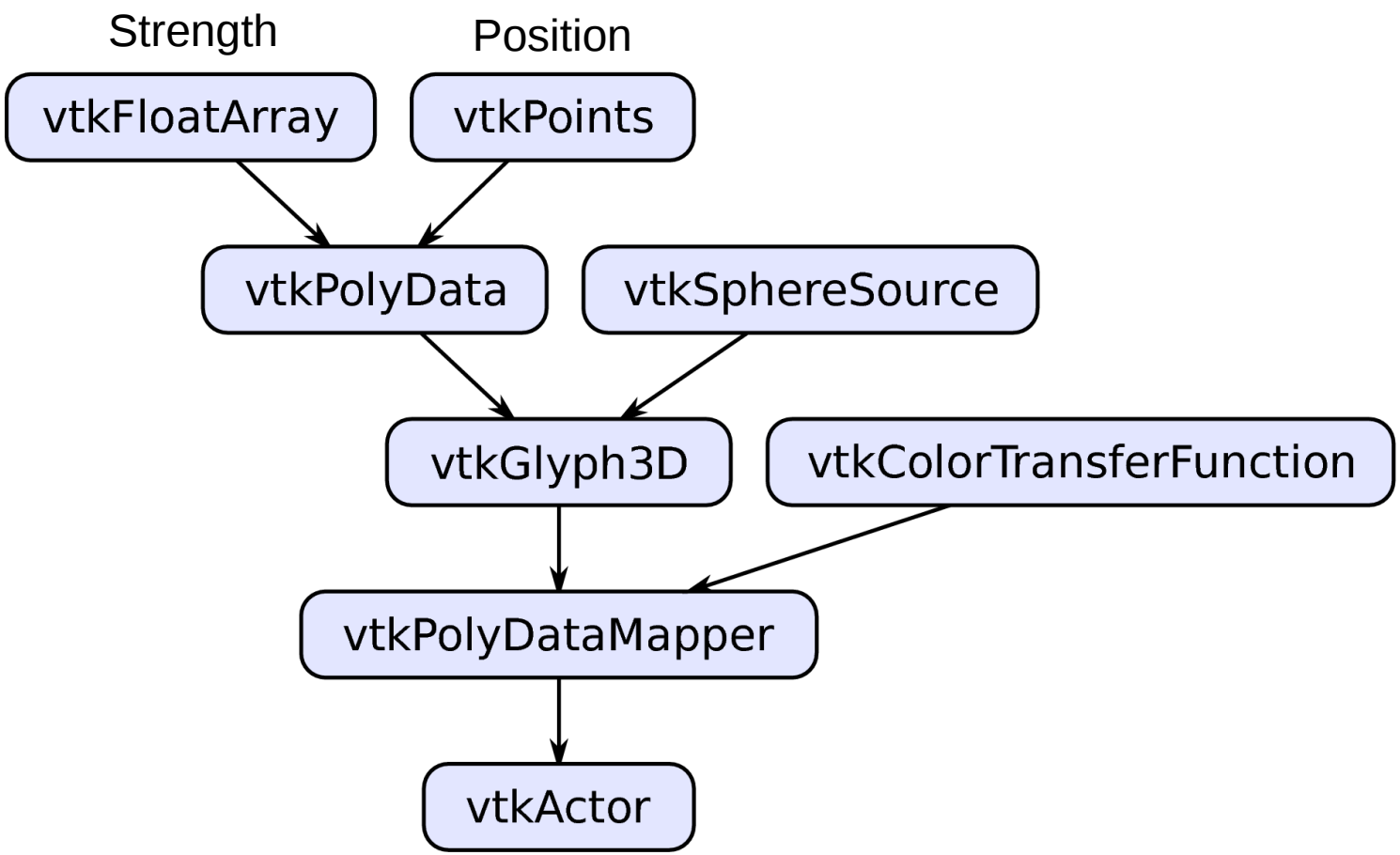
Example 2: Earthquake data



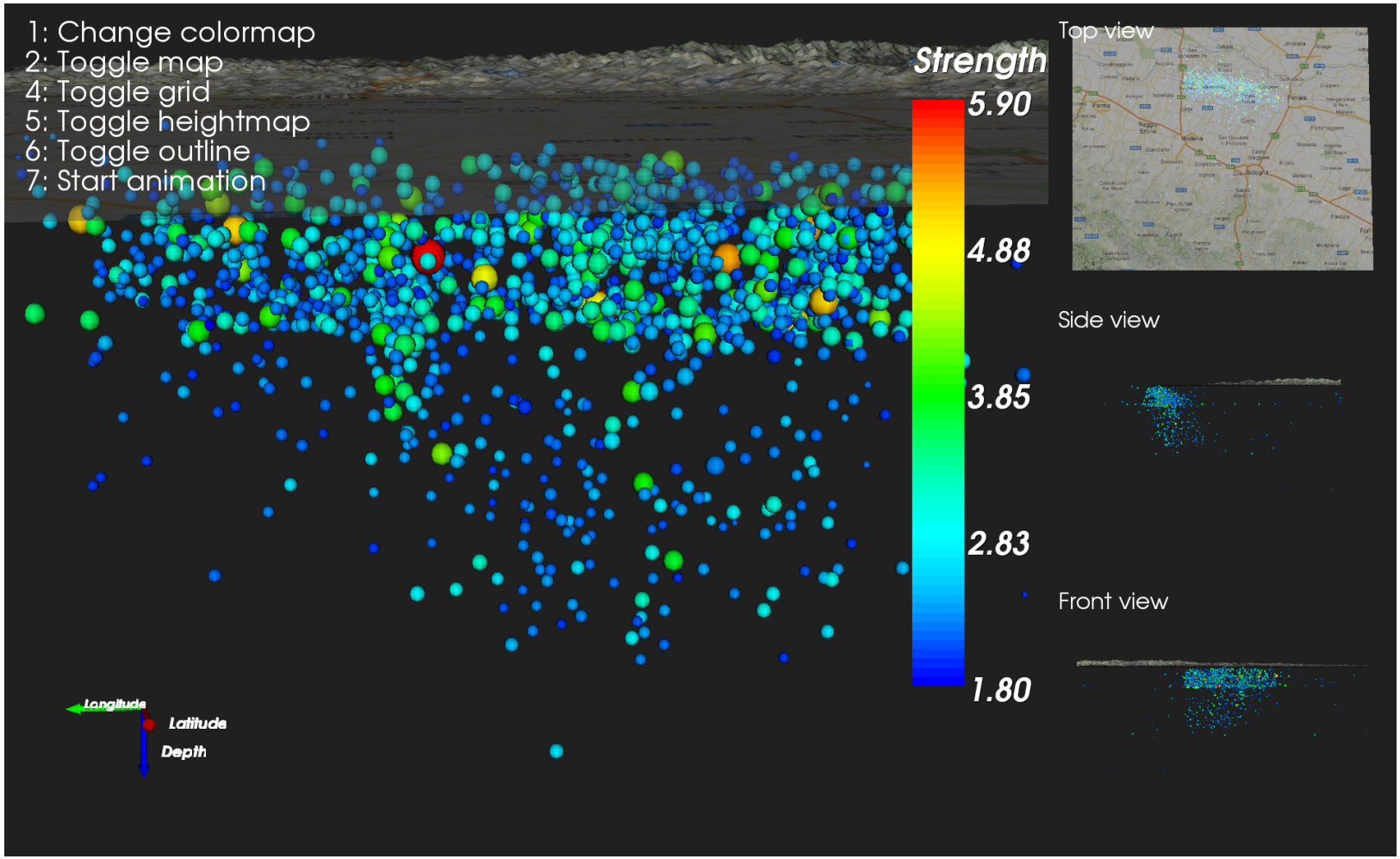
Visualizing the quakes with sphere glyphs



Sphere glyphs

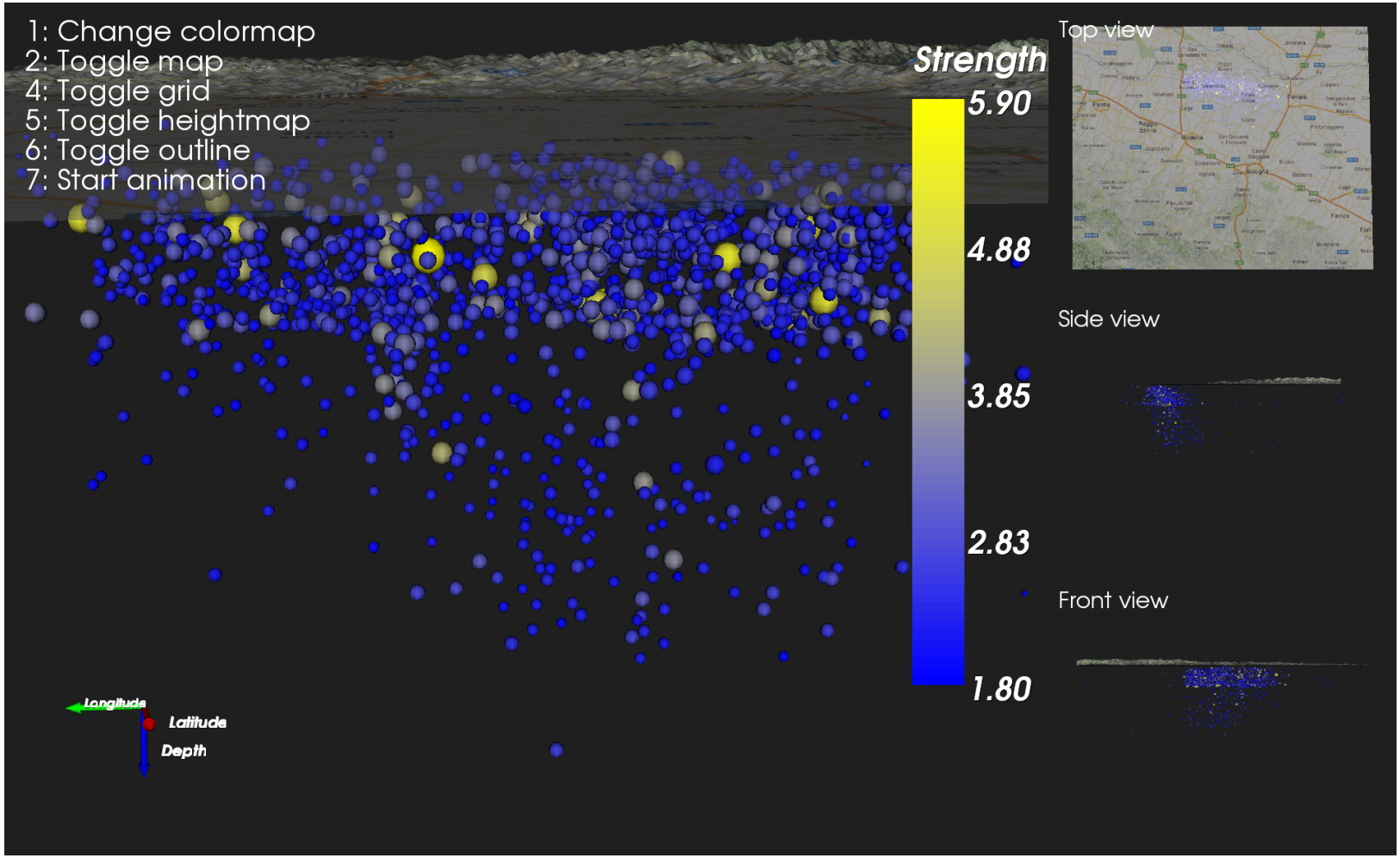


Colormaps

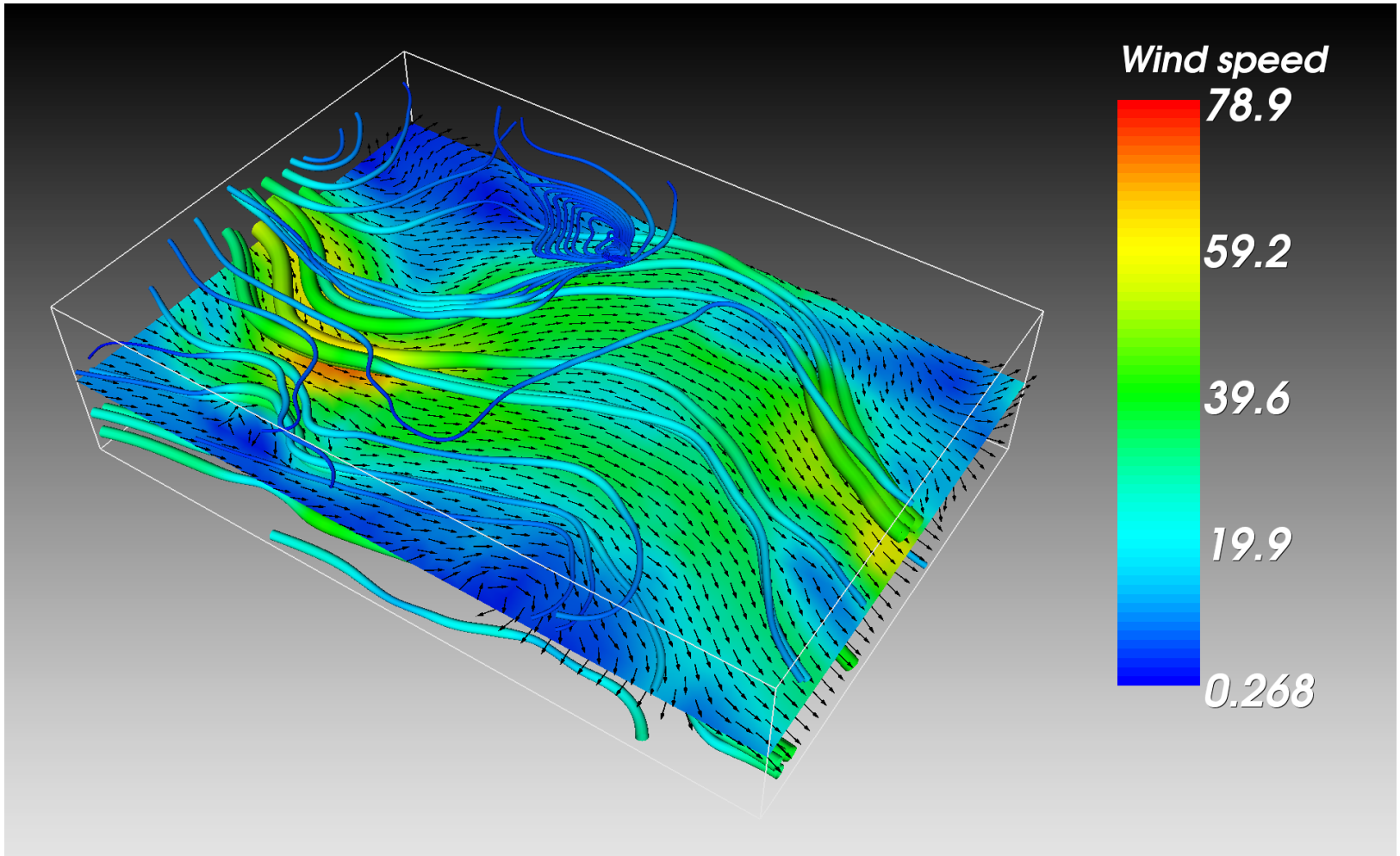


See this paper for a discussion on why the ”rainbow” colormap is a poor choice for most applications

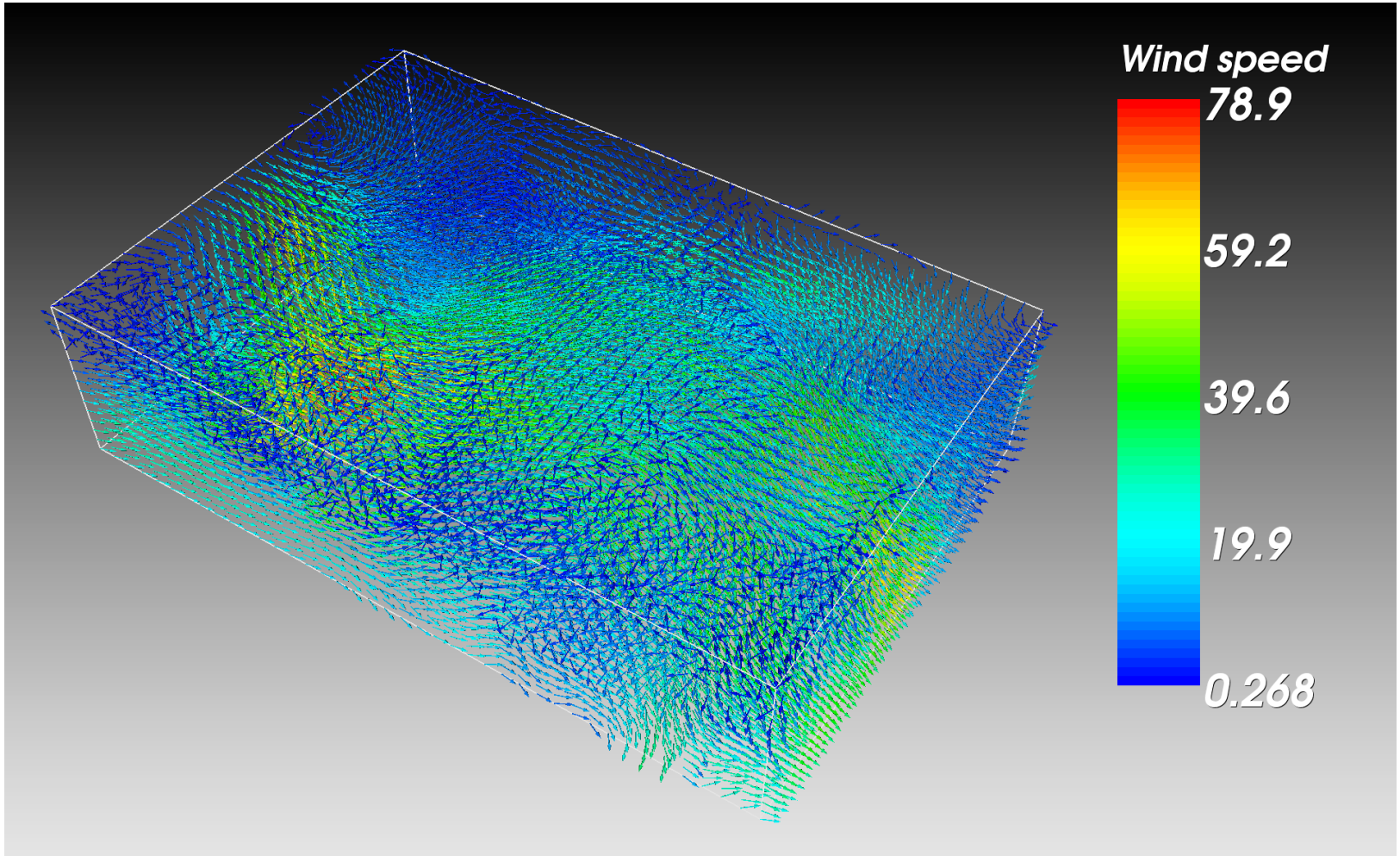
Colormaps


1: Change colormap
2: Toggle map
4: Toggle grid
5: Toggle heightmap
6: Toggle outline
7: Start animation
Strength
5.90
4.88
3.85
2.83
1.80
Top view
Side view
Front view
Longitude
Latitude
Depth

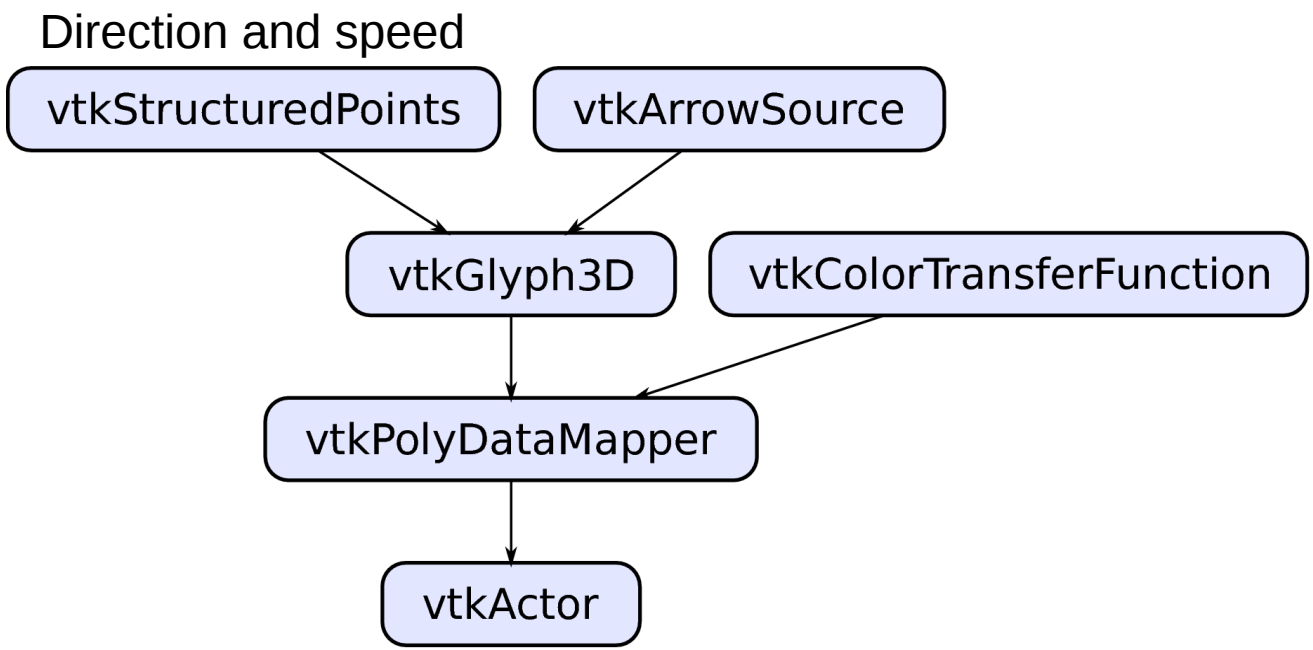
Example 3:
Air currents



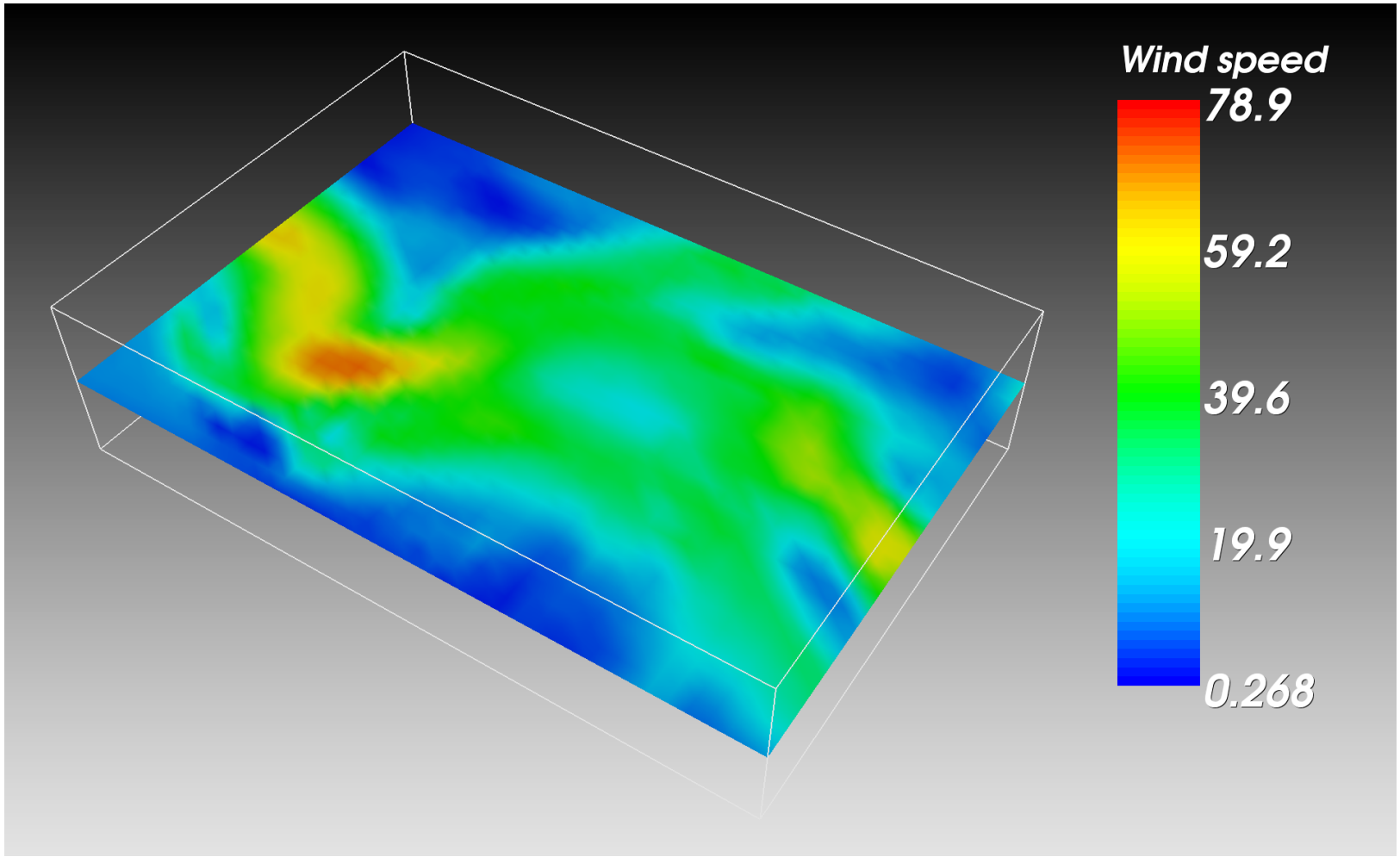
Arrow glyphs, first try



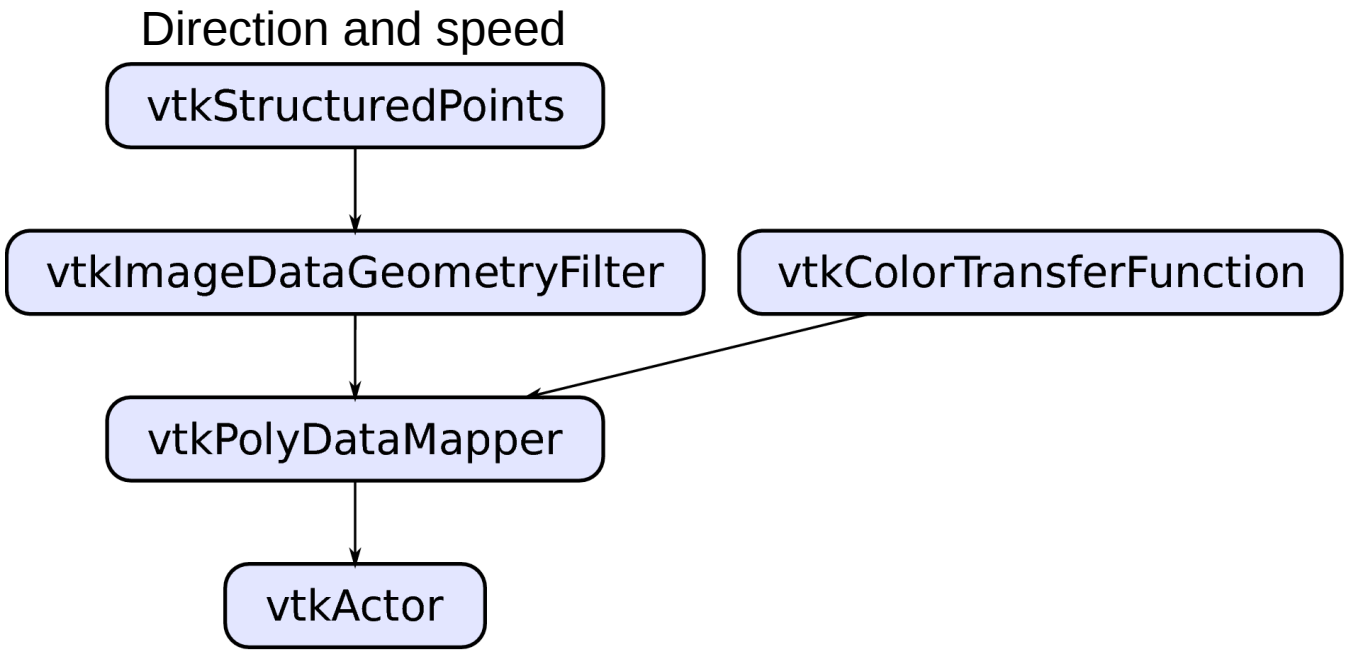
Arrow glyphs, first try



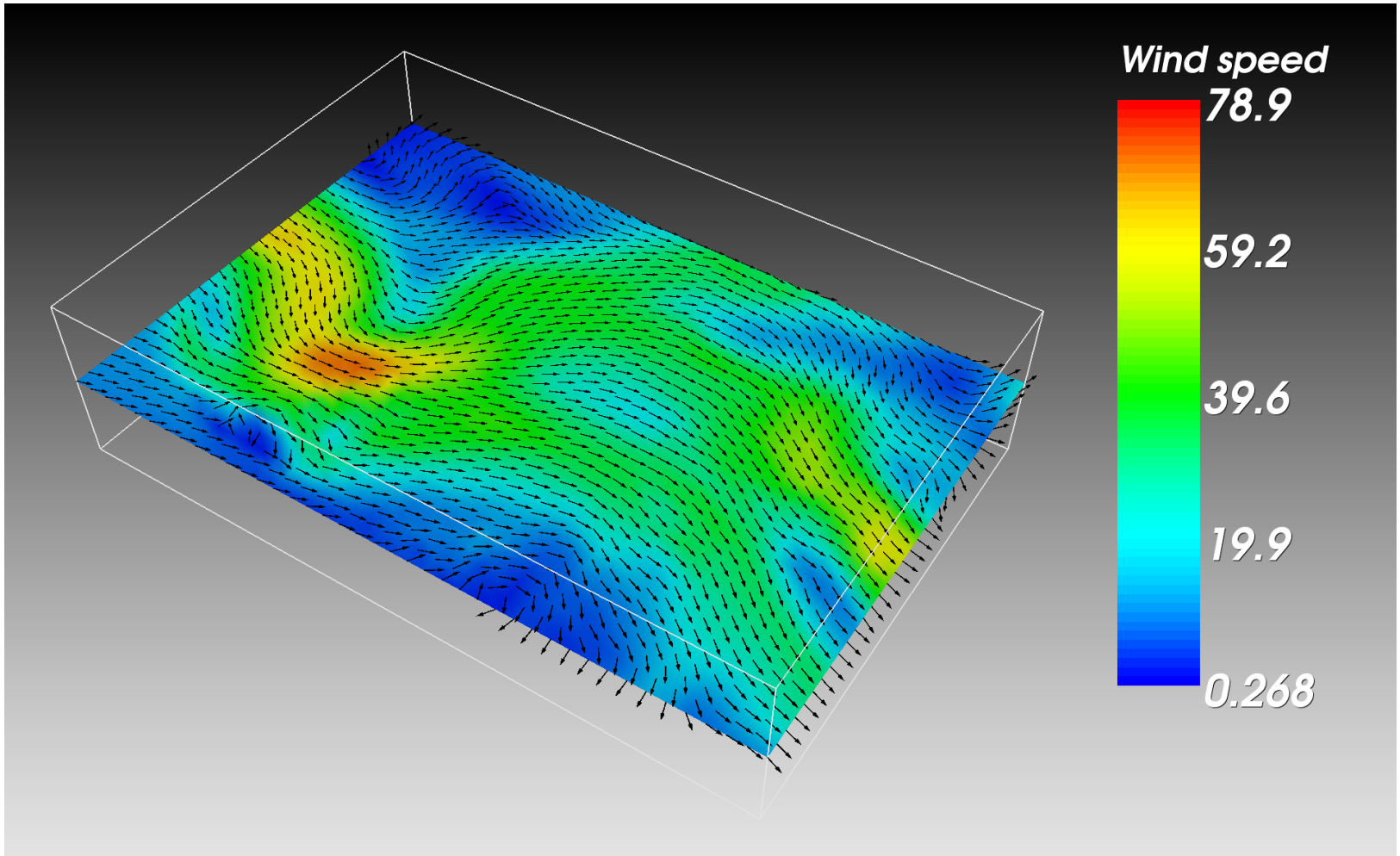
Cut planes



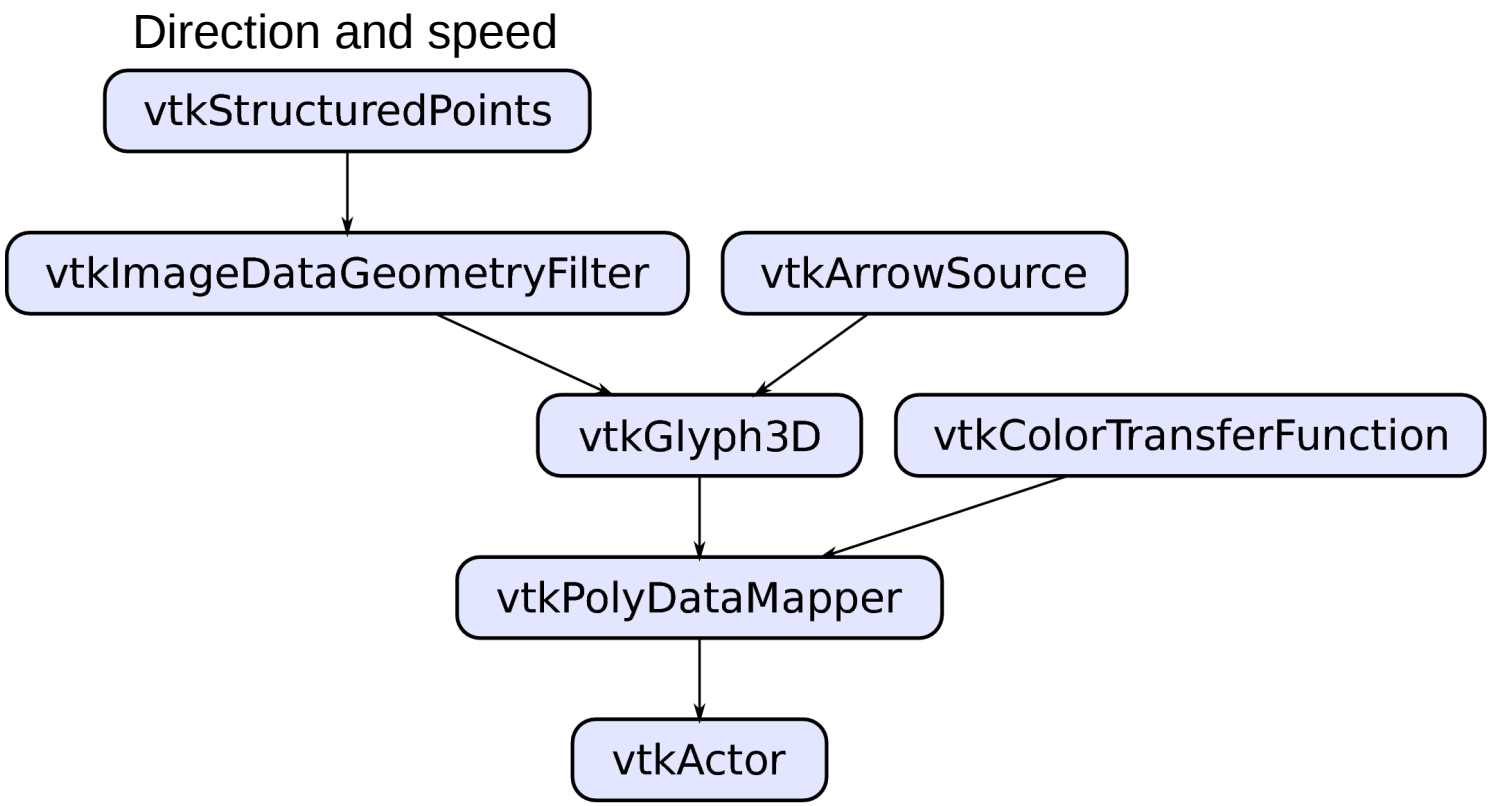
Cut planes


Direction and speed
vtkStructuredPoints
vtkImageDataGeometryFilter
vtkColorTransferFunction
vtkPolyDataMapper
vtkActor

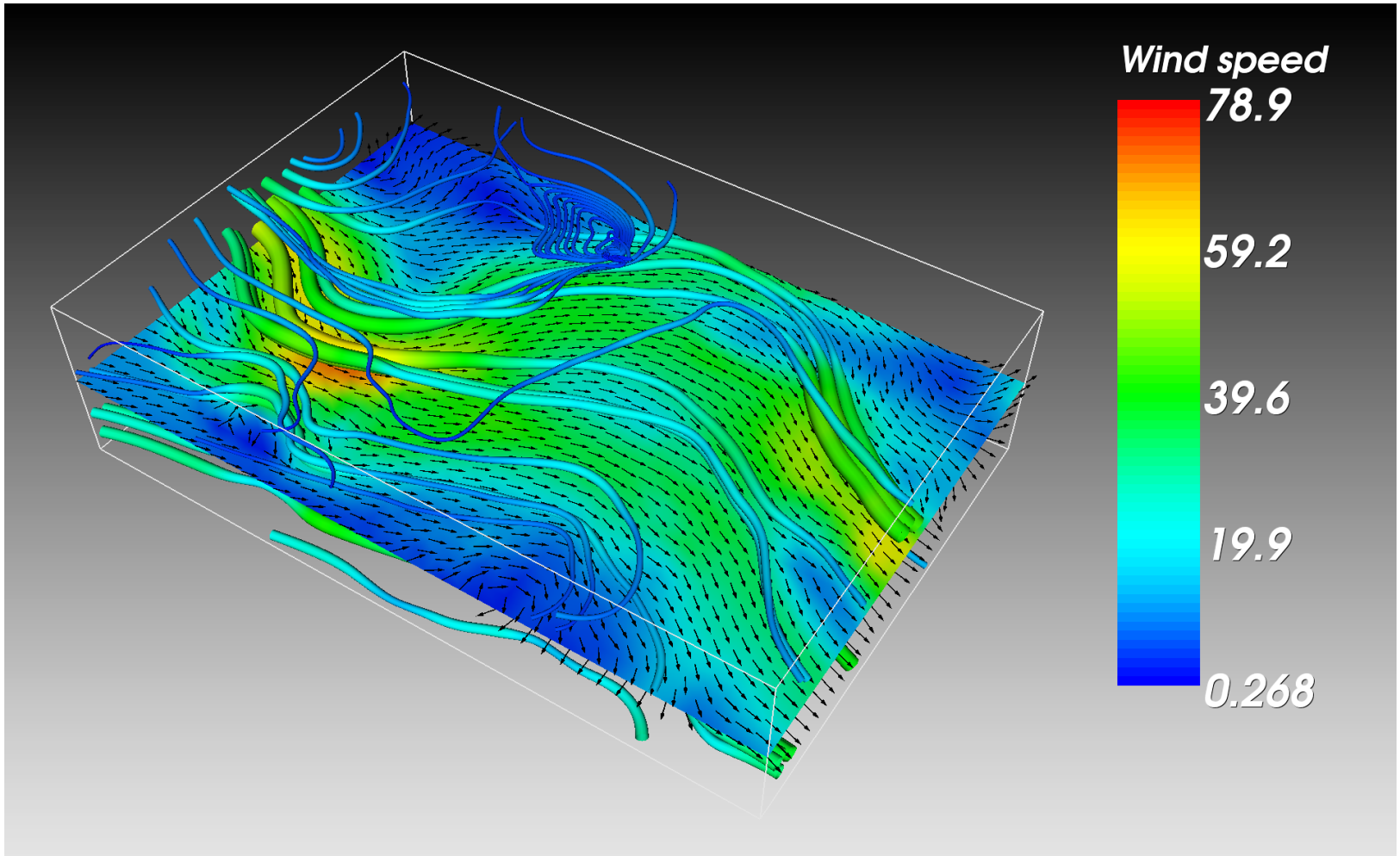
Arrow glyphs, second try



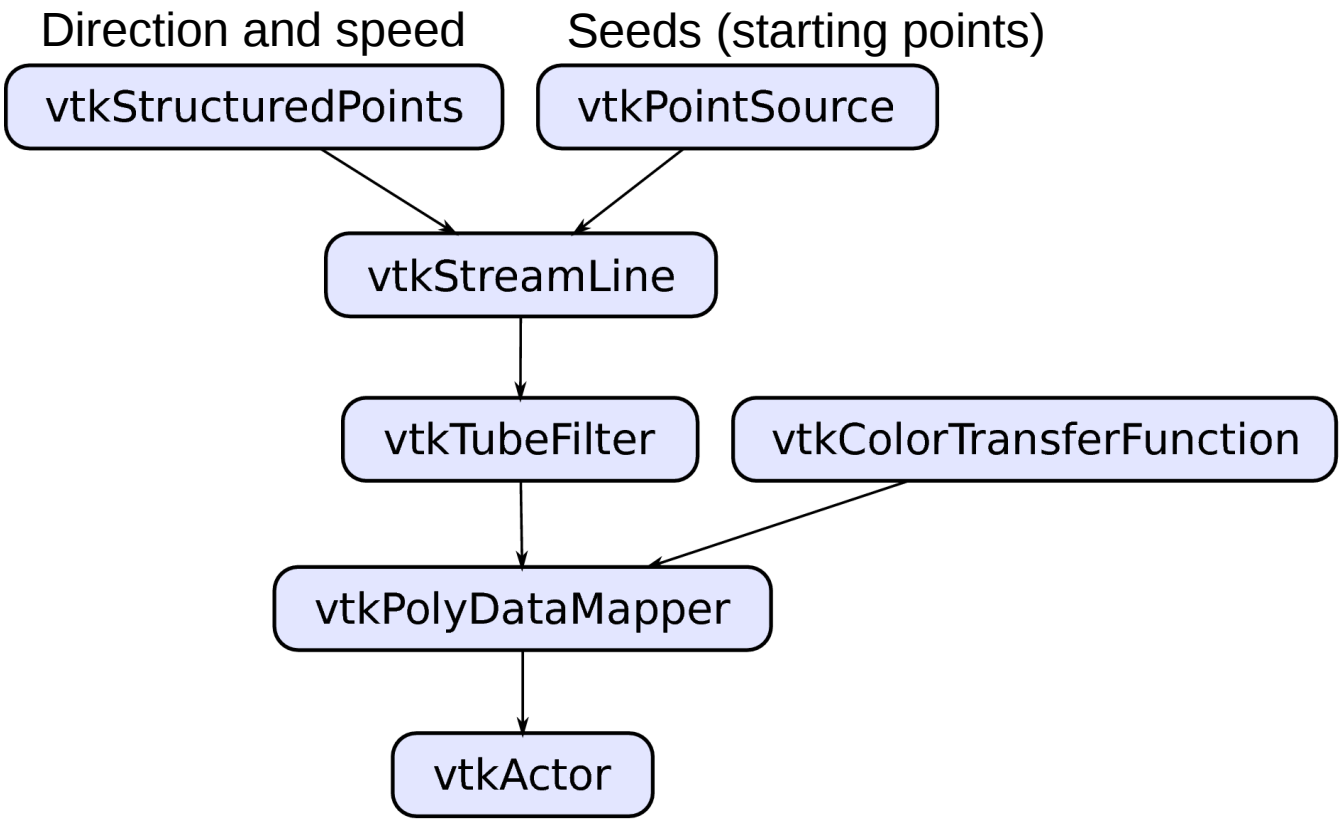
Arrow glyphs, second try



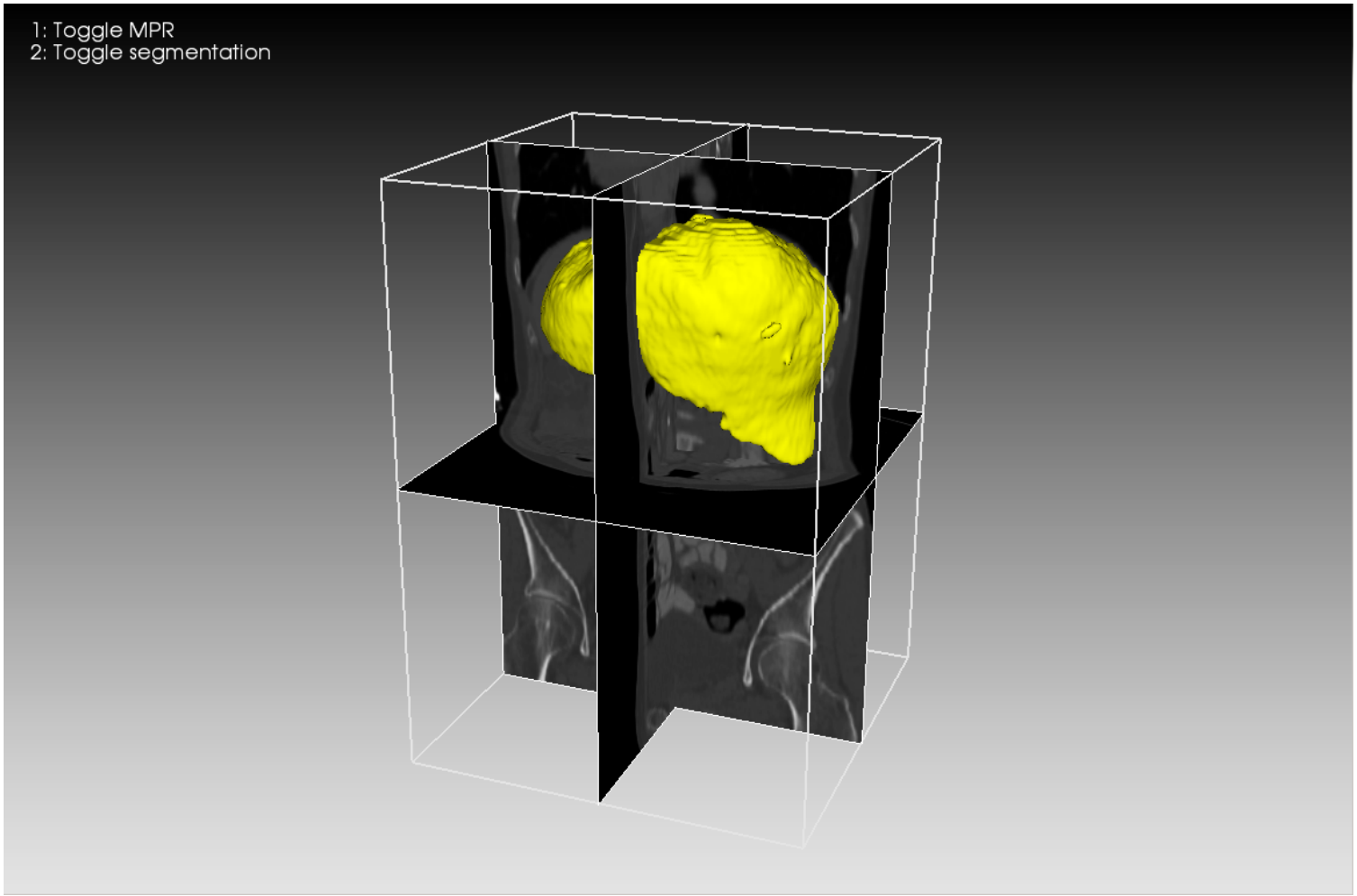
Streamtubes



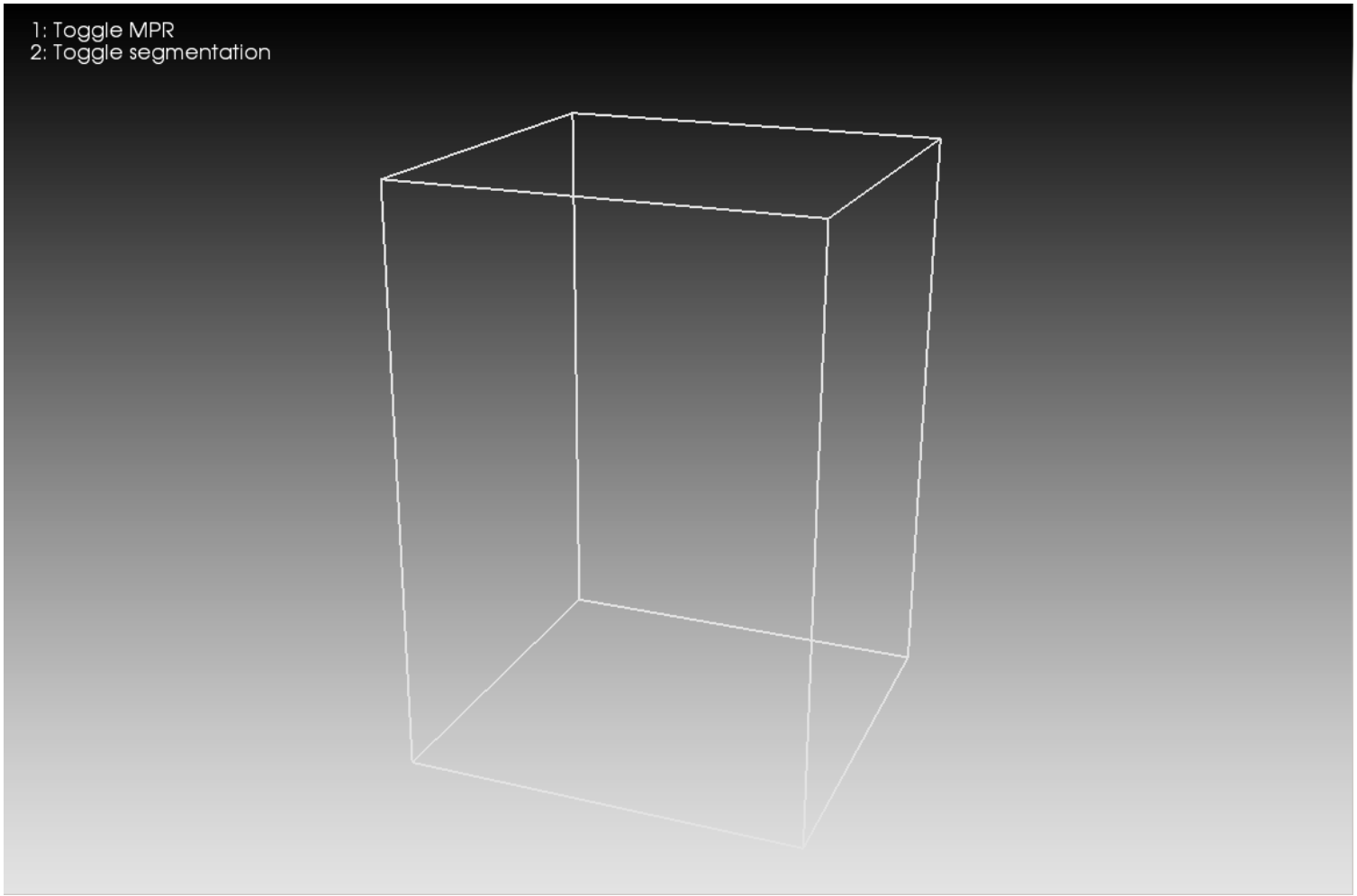
Streamtubes



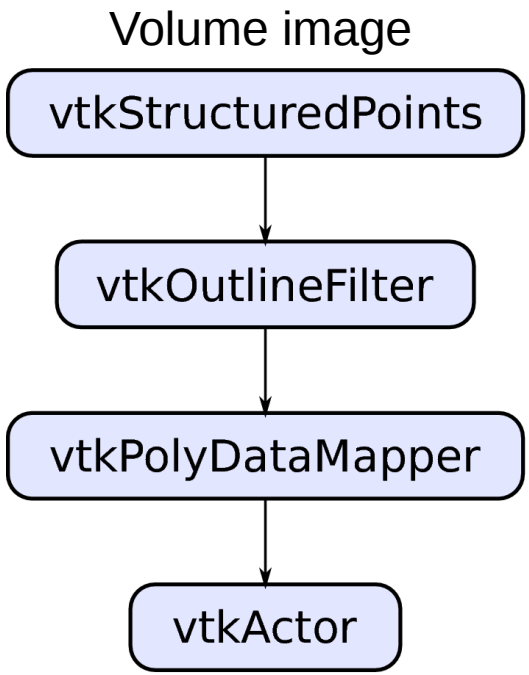
Example 4:
Medical 3D data



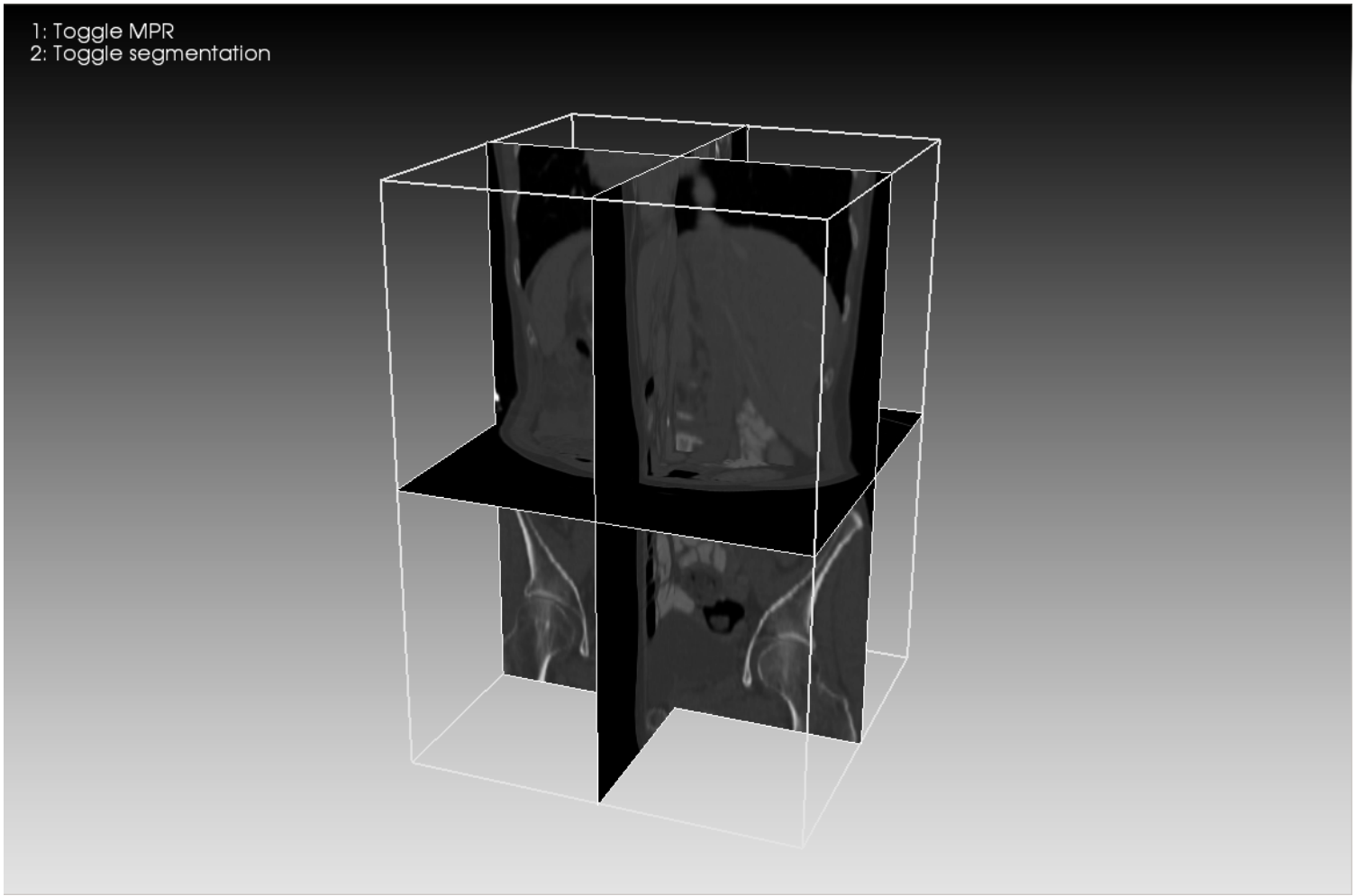
Outline



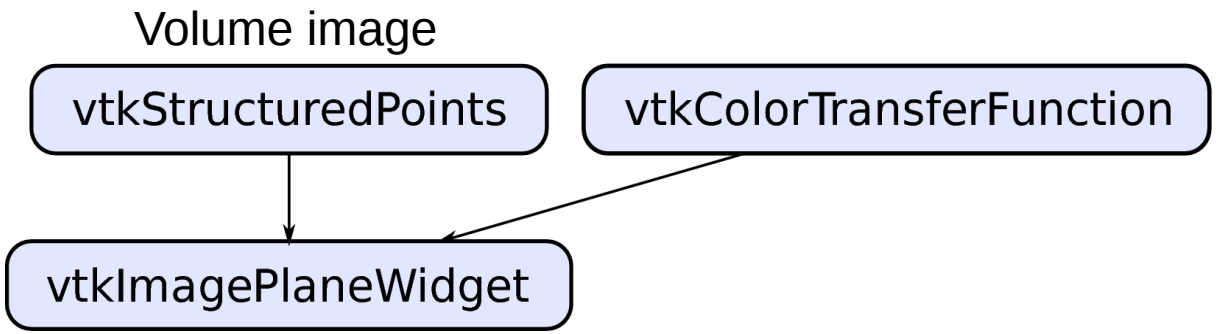
Outline


Volume image
vtkStructuredPoints
vtkOutlineFilter
vtkPolyDataMapper
vtkActor

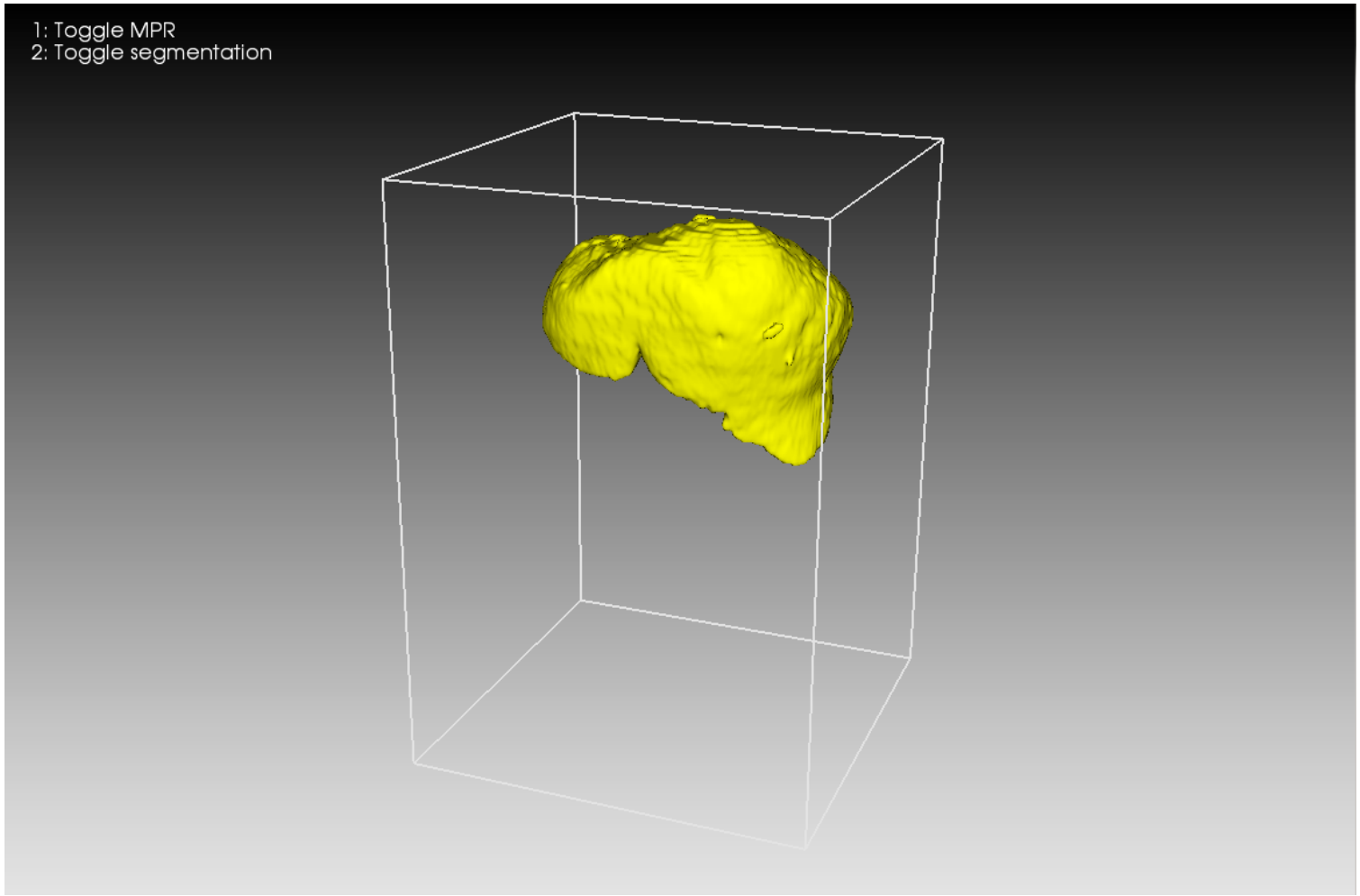
Multi-planar reformatting (MPR)



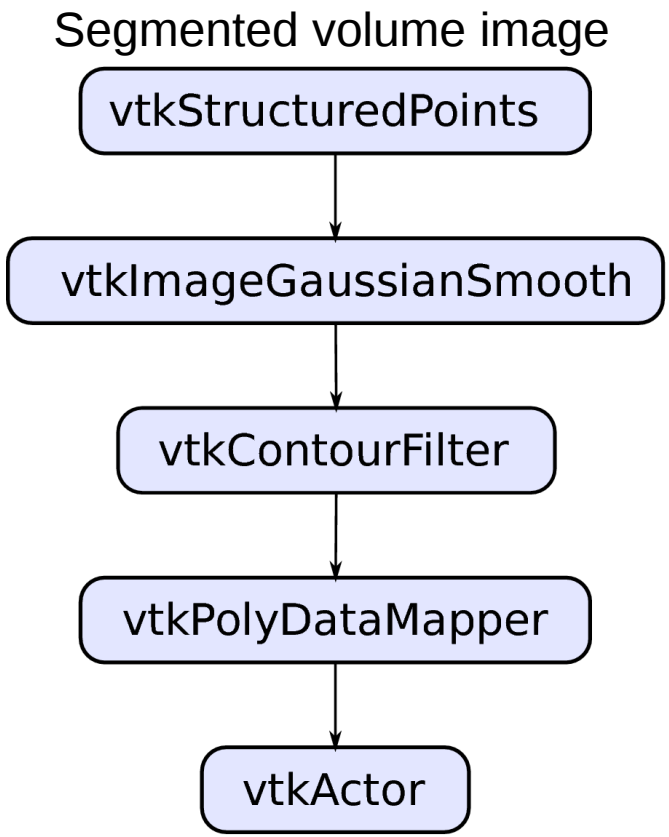
Multi-planar reformatting (MPR)



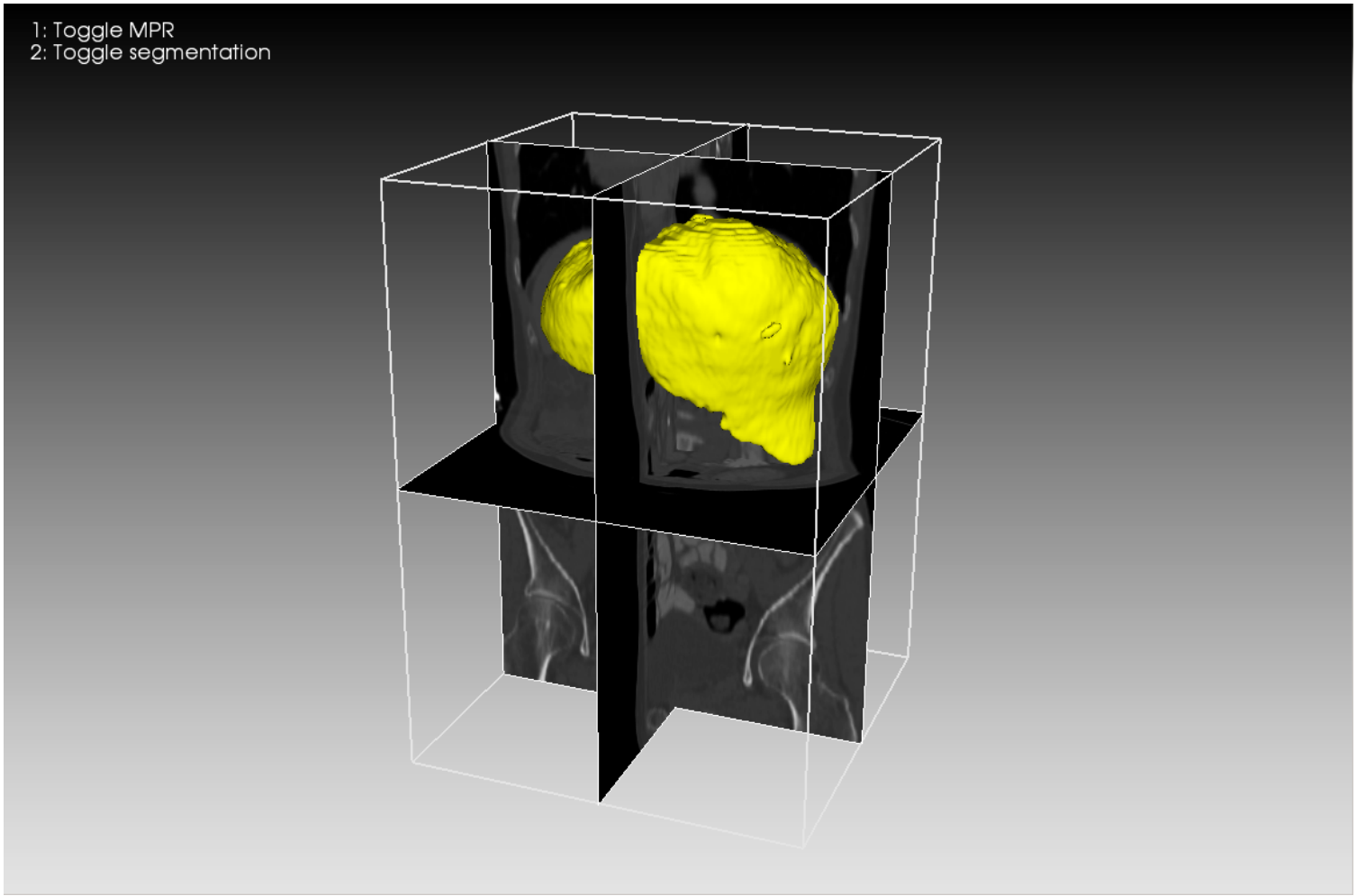
Surface rendering



Surface rendering

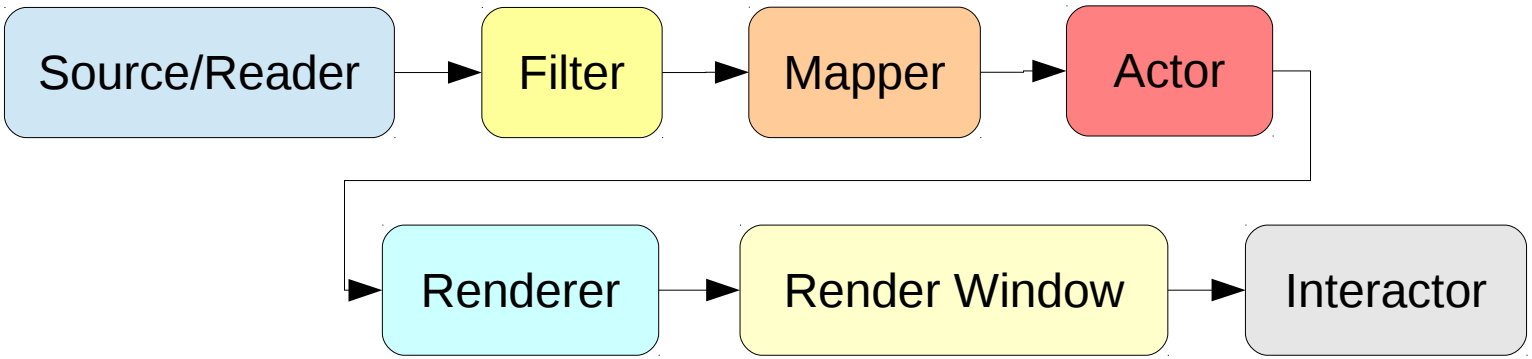


Combined visualization



VTK - Summary

- VTK contains thousands of classes and might seem a bit overwhelming...
  - however, one can create useful visualizations with just a few core classes
- The pipeline is typically

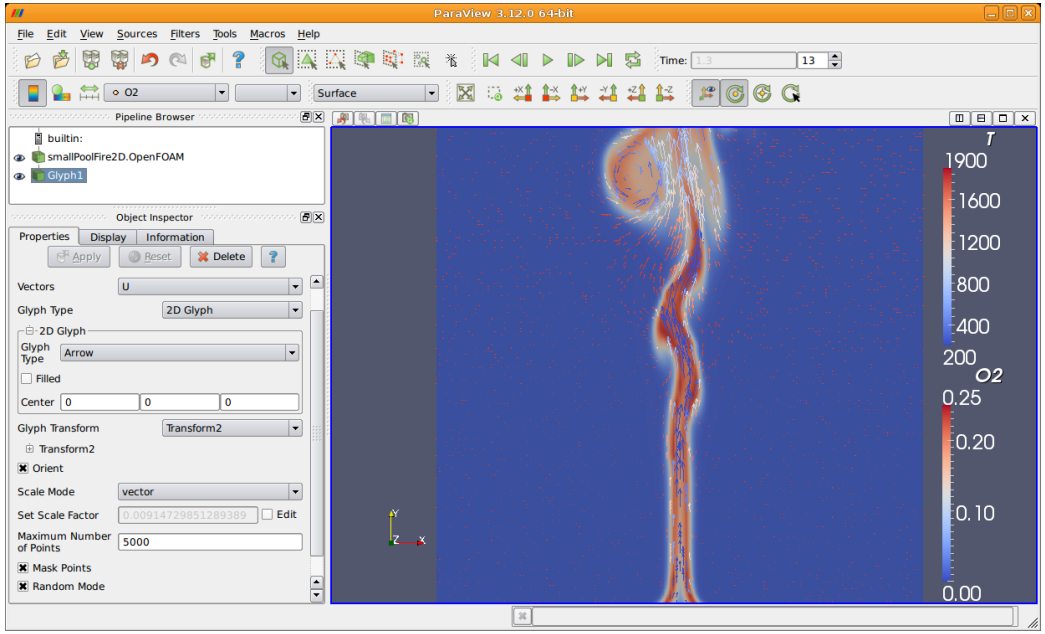


- In this course, we will use Paraview (instead of VTK directly) to create our visualisations.

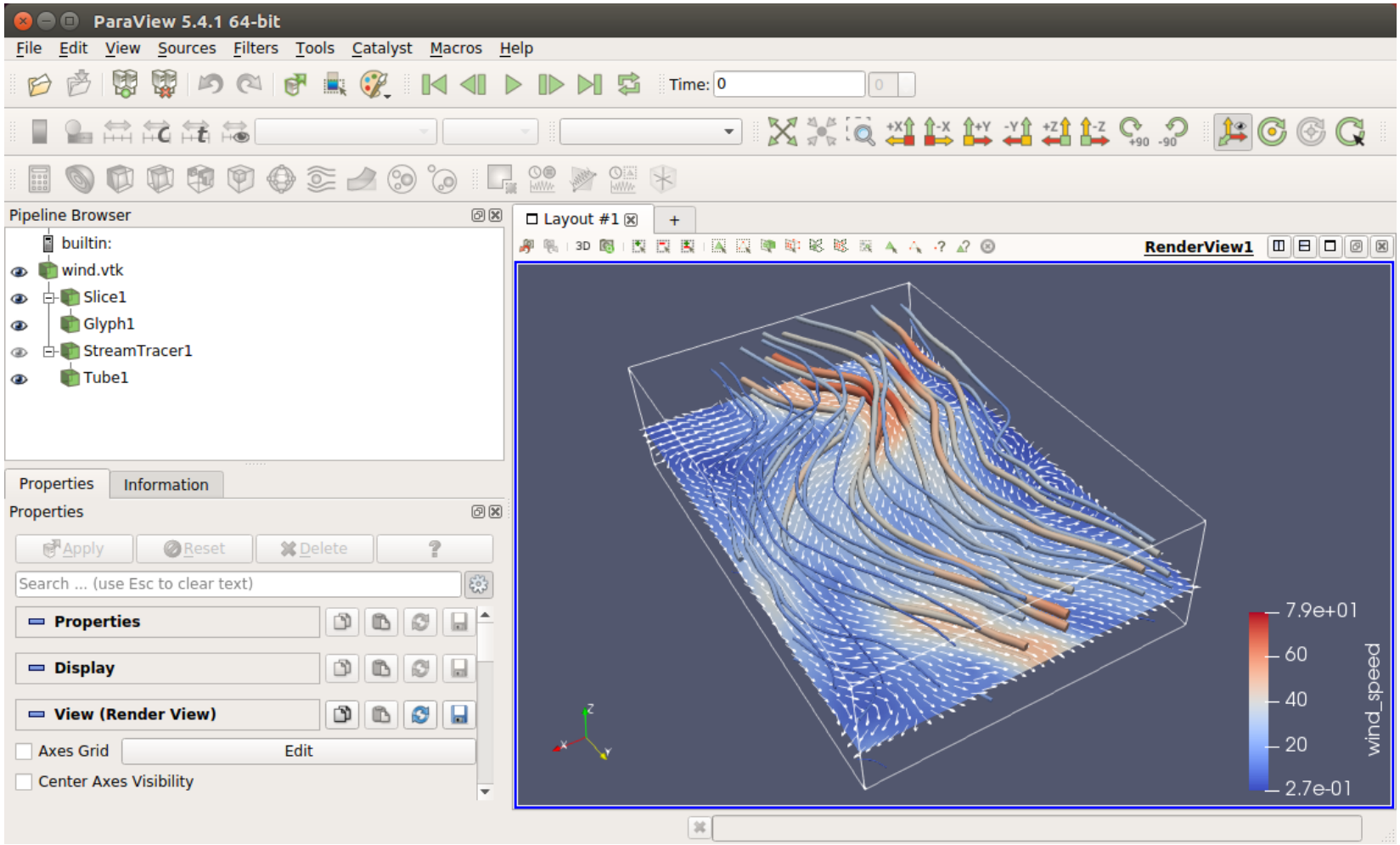
ParaView

Paraview

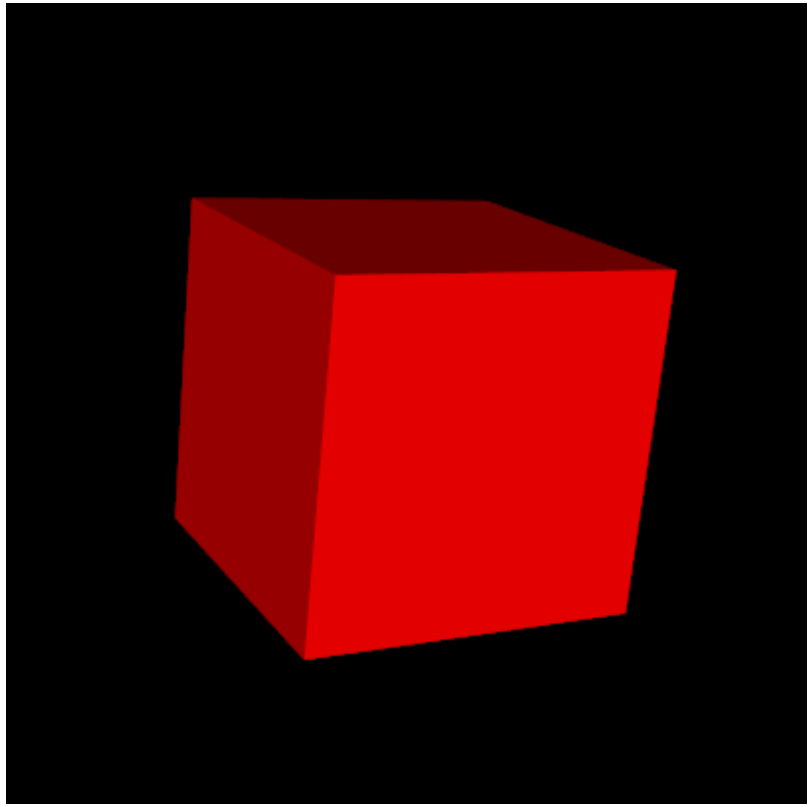
- Free data visualization tool built on VTK
- Useful for trying out different visualization techniques (without writing a single line of code)
- Links:
  - http://www.paraview.org/



The Paraview GUI



Simple example: Rendering a cube (again)



Rendering a cube

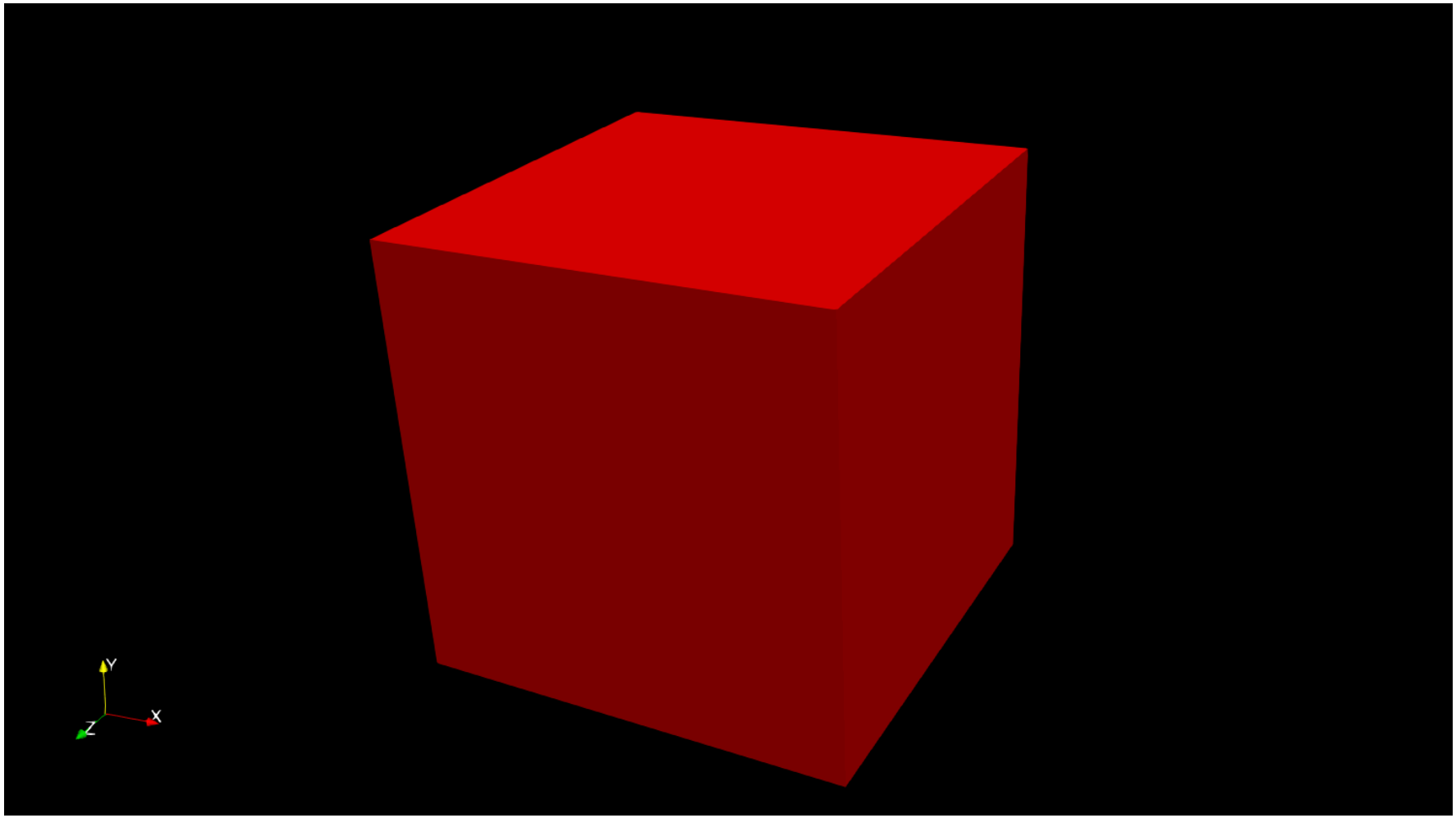
- In VTK

```python
import vtk

# Generate polygon data for a cube
cube = vtk.vtkCubeSource()

# Create a mapper and an actor for the cube data
cube_mapper = vtk.vtkPolyDataMapper()
cube_mapper.SetInputConnection(cube.GetOutputPort())
cube_actor = vtk.vtkActor()
cube_actor.SetMapper(cube_mapper)
cube_actor.GetProperty().SetColor(1.0, 0.0, 0.0)  # make the cube red

# Create a renderer and add the cube actor to it
renderer = vtk.vtkRenderer()
renderer.SetBackground(0.0, 0.0, 0.0)  # make the background black
renderer.AddActor(cube_actor)

# Create a render window
render_window = vtk.vtkRenderWindow()
render_window.SetWindowName("Simple VTK scene")
render_window.SetSize(400, 400)
render_window.AddRenderer(renderer)

# Create an interactor
interactor = vtk.vtkRenderWindowInteractor()
interactor.SetRenderWindow(render_window)

# Initialize the interactor and start the rendering loop
interactor.Initialize()
render_window.Render()
interactor.Start()
```

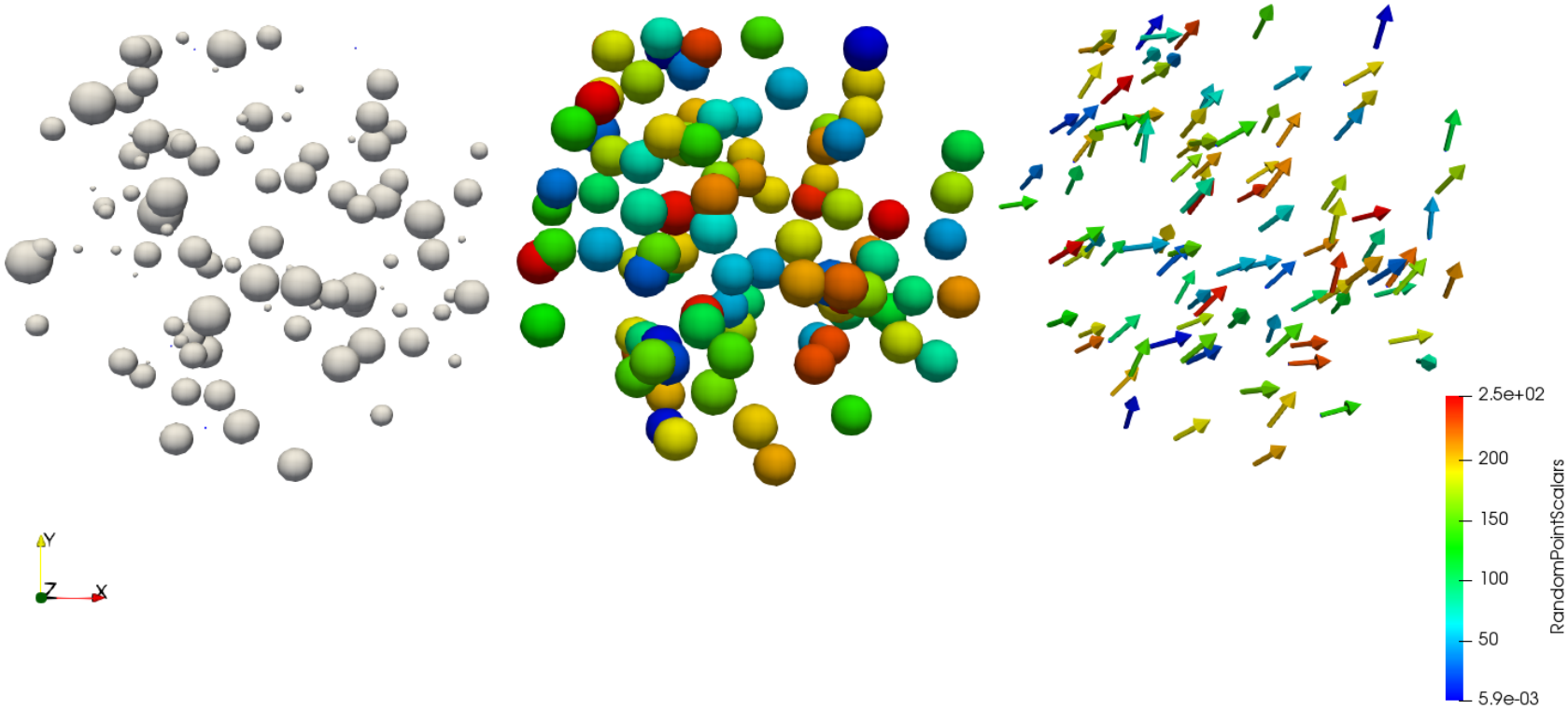
- In Paraview

1. Go to the **Sources** menu
2. Select **Box**
3. Go to the **Properties** panel and change the color under **Coloring->Edit**
4. Done :)

Demo 1: Cube

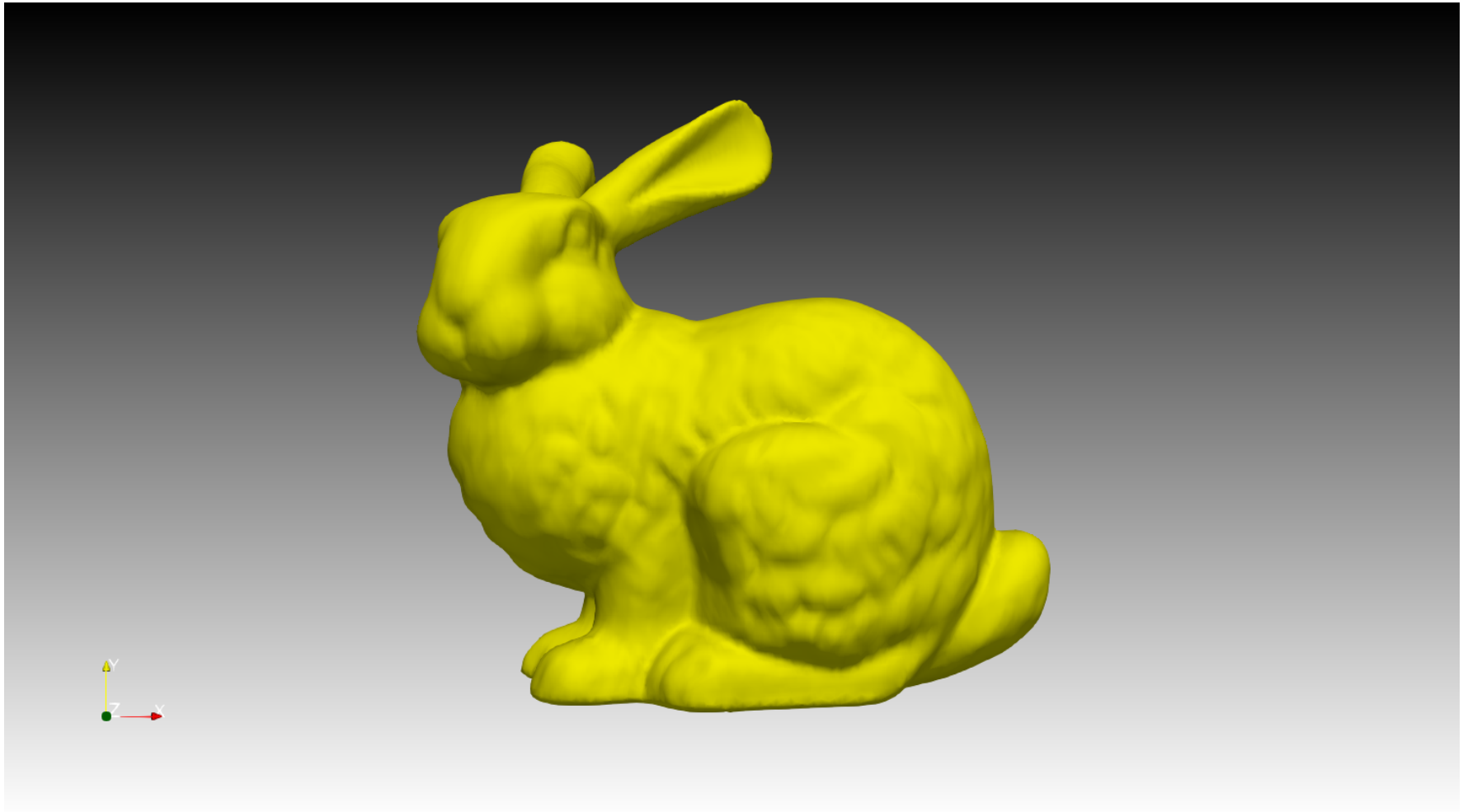


Demo 2: Glyphs

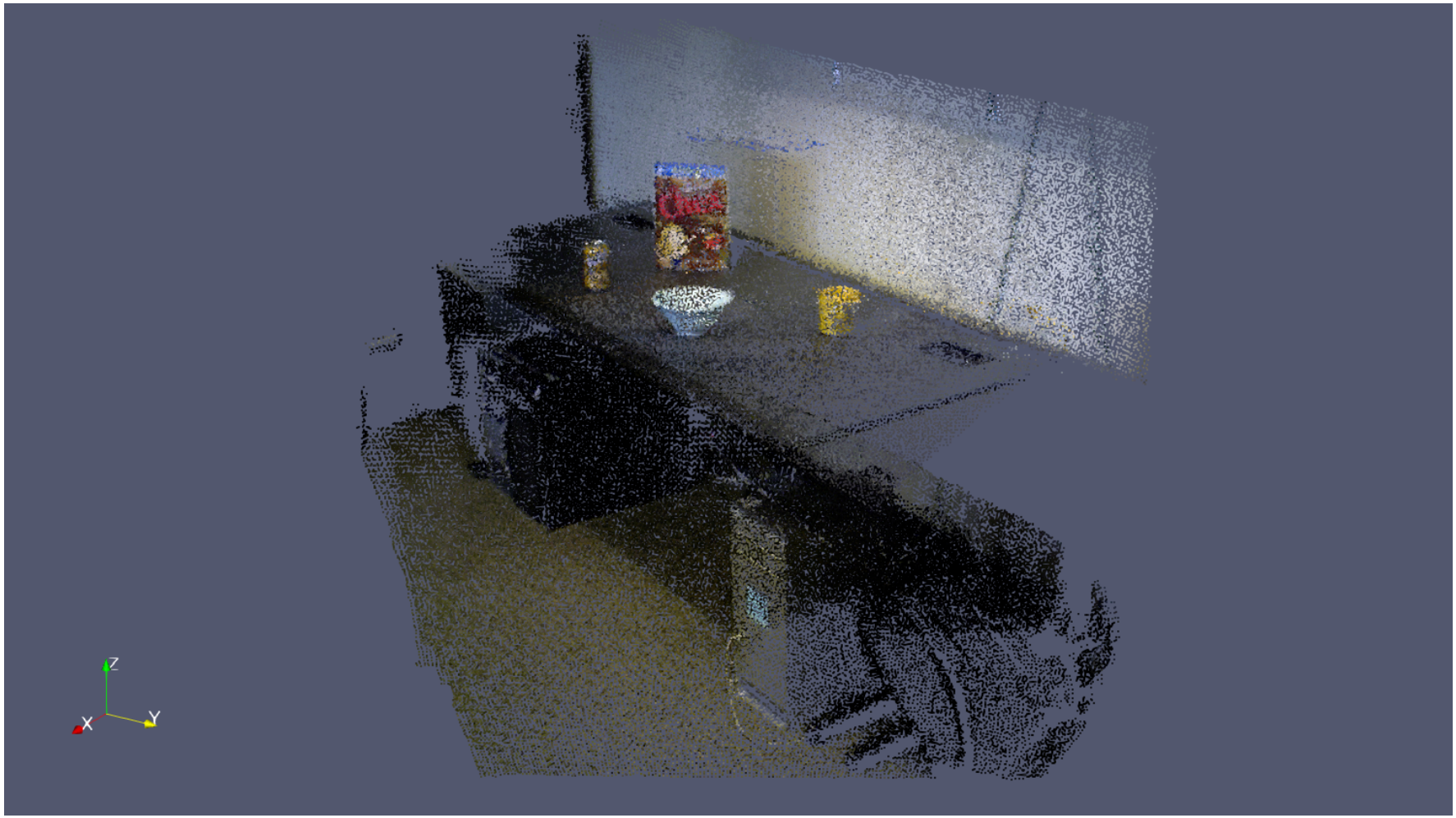


Demo 3: Transparency

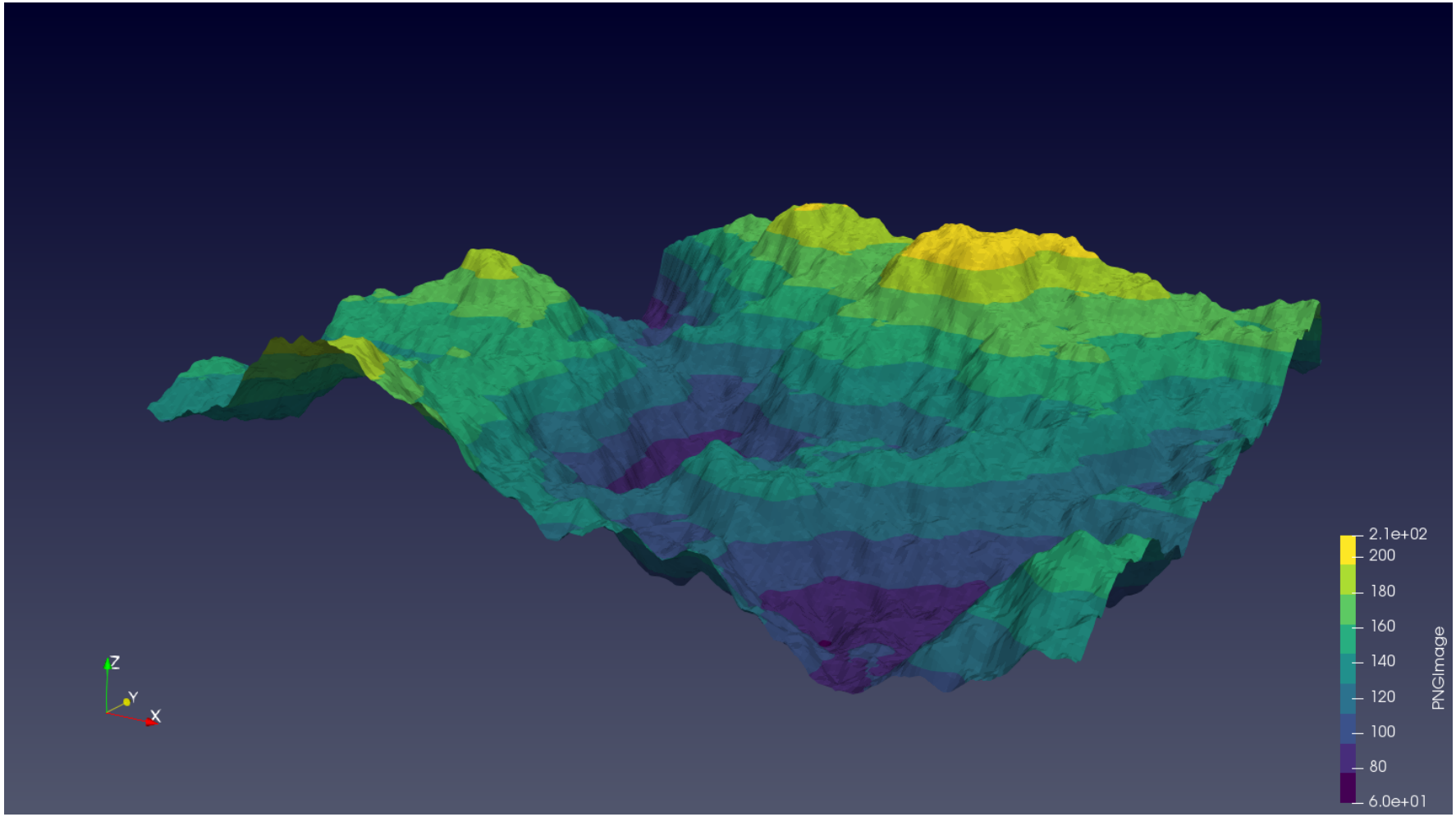
Demo 4: 3D model



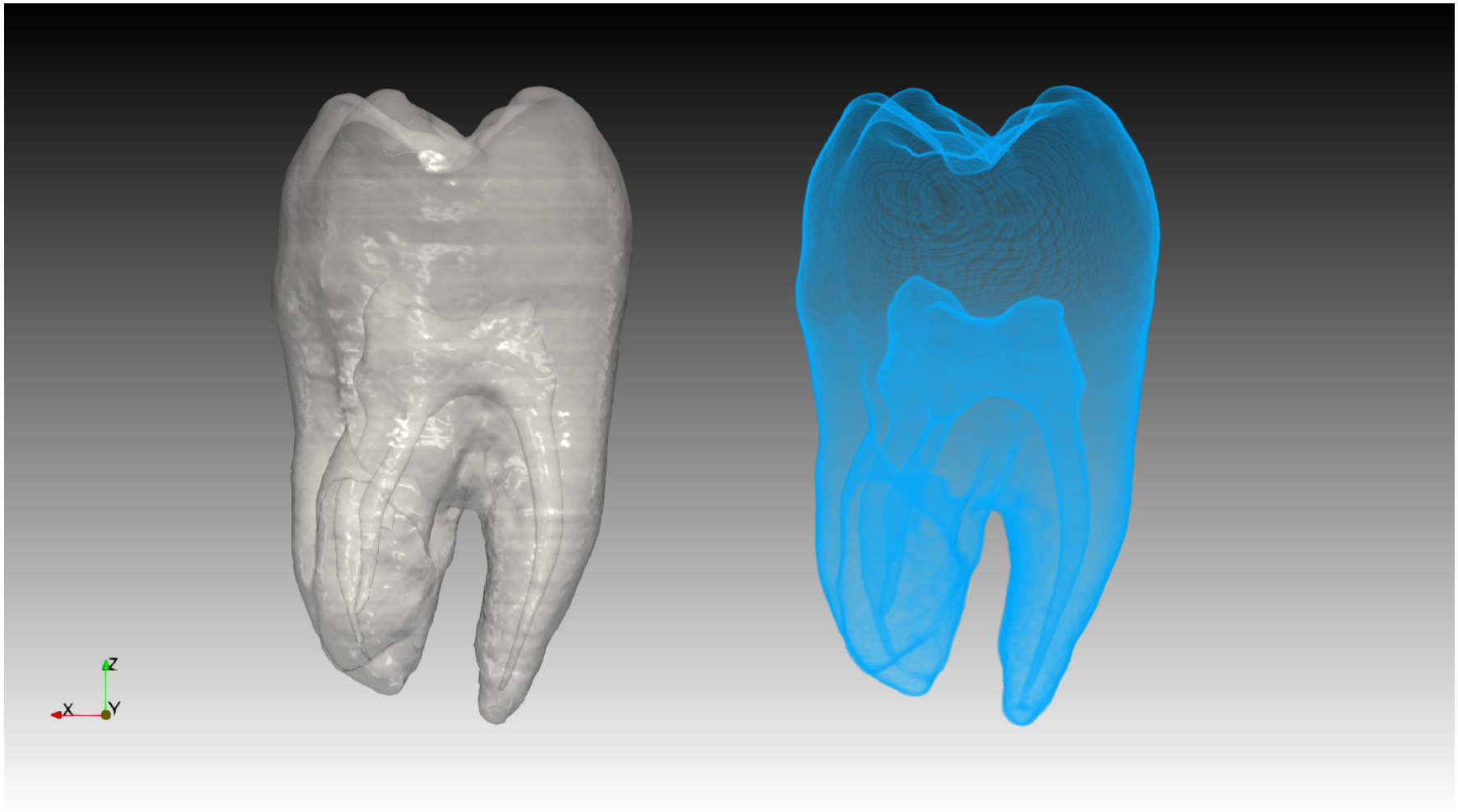
Demo 5: Point cloud



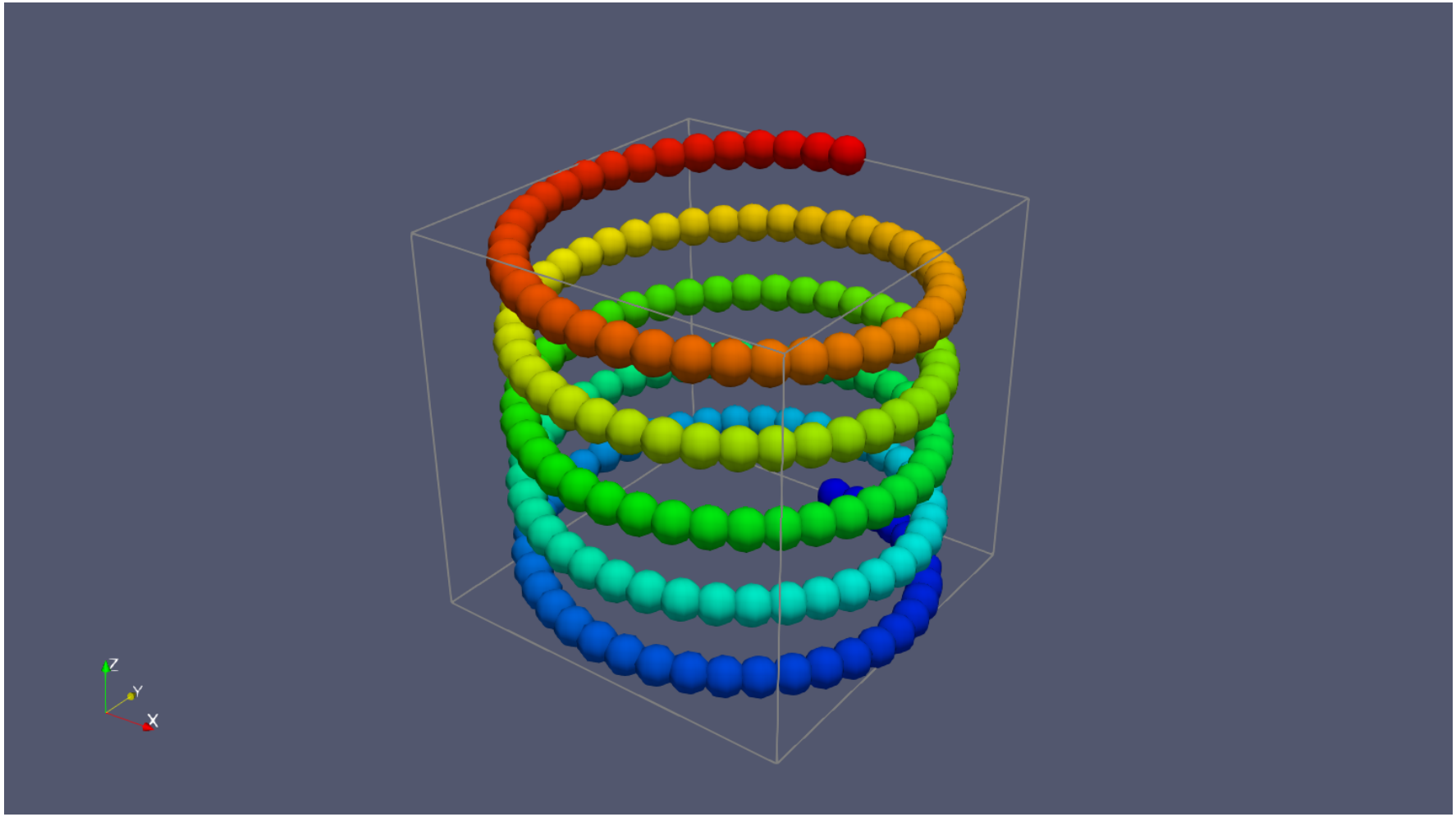
Demo 6: Height map



Demo 7: Volume rendering (CT)



Demo 8: Animation



About the assignments

- Two assignments (in Paraview)
- No project this year!
- The lab sessions will be in PC-lab 1312 and 1313
- For the assignments, you may work individually or in pairs
- Paraview 5.4.1 is installed on the lab PCs
- We highly recommend that you also install the software on your own computer!

See you on the first lab!