Large Scale Visualization with ParaView

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CTH Simulation with billions of cells visualized with ParaView. ParaView Tutorial.
Contents

- What is ParaView?
- Running ParaView in parallel.
- ParaView Tutorial: Ex 2.1-2.xx

Install ParaView 5.4.0
Windows: Install PuTTY
Mac OS: Install XQuartz

VPIC simulation with 3.3 billion structured cells. Image courtesy of Bill Daughton, LANL
What is ParaView?

An open-source application and framework for display and analysis of scientific datasets.

Record setting in-situ simulation run:
First in-situ run to exceed one million MPI processes.
ParaView on the Desktop
ParaView on the Web
Python scripts can control ParaView with or without the GUI in order to create reproducible and customizable visualizations.
ParaView Immersive
ParaView for HPC
Community Atmosphere Model (CAM5) 2D (PS) 3D data (T), Spectral Element dynamic module.
ParaView Custom Application: VeloView

Visualization of 3D LIDAR data.
User Interface

- Menu Bar
- Toolbars
- Pipeline Browser
- Object Inspector
  - Properties Tab
  - Properties
  - Display
  - View
  - Information Tab
- Filter reference
- View(s)
Help

- Getting Started With ParaView
- The ParaView Guide
- Filter Reference
- The ParaView Tutorial
- Example Visualizations
- ParaView Mailing Lists
- ParaView Wiki
- http://www.paraview.org/documentation/
How to Use ParaView

1. **Read in data**: File → Open
   - Tune reader properties
   - Over 100 file formats supported

2. **Add a filter** to process data:
   - Change Filter properties
   - Repeat Step 2 as needed

3. Modify **Display properties**
4. Tune **View properties**
5. Save datasets, rendered results (screenshot or animation) or ParaView state

Filter (Pipeline object) = an algorithm that operates on data
Reader, Writer, Source
Filter Properties and the Apply Button

- Active Filter properties
- ParaView is meant to process large data – it might take a long time when changing a filter property.
Multiple Views – Render View Active

- Buttons: Split (Vertical, Horizontal), Maximize, Restore, Close
Multiple Views – BarChartView Active
Multiple Views – Spreadsheet Active
Display Properties

- **A Representation** (a display): object that stores visual characteristics a data set in a view
- Display Properties are associated with the Active Filter and Active View.
Color Map (Transfer Function) Editor

- Interpolation control widget
- Label showing values at selected control pt
- Rescale to data range
- Rescale to a custom range
- Rescale to data range over all timesteps
- Invert the color transfer function
- Load color transfer function preset
- Save color transfer function to presets

- Opacity transfer function editor
- Control points
- Color transfer function editor
- Data value for selected control pt

- Use log scale when mapping data to colors
- Enable opacity mapping for surfaces
- Automatically rescale transfer functions to fit data
View Properties

Properties associated with the Active View
Find properties (for Filters, Displays and Views)

- Search for properties
- Toggle on/off advanced properties
Object Inspector
Information Tab

- Information about the Active Filter’s output
- Dataset Type
- Size (Bytes, #points, #cells)
- Geometric bounds
- Structured bounds
- Arrays:
  - Name
  - Association (point, cell)
  - Data Type
  - Data Ranges (and scalar/vector)
- Temporal Domain
ParaView Dataset Types

- vtkImageData
- vtkRectilinearGrid
- vtkStructuredGrid
- vtkPolyData
- vtkUnstructuredGrid

- Multi-blocks
- AMR
- Time-varying data

- points, cells
- values associated points and/or cells: scalars, vectors, tensors
Multi-View Visualization Pipeline
Filter Properties – acts on active filter

Source

Filter

Data

Representation

View

Representation

Representation

Representation

Representation

Data

Filter

Data

View
Information Tab – shows output data for the active filter
Display Properties – representation properties for active filter and view

Source

Data

Filter

Data

Representation

View

Representation

View

Representation

Representation

Representation
View Properties – acts on active view
Filters

- Filters Menu
  - Recent
  - Common
  - Data Analysis
  - Statistical
  - Temporal
  - Alphabetical
- Quick Launch
  - PC/Linux
  - CTRL-Space
  - Mac
  - ALT-Space
- Apply Undo/Redo

<table>
<thead>
<tr>
<th>Calculator</th>
<th>Glyph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contour</td>
<td>Stream Tracer</td>
</tr>
<tr>
<td>Clip</td>
<td>Warp By Vector</td>
</tr>
<tr>
<td>Slice</td>
<td>Group Datasets</td>
</tr>
<tr>
<td>Threshold</td>
<td>Extract Group</td>
</tr>
<tr>
<td>Extract</td>
<td>Subset</td>
</tr>
</tbody>
</table>
Query Data by Attributes Values – Find Data Dialog
Query Data Visually - Selection

- Visually select interesting data shown in all compatible views can then label, extract etc
  - ‘Select Cells On’ to get nearest cells
  - Select Points On’ to get nearest points
  - ‘Select Cells Through’ to get all cells intersecting a frustum
  - ‘Select Points Through’ for selecting points inside a frustum
    - Select Points/Cells With Polygon
    - Select Block
    - Interactive Select Point/Cells
    - Hover Points/Cells
Exporting data, images, state

- **File → Save** *
  - Active filter’s **data**, prompted for file format
    - List of file formats given in help primarily kitware
    - formats + exodus, ensight, xdmf/hdf5, csv
  - **Screenshot** (image)
    - In a format for **high quality rendering**
      - eps, pdf, ps, svg, pov, vrml, webgl, x3d, x3db
  - **Movie**
    - Image sequence, avi, ogg, ffmpeg → avi
  - **State**
    - for restoring ParaView state later

In-situ vis. 1.3 billion cells, 256K MPI processes, Image courtesy of Michel Rasquin, ANL
Large Data processed by ParaView

1 billion cell asteroid detonation simulation

source: Sandia National Lab

1 billion cell weather simulation
N component Data Parallelism for X GByte

Control, Display and Rendering of Small Data

Tile Display
## ParaView’s Running Modes

<table>
<thead>
<tr>
<th>Built-in aka Standalone aka Serial</th>
<th>all components within one process (client may be GUI or pvpython)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td>`paraview</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Combined Server</th>
<th>data processing and parallel rendering in MPI job of combined processes. control from TCP connected client.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><code>mpiexec -n x pvserver &amp;; paraview #</code> or <code>pvpython #</code> + Connect</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Batch</th>
<th>server is an MPI job which directly runs a python script</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><code>mpiexec -n x pvbatch / vis_script.py</code></td>
</tr>
</tbody>
</table>

DS = data server  
RS = render server
Fetch Server Configuration

- File > Connect > Fetch Servers

<table>
<thead>
<tr>
<th>Configuration Name</th>
<th>Server</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>COOLEY@ANL</td>
<td>Kitware Inc.</td>
<td></td>
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<tr>
<td>windows to COOLEY@ANL</td>
<td>Kitware Inc.</td>
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<tr>
<td>THETA@ANL</td>
<td>Kitware Inc.</td>
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</tr>
</tbody>
</table>

[Image of the Fetch Server Configurations window]

- Edit Sources
- Import Selected
- Cancel
Connect

**Mac Os:** Install Xquartz
Connect

Windows: Install PuTTY
Syrinx-Calore simulation with 10 million unstructured hexahedra cells. ParaView Tutorial.