Scientific Visualization with ParaView

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ParaView: http://www.paraview.org/download
Code & data: https://rhpcserv.rhpcs.mcmaster.ca/~guanw/ss2015viz.zip

What is Visualization

Data → Graphical representations

```
0265640 132304 133732 032051 037334 024721 015013 052226 001662
0265660 025537 064663 054606 043244 074076 124153 135216 126614
0265700 144210 056426 044700 042650 165230 137037 003655 006254
0265720 134453 124327 176005 027034 107614 170774 073702 067274
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0266040 070176 047705 113754 175477 105532 076515 177366 056333
0266060 041023 074017 127113 003214 037026 037640 066171 123424
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0266160 040223 050170 055164 164634 047154 126525 112514 032315
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0266220 117156 030746 154234 125001 151144 163706 136237 164376
0266240 137055 062276 161755 115466 005322 132567 073216 002655
0266260 171466 126161 117155 065763 016177 014460 112765 055527
0266300 003767 175367 104754 036436 172172 150750 043643 145410
0266320 072074 000007 040627 070652 173011 002151 125132 140214
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0266500 114060 042647 104475 110537 066716 104754 075447 112254
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0266560 166410 067251 156160 106406 136770 030516 064740 022032
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0266620 075074 016744 044055 102230 110063 033350 052765 172463
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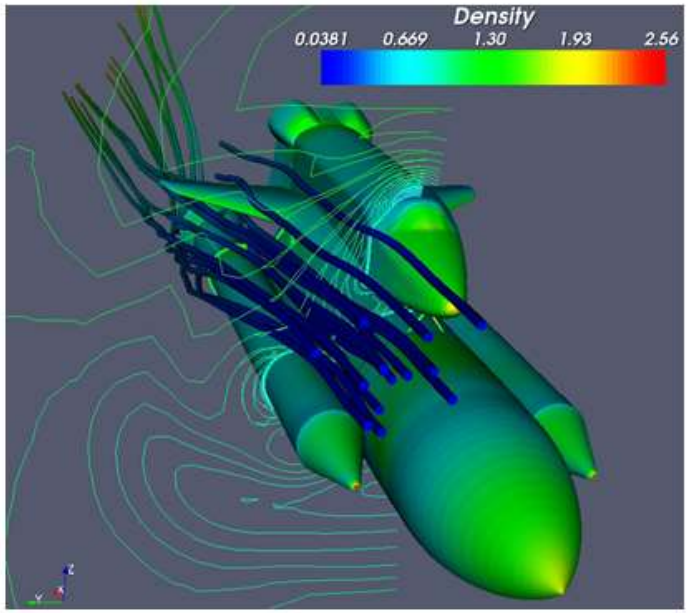

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What is Visualization used for

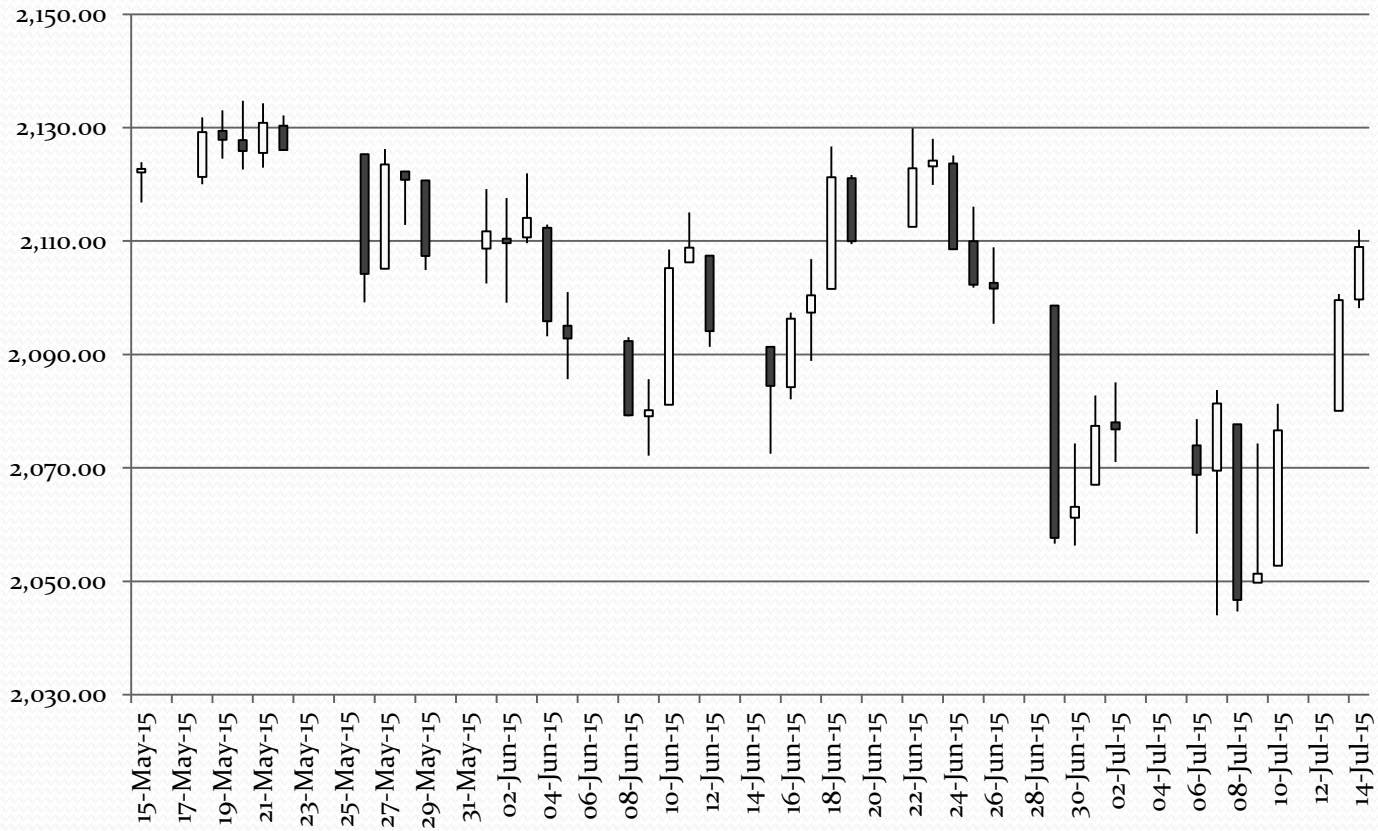
- To comprehend data
- To explore and discover
  - Patterns
  - Structures
  - Trends
- To monitor simulations
- To communicate with others

A picture is worth of thousand ~~words~~ **numbers!**

Numbers (S&P 500)

Date	Open	High	Low	Close
Jul 14, 2015	2,099.72	2,111.98	2,098.18	2,108.95
Jul 13, 2015	2,080.03	2,100.67	2,080.03	2,099.60
Jul 10, 2015	2,052.74	2,081.31	2,052.74	2,076.62
Jul 9, 2015	2,049.73	2,074.28	2,049.73	2,051.31
Jul 8, 2015	2,077.66	2,077.66	2,044.66	2,046.68
Jul 7, 2015	2,069.52	2,083.74	2,044.02	2,081.34
Jul 6, 2015	2,073.95	2,078.61	2,058.40	2,068.76
Jul 2, 2015	2,078.03	2,085.06	2,071.02	2,076.78
Jul 1, 2015	2,067.00	2,082.78	2,067.00	2,077.42
Jun 30, 2015	2,061.19	2,074.28	2,056.32	2,063.11
…	…	…	…	…

Graph (S&P 500)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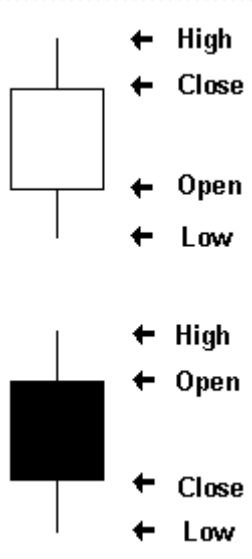
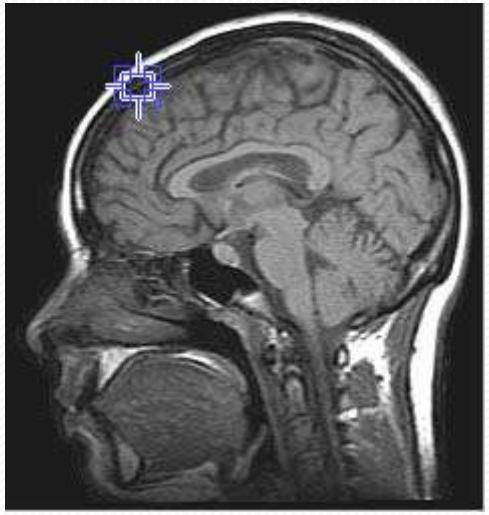
2,130.00
2,110.00
2,090.00
2,070.00
2,050.00
2,030.00
15-May-15
17-May-15
19-May-15
21-May-15
23-May-15
25-May-15
27-May-15
29-May-15
31-May-15
02-Jun-15
04-Jun-15
06-Jun-15
08-Jun-15
10-Jun-15
12-Jun-15
14-Jun-15
16-Jun-15
18-Jun-15
20-Jun-15
22-Jun-15
24-Jun-15
26-Jun-15
28-Jun-15
30-Jun-15
02-Jul-15
04-Jul-15
06-Jul-15
08-Jul-15
10-Jul-15
12-Jul-15
14-Jul-15

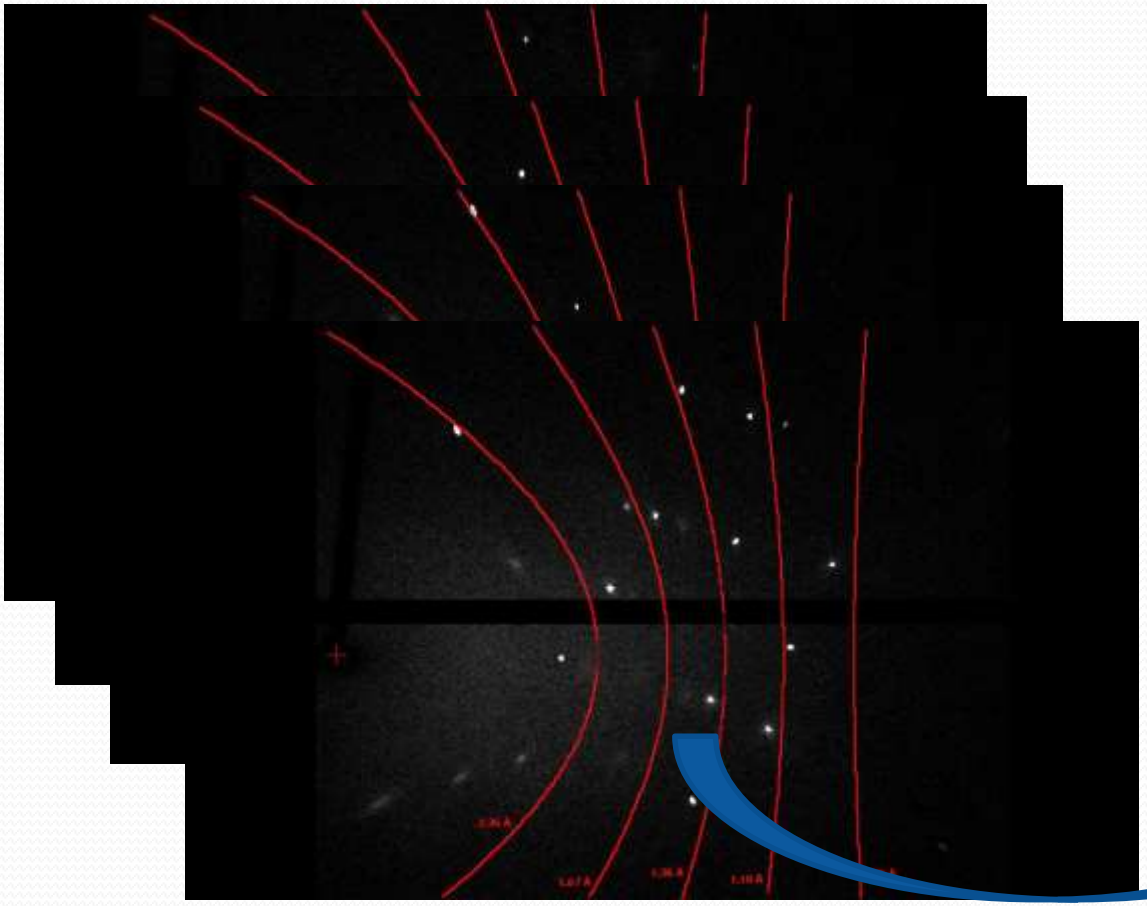

High
Close
Open
Low
High
Open
Close
Low

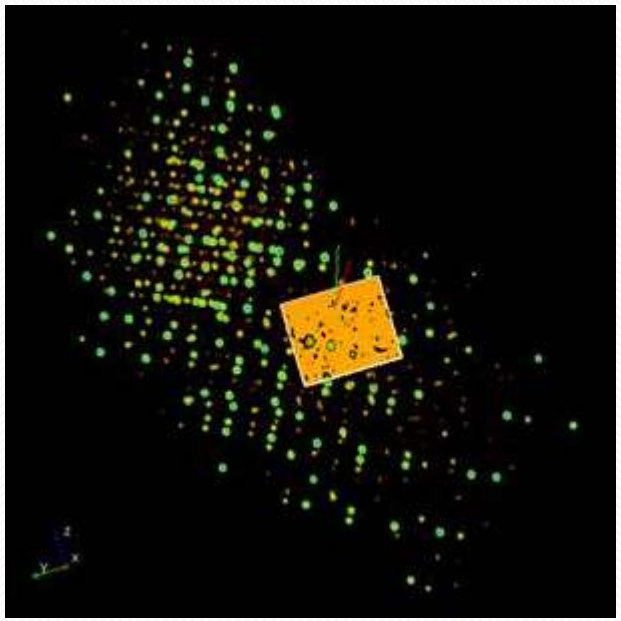
More examples

129	192	243	255	255	229	142	69	28	48	58	37	32	50	89	73
206	250	255	255	207	118	40	31	42	58	56	55	76	98	82	46
255	255	234	159	99	32	31	52	58	38	36	73	85	56	39	38
255	243	148	35	25	39	64	31	38	77	91	75	48	23	42	72
246	138	47	41	45	40	43	58	82	89	62	29	34	61	82	80
108	43	16	35	49	59	74	68	58	45	36	40	57	74	72	59
34	28	43	51	51	61	67	65	[illegible]	30	33	55	67	64	46	43
30	57	67	54	44	46	32	49	[illegible]	47	46	57	60	52	80	78
51	55	44	44	49	39	27	39	50	49	[illegible]	50	58	64	89	85
61	37	28	55	71	43	40	37	39	46	51	55	65	76	63	65
37	30	41	72	84	47	43	40	43	55	64	68	73	79	83	79

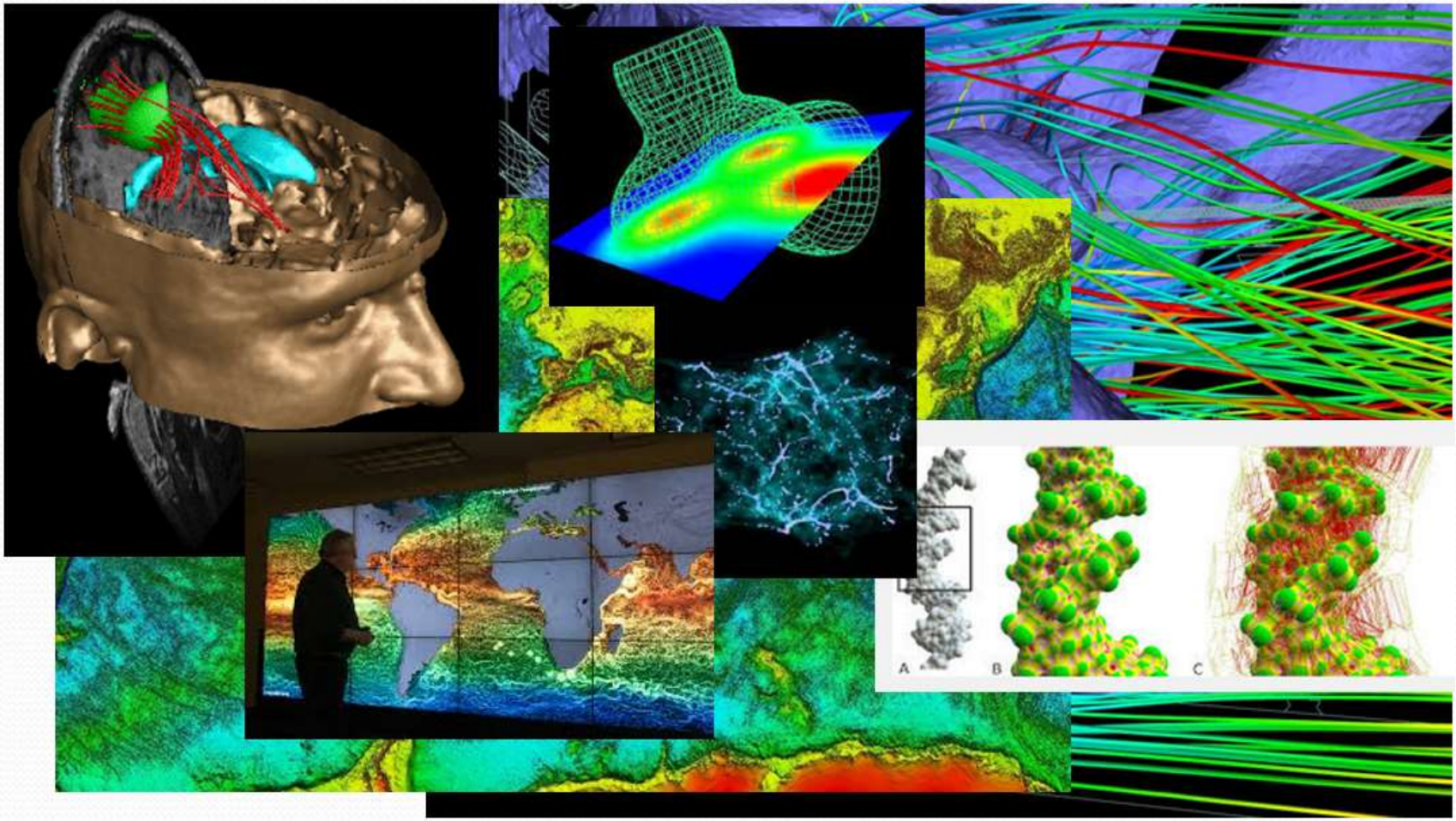


More examples





More and more examples



Sources of tutorial materials

- "The ParaView Tutorial", K. Morland
- "Large Scale Visualization with ParaView", K. Morland, et al, Supercomputing 2014
- "Scientific Visualization", Alex Razoumov, HPC Summer School 2014

NOTE: Some slices of above materials together with their scripts and data are copied and used in this tutorial.

Outline (3 hours)

- Overview of ParaView

- Basic Usage of ParaView

- Advanced Topics of ParaView

- Put It All Together






Overview of ParaView

- Introduction
  - www.paraview.org
  - Current version 4.4
  - Kitware, Los Alomas, Sandia National Labs, etc
  - Open source
  - General-purpose visualization package
  - Large user base

Overview of ParaView

- Introduction
  - Multiple platforms (Windows, Linux/Unix, MacOS)
  - Parallel visualization of large data
  - Multi-dimensional and/or Multi-variables
  - Either standalone or client/server mode
  - Rich functionalities implemented as filters
  - Many file formats
  - Various data types
  - Scripting

Overview of ParaView

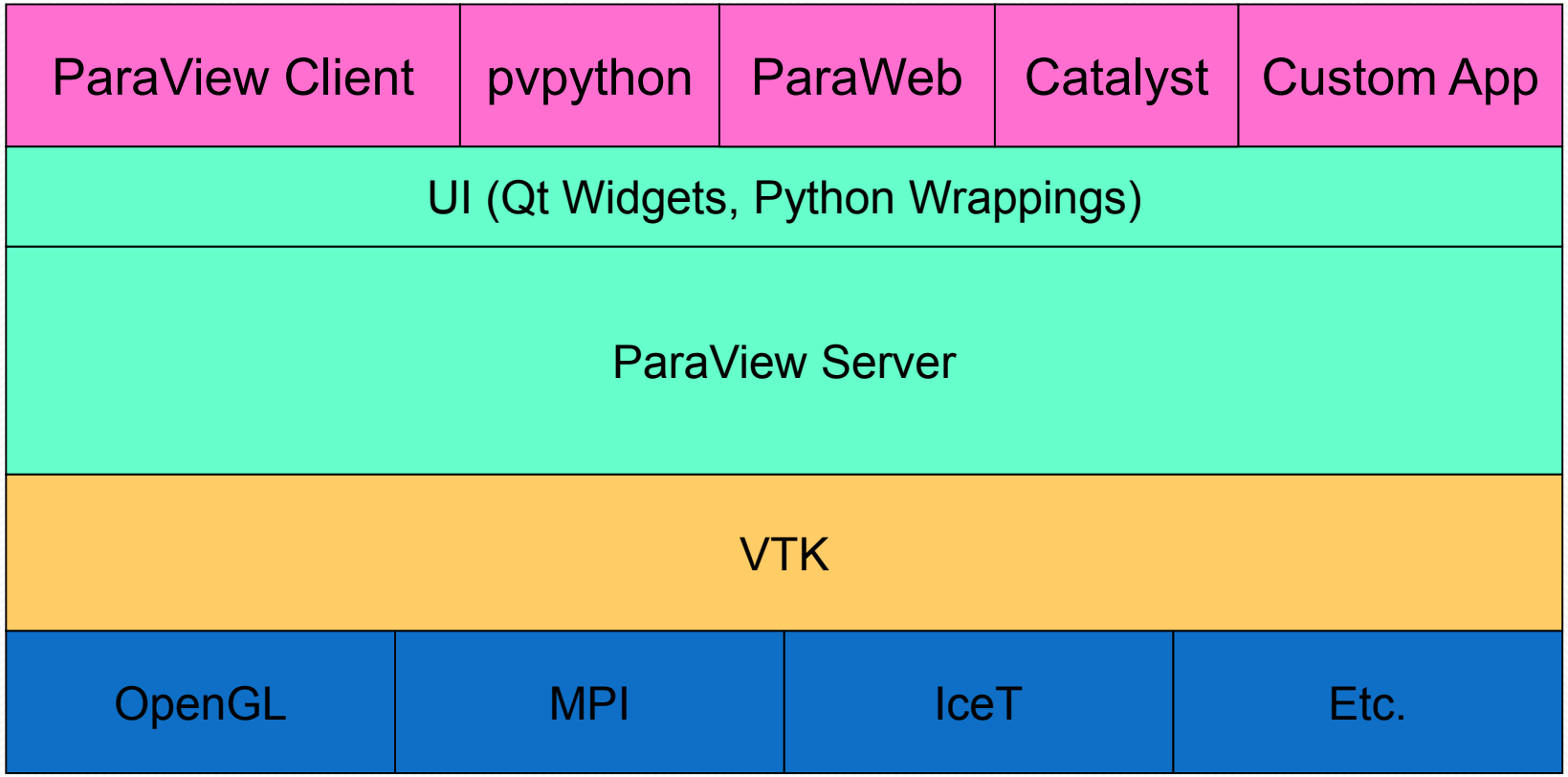
- Documentations and resources
  - Guide: http://www.paraview.org/paraview-guide
  - Wiki: http://www.paraview.org/Wiki/ParaView
  - Tutorials: http://www.paraview.org/tutorials
  - Webinars: http://www.paraview.org/webinars

Overview of ParaView

- Documentations and resources
  - Mailing lists:
    - Searchable archive: http://public.kitware.com/pipermail/paraview
    - Users: http://www.paraview.org/mailman/listinfo/paraview
    - Developers http://www.paraview.org/mailman/listinfo/paraview-developers
- Help online F1 ❓ or context-sensitive❓

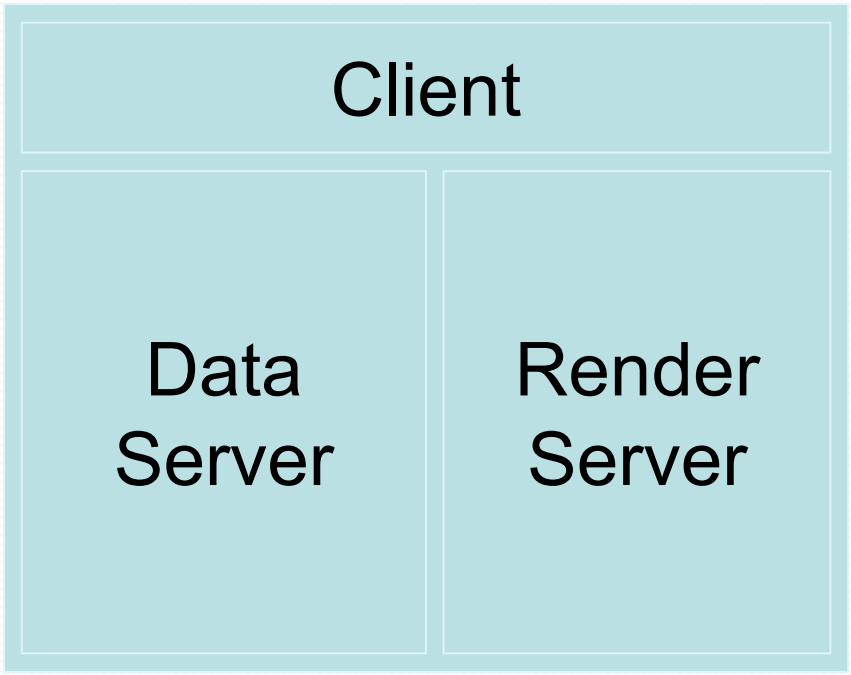
Overview of ParaView

- Architecture



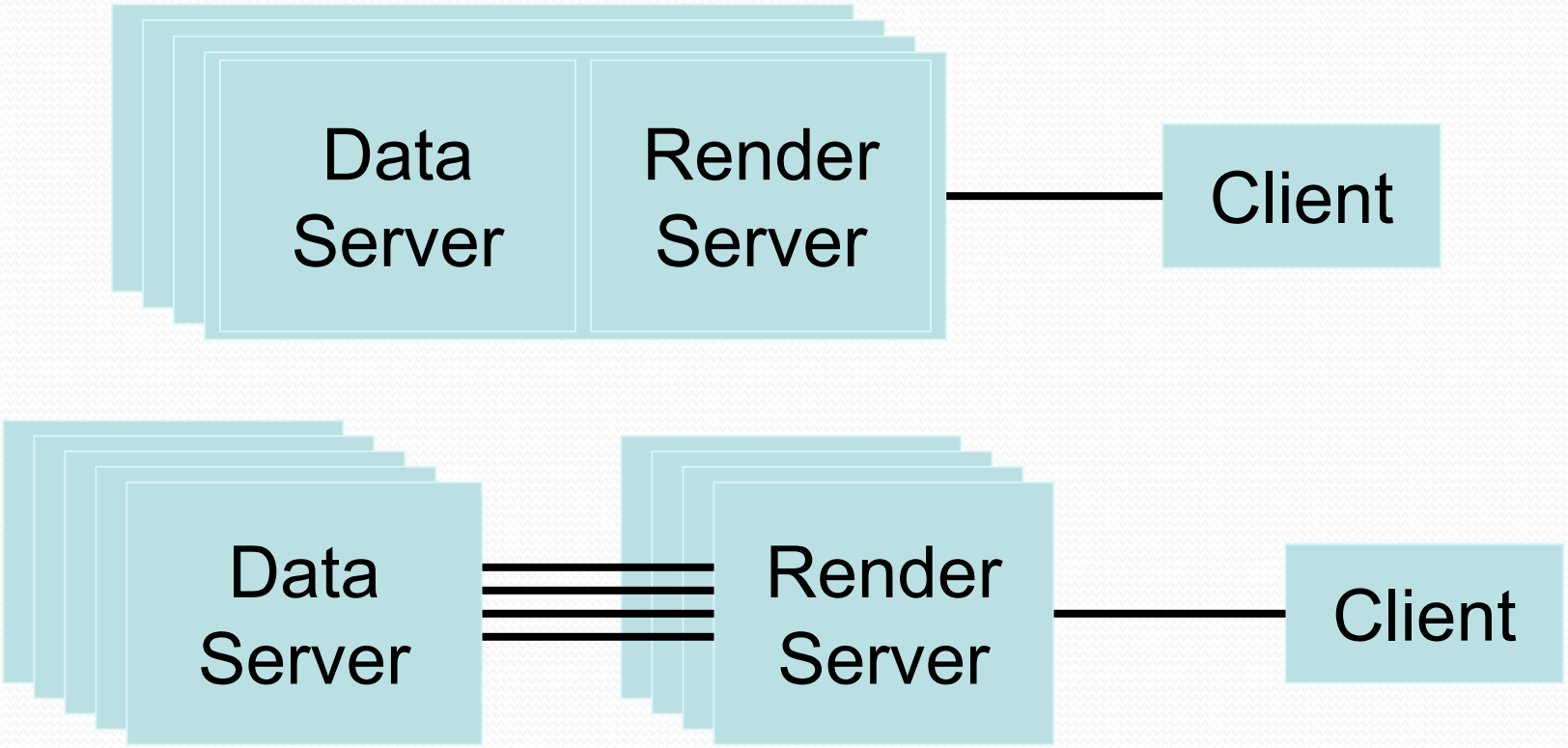
Overview of ParaView

- Standalone



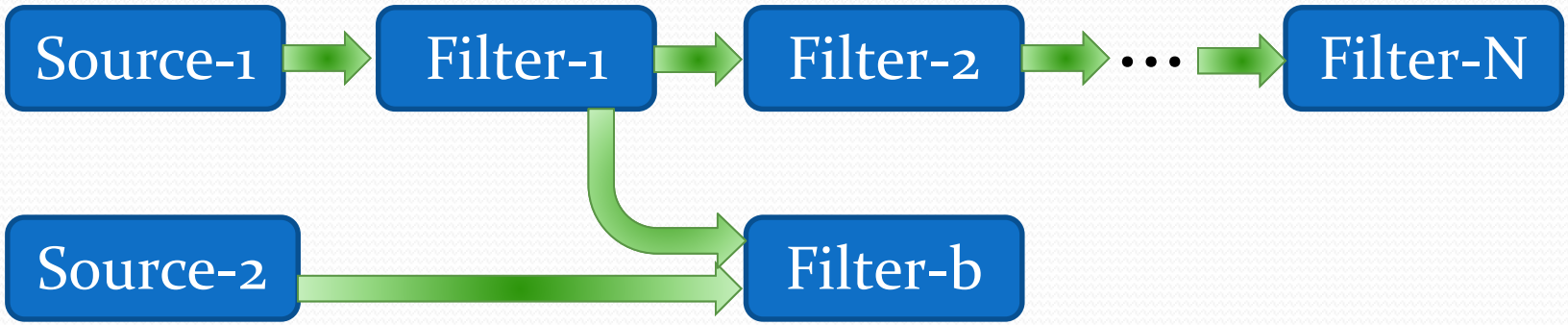
Overview of ParaView

- Client-Server mode



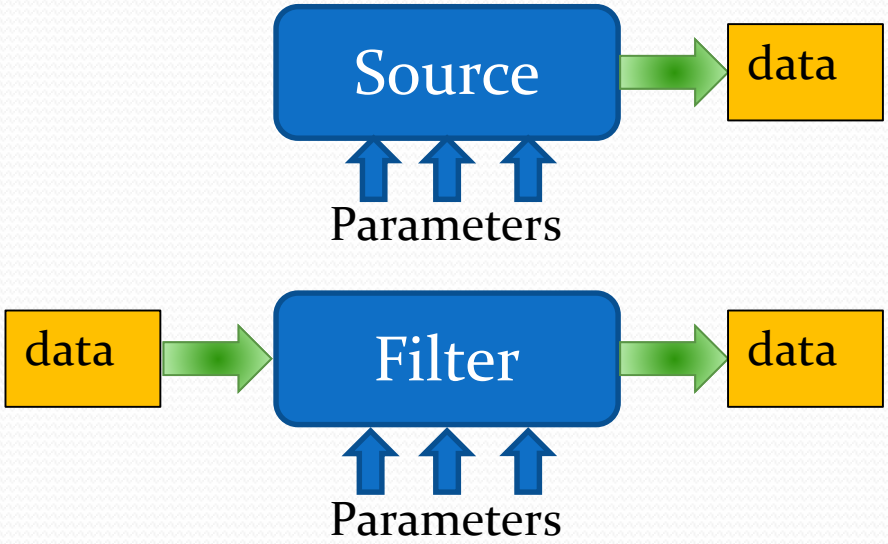
Overview of ParaView

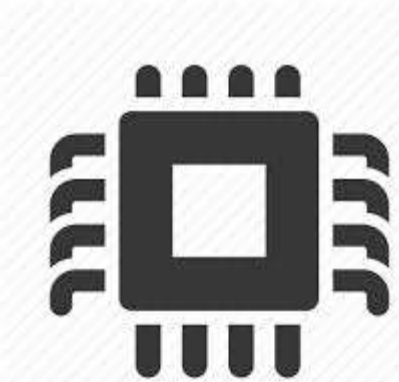
- Visualization pipelines



Overview of ParaView

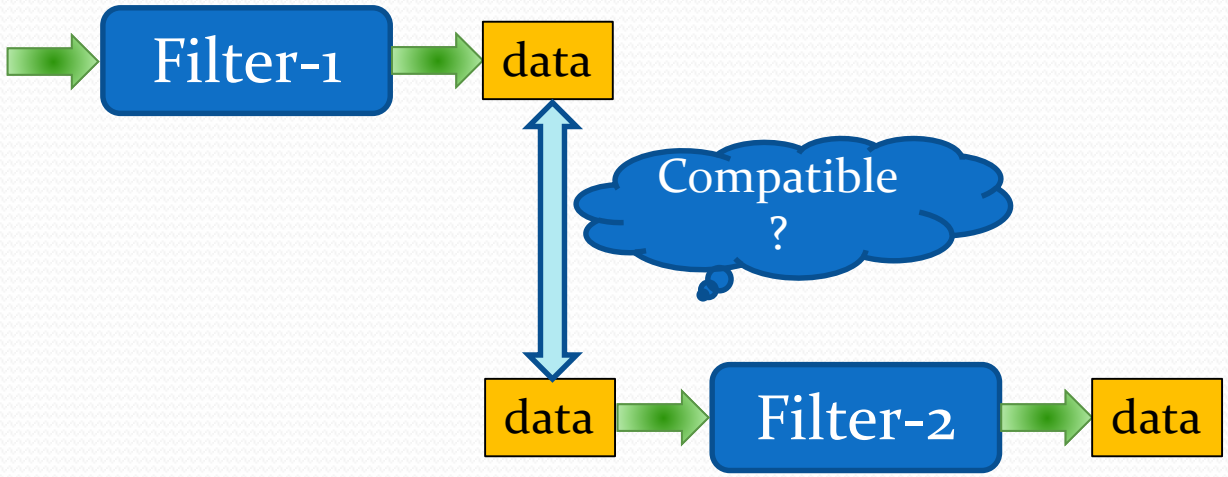
- Pipeline components
  - Source: no input, one or more outputs
    - Primitive objects (cube, cylinder, cone, sphere, etc)
    - Data file readers
  - Filter: one or more inputs, one or more outputs





Overview of ParaView

- Connections in pipeline
  - Outputs of one component become the inputs of another
  - Compatibility of data type between inputs and outputs

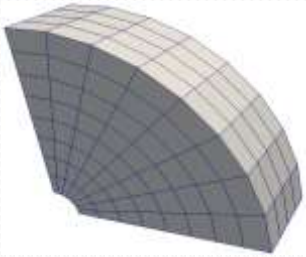


Overview of ParaView

- Data types (sampling structures)

Uniform Rectilinear
(vtkImageData)

Non-Uniform Rectilinear
(vtkRectilinearData)



Curvilinear
(vtkStructuredData)

Polygonal
(vtkPolyData)

Unstructured Grid
(vtkUnstructuredGrid)

Multi-block

Hierarchical Adaptive Mesh Refinement (AMR)

Hierarchical Uniform AMR

Octree

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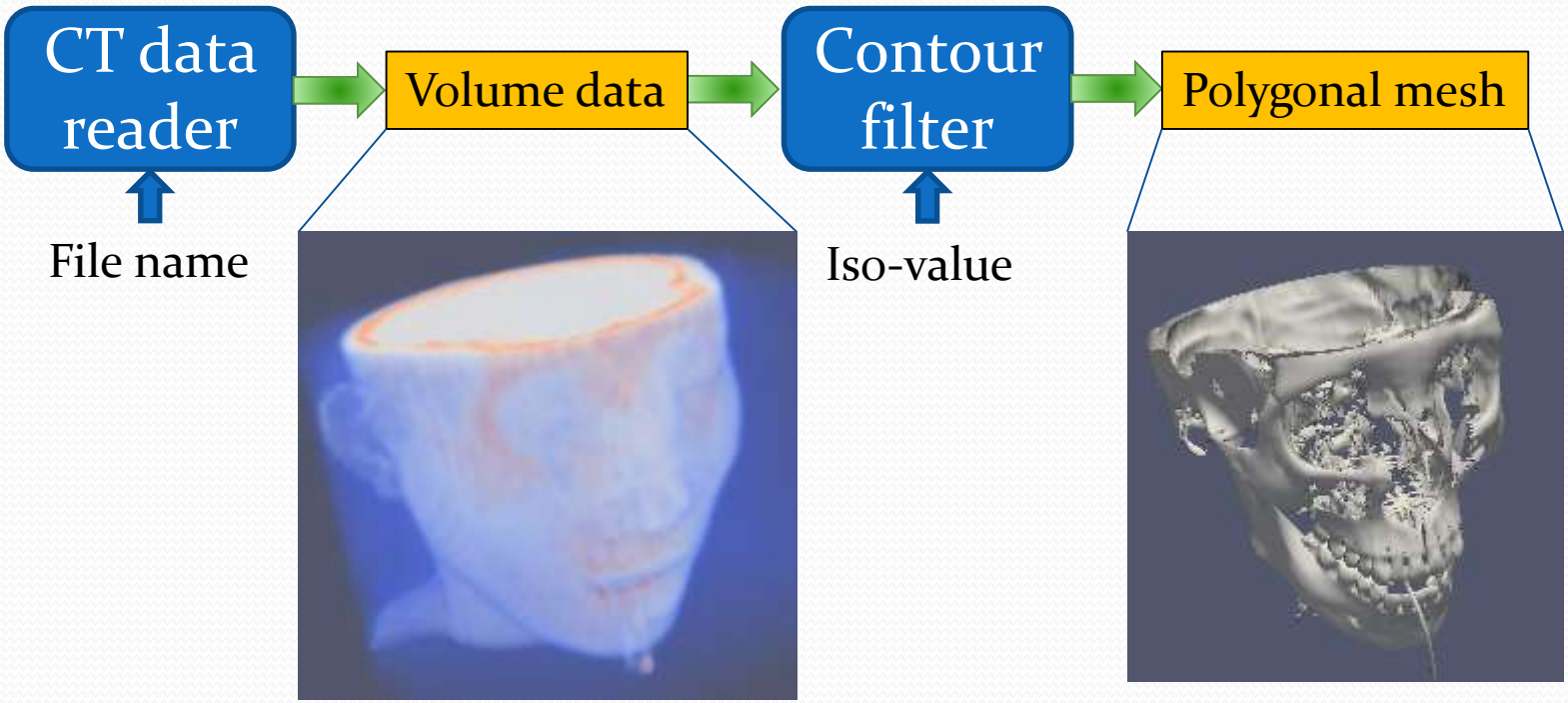
Overview of ParaView

- Data types at sampling points
  - Scalars (density, temperature, pressure, etc)
  - Vectors (velocity)
  - Normals
  - Texture Coordinates
  - Tensors

Overview of ParaView

- Example of pipeline



5 minutes

Basic Usage of ParaView

- Walk through GUI elements with simple examples
  - Primitives (Cylinder, sphere, etc)
  - Readers (air flow dynamics simulation, etc)
  - Filters (clipping, contouring, calculator, etc)
- What to learn
  - Create and manipulate pre-defined objects
  - Import objects from data files
  - View information of objects
  - Change display properties
  - Transform objects by applying filters
  - Multiple views and camera linkage
  - Save results (screenshots, animations, states)

Basic Usage of ParaView

- SHARCNet visualization stations
  - 10 viz stations (≤64GB momery, ≤12 cores, modern GPUs)
  - https://www.sharcnet.ca/my/software/show/67
- ParaView on SHARCNet viz stations
  - VNC (TigerVNC)
  - Client-server mode

Basic Usage of ParaView

- Start ParaView
  - Linux/Unix: type *paraview* in a command window
  - MacOS: click ParaView in *Applications* folder
  - Windows: click ParaView from Start Menu

Then

- ParaView GUI appears
- *Pvserver* running in the background

Basic Usage of ParaView

- ParaView GUI

Menu Bar

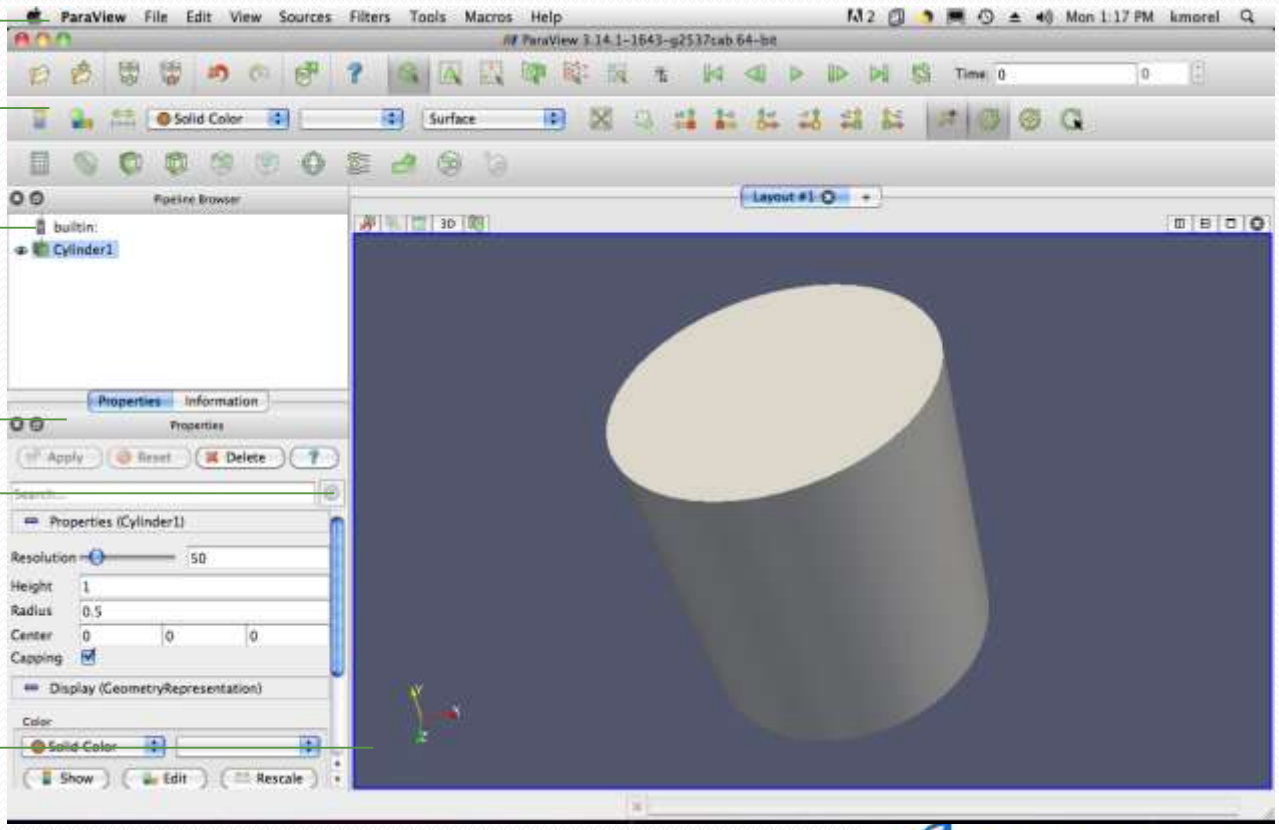
Toolbars

Pipeline Browser

Properties Panel

Advanced Toggle

3D View



Basic Usage of ParaView

- Example 1
  - Cylinder, sphere, cube
  - Multiple views and linking cameras
- Example 2
  - Loading file “disk_out_ref.ex2”
  - Volume rendering (transfer function)
  - Streamline and tube
- Example 3
  - Wavelet
  - Calculator

Basic Usage of ParaView

- Summary
  - Mouse interactions (Edit→Setting… Camera tab)
    - Me (Camera) or objects move?
  - Objects vs Views
    - An object can be displayed in more than one view
    - An object can have different appearances in different views
  - Active object (highlighted in pipeline browser)
    - Shown in *Properties Panel*
    - Subsequent transforms (filters) will apply to
  - Active view (highlighted by a blue outline)
    - Shown in *Properties Panel*

Basic Usage of ParaView

- Summary
  - Parameters
    - Define and change the underlying data
      - Geometric properties of primitives (height, radius, …)
      - Parameters of filters (iso-value, …)
    - Define and change only the appearance
      - Graphical representations (Surface, wireframe, points, etc)
      - Color
      - Lighting
      - Surface reflection properties

Basic Usage of ParaView

- Summary
  - Caution while handling large structured datasets

    Avoid using filters that generate unstructured data

    - Append Datasets
    - Append Geometry
    - Clean
    - Clean to Grid
    - Clip
    - Connectivity
    - D3
    - Delauney 2D3D
    - Extract Edges
    - Linear Extrusion
    - Lopp Subdivision
    - Reflect
    - Rotational Extrusion
    - Shink
    - Slice
    - Smooth
    - Subdivide
    - Tessellate
    - Tetrahedralize
    - Triangle Strips
    - Triangulate

5 minutes

Advanced Topics of ParaView

- Python scripting
- Importing your data
- Animation
- Visualization of large data in client-server mode

Advanced Topics of ParaView

- Python scripting
  - Scripting vs GUI-based operations
    - One GUI-based operation ←→ one or more scripting commands
  - Three ways of scripting
    - Tools→Python Shell, you can mix
      - Run scripts
      - Interactively issue commands
      - GUI-based operations
    - Pvpython: interactive client
    - Pvbatch: non-interactive batch execution

Advanced Topics of ParaView

- Python scripting
  - Basic elements
    - *from paraview.simple import* * # import paraview module
    - *sphere* = *Sphere()* # create a sphere
    - *Show()* # turn on visibility
    - *Render()* # refresh display
  - Help command
    - help(paraview.simple)
    - help(Sphere)
    - help(sphere)

Advanced Topics of ParaView

- Python scripting
  - Python basics
    - import os
    - os.getcwd()
    - os.chdir(*path*)
    - os.listdir(*path*)

    Example of displaying files in current working directory:
    os.listdir(os.getcwd())

Advanced Topics of ParaView

- Importing your own data
  - Write your data into
    - **Raw data file** (writeRawBinary.cpp). While loading file, you need to specify
      - Data type
      - Endianness
      - Dimensionality
      - Data array origin, extend, spacing along each dimension
    - CVS (not for large data)
    - **NetCDF** (writeNetCDF.cpp)
      - Meta data saved into file as well
    - Various VTK formats

Advanced Topics of ParaView

- Animation
  - Displaying time varying datasets
  - User defined animations
    - Dynamically changing parameters of objects you create
    - Dynamically changing parameters of camera

Advanced Topics of ParaView

- Visualization of large data in client-server mode
  - VNC and run ParaView remotely on supercomputers
  - Run ParaView in client-server mode
    - Place “servers.pvsc” file in
      - C:\Users\yourUserName\AppData\Roaming\ParaView on Windows
      - /home/yourUserName/.config/ParaView on Linux/MacOS
    - Set up passphraseless ssh by adding your public key to .ssh/authorized_keys on remote computer
    - *File*→*Connect* …
  - ParaView (VTK inside) has built-in parallel mechanisms

Questions?

or

Put It All Together

Task: Create an animation, in which a skull moves in a 3D scalar field (e.g., temperature). The skull surface is color-mapped with the intensities it insects with the field. As the skull moves, colors on its surface changes as well.

- Create a skull from medical images
- Create a scalar volume representing temperature
- Attach a “Transform” filter to skull
- Map volume data on the transformed skull by using “Resample with dataset” filter
- Create an animation on parameters of the “Transform” filter