Scientific Visualization with Open Source Tools

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Visualization is Communication
Challenges of Visualization
Challenges of Visualization

- Heterogeneous data
- Large/many/big data
- Distributed data
- Computing resources
- Domain-specific
- User-specific
- Heterogeneous devices
- Uncertainties
HOW TO OVERCOME THESE CHALLENGES
The Visualization Toolkit (VTK)

- www.vtk.org
- Started in 1993 at GE
- Visualization Library
  - Written in C++ (+5.5 million LOC) – BSD License
  - Automatic binding for Java, TCL, Python
  - Portable by design: Linux, Windows, Mac OSX, Solaris...
- Very active community: 4000+ users on the mailing list
What can VTK do for me?

• Sci Vis: 2 to 4D data processing and (volume) rendering
• Image processing
• Info Vis (0D)
• Charting/plotting
• Application support (GUI support, Widgets)
Design Philosophy

• Underlying theme is to **process data**
  • Find the salient features
  • Produce imagery that conveys meaning

• An open-ended architecture used to **construct programs**
  • These programs usually give interactive controls to the user
  • Let the end user do the searching, **visually**

• Modular architecture
  • Modules implemented in Object-Oriented Classes
  • Pipeline: Data flows through modules in a pipeline
  • Lazy evaluation: Only process what is changed (for big data)
VTK Main Components

• **Data structures**
  • How VTK stores/provides access to arbitrary data

• **Algorithms/filtering pipeline**
  • Manipulate data
  • Readers, sources, filters, writers, mappers

• **Rendering classes**
  • Display that data on the screen
  • Mappers, actors, lights, cameras, renderers, RenderWindows

• **Interaction classes**
  • Events, interactors, widgets

• **Application support**
  • Views, representations, Qt and MFC interfaces, wrapping
VTK Main Components

• **140 Readers**
  - STL, EnSight, TecPlot, BMP, JPEG...

• **150 Filters**
  - Contour, Subdivision, Delaunay, Elevation...
  - Statistics, Parallel, Geometry, FlowPaths, Extraction...

• **40 Widgets**
  - Distance, Angle, Plane, Seed, Checkerboard

• **Application domains**
  - Geo visualization
  - Chemistry
  - Imaging
2D: Graphs and Charts
Interactive Widgets
```python
# Load an STL File
reader = vtk.vtkSTLReader()
reader.SetFileName("myfile.stl")

# Visualization Pipeline
mapper = vtk.vtkPolyDataMapper()
mapper.SetInputConnection(reader.GetOutputPort())

actor = vtk.vtkActor()
actor.SetMapper(mapper)

# Create a rendering window and renderer
ren = vtk.vtkRenderer()
renWin = vtk.vtkRenderWindow()
renWin.AddRenderer(ren)

# Create a renderwindowinteractor
iren = vtk.vtkRenderWindowInteractor()
iren.SetRenderWindow(renWin)

# Assign actor to the renderer
ren.AddActor(actor)

# Enable user interface interactor
iren.Initialize()
iren.Start()
```
Volume Rendering
Visible Patient extracts the 3D models of patient
LARGE DATA VISUALIZATION
ParaView

- www.paraview.org
- OpenSource (BSD)
- Based on VTK
- C++/Qt
- Cross-platform: Linux, Mac, Windows
- Python support
- Very active community (HPC Wire Award)
- Multi-core support (MPI)
- Co-processing (in-situ)
- More than 50 data readers
General Purpose Tools

- EnSight
- ParaView
- VisIt
- FieldView
- TecPlot
- ...

[Diagram showing various tools and visualization interfaces]
ParaView

- An application and an architecture to visualize and analyze massive datasets
- A turn-key visualization application

1 billion cell asteroid detonation simulation
½ billion cell weather simulation
Fire simulation
ParaView is a Framework

- ParaView extends VTK to provide:
  - Client-server computing
  - State management
  - Python modules
  - Application/GUI framework
- ParaView framework can be used to develop other applications
- ParaView can be embedded in other applications and frameworks
ParaView Architecture

- Render Server
- Data/Compute Server
- Client

Communication Protocols:
- MPI
- TCP/IP and/or SSH
Large Data - Unstructured

- CFD simulation
- 20-30 million elements
- Load balancing
Large Data - Unstructured

- Fire simulation
- 150 million elements
Large-scale AMR
ParaView in Use: Immersive Visualization
Co-Processing/InSitu with ParaView Catalyst
try: paraview.simple
except: from paraview.simple import *

for idx in range(1, 100):
    reader = Read(FileName='e%d.dat' % idx)

DataRepresentation3 = Show()

Contour2 = Contour()
Contour2.ContourBy = ['POINTS', 'Density']
Contour2.Isosurfaces = [2.5850499793887138]

DataRepresentation4 = Show()

Render()

SaveImage("contour%d.png" % idx)
SOME OTHER TOOLS...
ParaViewWeb - Collaboration
Web Visualization – vtkWeb/ParaViewWeb

- http://www.webviz.org
- No plugin
- Works on all devices and browsers
- Instant visualization (fast loading)
- Fully interactive visualization
Mobile Visualization: VES/VTK
Tangelo

- http://tangelo.kitware.com
- Web framework
- HTML5 web architecture
- Packages several other frameworks too
  - Bootstrap, D3, Vega, MongoDB
- Facilitates development & deployment of web apps
Digital Pathology

- https://slide-atlas.org/
VTKWeb and Open Chemistry

http://data.openchemistry.org/
Benefits of Open-Source

• Extended support
  • The Visualization Toolkit: ~$100M
• Active maintenance
  • Community-supported
• Access to expertise
• Reduce costs
  • Development
  • Maintenance
  • Evolution
  • No licensing fee
Thank You!

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