DATA FOR TUTORIAL

- [website](https://www.kitware.com/Customers/IEEEVIS09)
- username=password="IEEEVIS09"
- multicomb_0.vts

- DataSet is part of ParaViewData, which is available from www.paraview.org
Why?

• Run in Batch mode
  – Set up Vis task on small dataset locally
  – Repeat with real data on supercomputer
• Interface ParaView with other tools
• Scripted tasks in GUI
• Rapid Prototyping
• Script arbitrary parallel processing tasks
  – Not just visualization
  – A parallel interpreted programming environment
  – Manipulate individual values in huge data sets
ParaView Architecture

VTK Pipeline, in parallel, on remote server(s),

controlled by and feeds into client application.
ParaView Scripting

VTK Pipeline, in parallel, on remote server(s),

controlled by and feeds into python script.
ParaView Scripting

VTK Pipeline, in parallel, on remote server(s), controlled by and feeds into python script.
Proxies, Properties

- Client makes Proxies to control remote objects
- Proxies that control filters are called SourceProxies
- Proxies’ Properties call specific methods on those objects

```cpp
aVtkContourFilter->SetValue(0.0);
aContour.ContourValues = [0.0]
```
How it Works

• Python wrapping of VTK
  – All public methods* of concrete classes callable
  – Unfortunately, can only call them on objects that live on client

• Python wrapping of ServerManager (SM)
  – vtkServerManager library is what allows client to control remote
    vtkSMSourceProxy, vtkSMProperty, etc
  – At this level you can control things on server

• Layered modules on top of wrapping simplify life
  >>> import paraview (deprecated, PV <= 3.2 )
  >>> from paraview import servermanager (deprecated, PV <= 3.4)
  >>> from paraview.simple import * (New and Improved! PV >= 3.6)

* That do not take pointer arguments, are not within //BTX ... //ETX, and are not in manually excluded files
WARNING!

• ParaView evolves quickly
  – 3.6.2 Trace
  – create python scripts that track GUI actions
  – then look at the script to see how to do X
  – most of this talk is lower level than you need

  – But it helps you understand the scripts
• Shell within GUI
  – Tools->Python Shell
  – Fixed to same server that GUI is connected to

• Any python interpreter
  – Set PATHS to include ParaView libraries (bin and Utilities/VTKPythonWrapping)

• pvpython
  – python interpreter that comes with ParaView
  – Paths are set automatically

• pvbatch
  – MPI pvpython
  – Made to run on supercomputer
  – Can not interact with it, must give it filename of a script to run
  – Can not change server (no TCP) it actually runs inside the server

• All: Start script with “>>> from paraview.simple import *”

  WARNING! None have event loop -> No mouse, just good old command line
Using External Interpreter

- Mac/Linux

```
% set PVBUILD=/Builds/ParaView/devel/build
% export PATH=${PATH}:${PVBUILD}/bin
% export LD_LIBRARY_PATH=${LD_LIBRARY_PATH}:${PVBUILD}/bin
% export PYTHONPATH=${PVBUILD}/bin:
% export PYTHONPATH=${PYTHONPATH}:${PVBUILD}/Utilities/VTKPythonWrapping
```

- Windows

Start->Control Panel->Performance and Maintenance ->
   System->Advanced->Environment Variables

Add new user variable PVBUILD C:\Builds\ParaView\devel\build
Add/Edit user variable PATH %PVBUILD%\Debug\bin
Add/Edit user variable PYTHONPATH %PVBUILD%\Debug\bin;
Edit user variable PYTHONPATH %PVBUILD%\Utilities\VTKPythonWrapping
Where to Start?

- build a pipeline by creating SourceProxies*
- Use properties to inspect and change the filter’s settings
- Properties are often assigned at instantiation

```python
>>> myCone = Cone()
>>> print myCone.Center
>>> myCone.Center = [10,10,10]
>>> aDuplicateCone = Cone(Center=[10,10,10])
```

* SourceProxy – ParaView term for any reader, procedural generator, filter, or writer
Getting Help

- `help(paraview.simple)`
  - lists all functions that `paraview.simple` gives you
  - Includes names and descriptions of all SourceProxies

- `help(Cone)`
  - gives top level information about Cones (the class)

- `help(myCone)`
  - gives more details (ex properties you can access) when you give it a particular Cone (the object)

- `dir(myCone)` compact and sometimes more complete alternative
- `print(myCone)` sometimes gives more details about member values
About Properties

• Properties are python-esque
  ```python
  >>> myCone.Center = [0,0,0]
  >>> myCone.Center[0] = [1]
  >>> myCone.Center[2:3] = [2,3]
  >>> myCone.Radius = 2.0
  >>> Show(myCone)
  >>> Render()
  >>> myCone.Radius = 0.1
  >>> #!? Why no change?
  >>> Render()
  ```

• VTK and ParaView are lazily evaluated. You don’t see results until you tell Pipeline to run
Building a Pipeline

• Like in GUI, build on top of the “Active” source

• Set Properties as you go, like editing Property Tab in GUI’s ObjectInspector

```python
>>> aReader = XMLStructuredGridReader(FileName="multicomb_0.vts")
>>> aClip = Clip()
>>> aClip.ClipType.Normal = [0,-1,0]
>>> aContour = Contour()
>>> aContour.ContourBy = "Density"
>>> aContour.Isosurfaces = [0.5]
```
Building a Pipeline

- Branch by changing the active source, like choosing in GUI’s PipelineBrowser
  ```python
  >>> SetActiveSource(aReader)
  >>> aST = StreamTracer()
  >>> aST.Vectors = "Momentum"
  >>> aSTSeedType.Center = [3,2,28]
  >>> aSTSeedType.Radius = 2
  >>> aSTSeedType.NumberOfPoints = 100
  >>> Show(aContour)
  >>> Show(aStreamTracer)
  >>> Render()
  ```

- Unlike in GUI, displays are not automatically made or refreshed
Navigating the Pipeline

- Don’t have to use active source to branch, can assign at creation
  >>> aST = StreamTracer(Input=aReader)
  >>> aST = StreamTracer()
  >>> aST.Input = aReader
  >>> aST.Input = aClip
- Can change after the fact
- Can inspect ActiveSource
  >>> aSource = GetActiveSource()
- Can get a hold of all or any particular SourceProxy
  >>> GetSources()
  >>> someSource = FindSource("Contour1")
Merging and Multiplicity

- Some SourceProxies require multiple inputs, usually named “Input” and “Source”, but not always

- Some SourceProxies have inputs that are repeatable, use array notation to assign them

- A few SourceProxies produce multiple outputs, use array notation to retrieve them

```python
>>> probe = ProbeLocation()
>>> probe.Input = Mandebrot()
>>> probe.ProbeType = Sphere()

>>> append = AppendGeometry()
>>> append.Input = [poly1, poly2]

>>> reader = GaussianCubeReader(filename="my.cube")
>>> shrink = Shrink()
>>> shrink.Input = reader[1]
```
Displaying Results

- Parallel Flexible Display Pipeline complexity encapsulated by “Representations” in “Views”
- **Representation** – visual qualities of an output
  $\approx$ Mapper + Actor + parallel transport
  Show() returns a Representation
- **View** - Visual qualities of a window
  $\approx$ Renderer + Camera + Lights +RenderWindow
  Render() returns a View
- To make it easier to build, commands default to working with the **Active Representation** and **Active View**
Controlling Display

• Change Properties of View and Representation Proxies to affect display

>>> aView = GetActiveView()
>>> help(aView)
>>> aView.Background = [0.0,0.0,0.0]

• Don’t forget lazy evaluation

>>> Render()

• Visibility is particularly important, since all pipeline stages can be shown
  Show() and Hide() shortcuts set Visibility property

>>> aRep = GetRepresentation()
>>> help(aRep)
>>> Show(aRep)
>>> Hide(aRep)
Controlling Display

• Many methods take ActiveRepresentation and ActiveView as default arguments

```python
>>> clipFiltersRepInMyView = GetDisplayProperties(aClip, myView)
>>> clipFiltersRep = GetDisplayProperties(aClip)
>>> activeSourcesRep = GetDisplayProperties()
```  

• But can get hold of and then control any View and Representation

```python
>>> GetRenderViews()
>>> view0 = GetRenderViews()[0]
>>> allReps = view0.Representations()
>>> rep0_0 = allReps[0]
```
Camera

- RenderViews (not PlotViews etc) have Cameras
- View has properties to manipulate them

```python
>>> view0.CameraPosition
>>> view0.CameraPosition = [16,0,51]
>>> view0.CameraFocalPoint
>>> view0.CameraFocalPoint = [0,0,0]
>>> view0.CameraViewUp
>>> view0.CameraViewUp = [0,1,0]
>>> view0.CameraAngle
>>> view0.CameraAngle = 20
```
Rendering Modes

- A Representation’s *Representation* property controls rendering mode:

  Bounding Box
  Points
  Wireframe
  Polygons (surface)
  Volume Render
  etc

Python code examples:

```python
>>> aRep = Show(aClip)
>>> aRep.GetProperty("Representation").Available
>>> aRep.Representation = ‘Outline’
>>> Render()
>>> aRep.Representation = ‘Points’
>>> Render()
>>> aRep.Representation = ‘Wireframe’
>>> Render()
>>> aRep.Representation = ‘Surface With Edges’
>>> Render()
>>> aRep.Representation = ‘Surface’
>>> Render()
```

* Yes terminology is confusing, so top level is often called “Display Property” or “Display Pipeline”
Color Mapping

• Representations have LookupTables that assign colors to values
• MakeBlueToRedLT(min,max) is a convenient way to make one

• You can design your own if you need to:
  Pick an array to color with
  Pick the value ranges
  Pick the colors

```python
>>> aRep.ColorArrayName = 'Density'
>>> aRep.LookupTable= MakeBlueToRedLT(0,1)
>>> Render()

>>> aRep.ColorAttributeType='POINT_DATA'
>>> aRep.ColorArrayName="Density"
>>> lut = servermanager.rendering.PVLookupTable()
>>> aRep.LookupTable = lut
>>> # value, R,G,B
>>> lut.RGBPoints = [  0.0, 0.0, 0.0, 1.0,
                      0.1, 0.5, 0.0, 0.5
                      1.0, 1.0, 0.0, 0.0]
```
Getting information

• ParaView has a client server architecture, and is lazily evaluated (designed for large data)
• You have to ask ParaView politely when you need results back from server (other than display)

• Three ways ways to get quantitative results back
  – Information properties
  – DataInformation
  – Fetch
Information Properties

• Properties
  Most VTK methods on server set parameters
  `SetFileName()`, `SetContours()`

• Information Properties
  Some VTK methods return simple results
  `GetFileName()`, `GetNumberOfPoints()`

Information Properties let the client read these results

```python
>>> aReader.FileName = "multicomb_0.vts"
>>> print aReader.FileName
foo.ex2
>>> #does not ask server, just remembers
>>> #what we set
```

```python
>>> aReader.UpdatePropertyInformation()
>>> print aReader.TimestepValues
```

```python
>>> aST2 = StreamTracer(Input=aReader)
>>> aST2.UpdatePipeline()
>>> aST2.UpdatePropertyInformation()
>>> aST2.GetProperty("NumberOfPoints")
```
Data Information

- What GUI shows in Pipeline Browser’s Information Tab
- What GUI uses to assign filter default settings
- Meta-Information about output of a SourceProxy
  - CLASSNAME,
  - MEMORYSIZE,
  - EXTENT,
  - NUMCELLS, NUMPOINTS,
  - ARRAYS, ARRAY NAMES,
  - ARRAY RANGES
- Can’t get individual values out

```python
>>> aReader.UpdatePipeline()
>>> aReader.UpdatePipelineInformation()
>>> dInfo = aReader.GetDataInformation()
>>> dInfo.GetDataClassName()
>>> pdInfo = dInfo.GetPointDataArrayInformation()
>>> pdInfo.GetNumberOfArrays()
>>> ai0 = pdInfo,GetArrayInformation(0)
>>> ai0.GetName()
>>> ai0.GetNumberOfComponents()
>>> ai0.GetComponentRange(0)
>>> ai0.GetNumberOfTuples()
```
Fetch

- Copies entire DataSet from server to Client
- Once local, you can manipulate the data with python Wrapped VTK API and access individual data values
- Since data is large, don’t often want whole data set on client
- Can also do some simple aggregation of attribute values. Just specify an aggregator function to apply on the way.

```python
>>> output = servermanager.Fetch(aClip)
>>> print(output)

>>> processor1sOutput = servermanager.Fetch(aClip, 1)

>>> mm = MinMax()
>>> mm.Operation = "MIN"
>>> minResult = servermanager.Fetch(elev, mm, mm)

>>> a0 = minResult.GetPointData().GetData().GetArray(1)
>>> a0.GetName()
>>> a0.GetValue(0)
```
Now that you know…

• Choosing a server
  Disconnect from one server (destroying pipeline there) and connect to another.
  >>>> Connect(host, portnum)
  >>>> Help(Connect)

• Writers
  Save output of any SourceProxy on server’s file system
  >>>> writer =XMLUnstructuredGridWriter()
  >>>> writer.FileName = “foo.pvtk”
  >>>> writer.Input = aClip
  >>>> writer.UpdatePipeline()
Features I’m skipping

• Screen Shots
  >>> WriteImage(filename, view==ActiveView, Magnification==0.0)

• Animation
  Create key frames in tracks and automatically animate through them. Like GUI’s Animation View
  >>> scene = servermanager.animation.AnimationScene()
  >>> track1 = servermanager.animation.KeyFrameAnimationCue()
  >>> keyframe1 = servermanager.animation.CompositeKeyFrame()
  >>> track1.KeyFrames = [keyframe1, keyframe2]
  >>> scene.Cues = [track1]

• Movies
  Save as series of screenshots or into a movie file*
  >>> AnimateReader(reader, view, “myMovie.png”)

*Assuming your ParaView has a codec, otherwise limited to numbered screenshots
Even More Features

• State
  Save state in GUI, load it in python (and vice-versa)
  >>> servermanager.LoadState("myteststate.pvsm")
  >>> SetActiveView(GetRenderView())
  >>> Render()

• Python Programmable Filter
  A white box filter
  Arbitrary scripted parallel processing
  Numerous examples on wiki
Python Programmable Filter

runs inside a filter’s RequestData() on server
python wrapped VTK API
Get hold of input and output DataSet(s)
examine geometry, topology and attributes
Do some arbitrary calculation

>>> pfilter = ProgrammableFilter()
>>> pfilter.Script = ""
    pdi = self.GetPolyDataInput()
pdo = self.GetPolyDataOutput()
newPoints = vtk.vtkPoints()
umPoints = pdi.GetNumberOfPoints()
for i in range(0, numPoints):
    coord = pdi.GetPoint(i)
    x, y, z = coord[:3]
    x = x * 1
    y = y * 1
    z = 1 + z*0.3
    newPoints.InsertPoint(i, x, y, z)
pdo.SetPoints(newPoints)
"""
Getting More Help

• Wiki Page
  – http://www.paraview.org/Wiki/ParaView

• Source Code Documentation

• Mailing List
  – Sign up- >http://public.kitware.com/mailman/listinfo/paraview
  – Search ->http://markmail.org/search/?q=list:paraview

• Bug Tracker
  – Project:-> ParaView3