Introduction to Visualization on Stampede

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With contributions from TACC visualization training materials

Parallel Computing on Stampede
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From data to Insight

Data Representation → Visualization Operations → Graphics Primitives → Display

Iteration and Refinement
Points, Meshes, and Coordinates

From *The Visualization Toolkit* by Schroeder et al.

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Data

- Values at each point
- Type and nature will determine applicable techniques
  - Scalar, Vector, Tensor?
  - Discrete? Continuous?
  - Nominal, Ordinal, Interval, Ratio?
- Now what do want to show about your data?
Surface Shading (Pseudocolor)

Given a scalar value at a point on the surface and a color map, find the corresponding color (and/or opacity) and apply it to the surface point.
Isosurfaces (Contours)

- Surface that represents points of constant value with a volume
- Plot the surface for a given scalar value.
- Good for showing known values of interest
- Good for sampling through a data range
Volume Rendering

Expresses how light travels through a volume
Color and opacity controlled by transfer function
Smotherer transitions than isosurfaces
Particle Traces (Streamlines)

Given a vector field, extract a trace that follows that trajectory defined by the vector.

\[ P_{\text{new}} = P_{\text{current}} + V_{P} \Delta t \]

Streamlines – trace in space
Pathlines – trace in time
Graphics Primitives

- Basic unit: Polygons, Colors, Textures, Opacity
  - Flat surface formed between points
  - This surface may have an associated color or texture, or opacity
- Complex surfaces composed of several polygons
- A dataset in and of itself!
Graphics Pipeline

Modeling Transformation → Trivial Rejection → Illumination → Viewing Transformation

Clipping → Projection → Rasterization → Display
Visualization applications

• Support for many input formats
  – Some may be better than others for certain tasks
• Aim for realtime point and click image manipulation
  – Data exploration
• Pipeline of data refinement or visualization operations
• Lots of tweakable parameters
• Parallel rendering (more on this later)
• Ease of use and suitability for certain tasks can vary
  – Definitely not one-size-fits-all
ParaView

- Open-source, multi-platform parallel data analysis and visualization application
- Mature, feature-rich interface
- Good for general-purpose, rapid visualization
- Built upon the Visualization ToolKit (VTK) library
- Primary contributors:
  - Kitware, Inc.
  - Sandia National Laboratory
  - Los Alamos National Laboratory
  - Army Research Laboratory
ParaView

- Supports derived variables
  - New scalar / vector variables that are functions of existing variables in your data set
- Scriptable via Python
- Saves animations
- Can run in parallel / distributed mode for large data visualization
ParaView

- All processing operations (filters) produce data sets
- Can further process the result of every operation to build complex visualizations
  - e.g. can extract a cutting plane, and apply glyphs (i.e. vector arrows) to the result
  - Gives a plane of glyphs through your 3D volume
VisIt

- [https://wci.llnl.gov/codes/visit/](https://wci.llnl.gov/codes/visit/)
- Open Source, Multiplatform, interactive parallel visualization and graphical analysis tool
- Developed by the Department of Energy (DOE) Advanced Simulation and Computing Initiative (ASCI)
- Although VisIt was developed for visualizing terascale data, it is also well suited typical desktop simulations
- Can run in parallel/distributed mode for large-scale visualization
VisIt

• VisIt’s visualization capabilities are grouped into two categories:
  - Plots are used to visualize data and include boundary, contour, label, mesh, pseudocolor,
  - Operators consist of operations that can be performed on the data prior to visualization. (Examples include slice, isosurface, threshold among others)
Parallel Visualization

• Why? Performance
  – Processing may be too slow on one CPU
    • Interactive visualization requires real-time frame rates
    • Use lots of CPUs
    • Shared-memory/multicore or distributed
  – Data may be too big for available node
    • Virtual memory works, but paging is slow
    • Use lots of nodes to increase physical memory size
    • Big shared-memory/multicore scaling is costly ($/CPU)

Increase interactivity or feasibility
Memory Utilization

• Some visualization techniques cause memory use to skyrocket!
Memory Utilization: Regular Grids

- Specified by:
  - (x,y,z) origin
  - (nx, ny, nz) counts
  - Data array
- Requires very little memory
Memory Utilization: Regular Grids

• Chop off corner -> need an unstructured grid to represent data points
• Specified by
  – Explicit list of vertices
  – Explicit list of triangles
• Memory use can go up many times
Memory Utilization: examples

- **Mummy.vtk:**
  - Structured Grid
  - (128x128x128)
  - 2MB raw data
- **Contour:** 7MB
  - Polygonal Mesh
- **Slice of Contour:** .1MB
- **Tetrahedralize:** 520MB!!
  - Unstructured Grid
  - Data points -> Tetrahedrons
Visualization scales with HPC

- Large data produced by large simulations require large visualization machines and produce large visualization results
- Data and all derivations in memory, cumulative!
Large data, Remote Systems

- Stampede compute nodes
- Stampede Visualization nodes
- CAC, other HPC
- /scratch, /work
- Shared storage
- Your machine
Visualization nodes

• Stampede:
  – 128 nodes
  – K20 GPU in each node, 8GB GDDR5 RAM
  – viz, gpu queues
  – 32 GB RAM, 16 cores
  – Share Stampede’s lustre filesystems

• Longhorn
  – 256 nodes
  – 48GB-144GB RAM, 8 cores per node
  – Dual Nvidia Quadro FX5800 GPUs in each node, 4GB RAM
  – Lustre filesystems separate from Stampede
Data parallelism

Data set is partitioned among the processes and all processes execute same operations on the data.
Scales well as long as the data and operations can be decomposed.

<table>
<thead>
<tr>
<th>Timesteps</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1: Read partition 1, Isosurface partition 1, Render partition 1</td>
</tr>
<tr>
<td>2</td>
<td>2: Read partition 2, Isosurface partition 2, Render partition 2</td>
</tr>
<tr>
<td>3</td>
<td>3: Read partition 3, Isosurface partition 2, Render partition 3</td>
</tr>
</tbody>
</table>
Parallel algorithms: What doesn’t work

• Streamlines!
  – Not data-parallel
  – Partial streamlines must be passed from processor to processor as the streamline moves from partition to partition
  – No more parallelism available than the number of streamlines!
  – If >1 streamlines pass through the same partition, you may not even get that
Rendering

• Many graphics primitives spread out over nodes
• Rendering solutions
  – 1. Gather triangles onto one node, render there
     • Best when there’s not a lot of data to render
  – 2. Render triangles in place, gather and Z-composite the results
     • Best when there is a lot of data to render
     • Overhead is *almost* independent of data size
• VisIt and ParaView both do it both ways
  – User controls threshold, but both apps aim for reasonable defaults

• Now how do we get rendered graphics to the user?
Remote Visualization Model

- **HPC System**
- **Data Archive**
- **Large-Scale Visualization Resource**
- **Pixels**
- **Mouse**
- **Display**
- **Remote Site**
- **Wide-Area Network**
- **Local Site**
VNC

- Desktop process runs on remote server: vnc session
  - Windows, applications, mouse position
- Rendering occurs on server
  - Render on remote GPU. Send pixels to client
- Collaboration
  - Many can join vnc session, share control of mouse.
- VNC password to protect *session*
  - Share passwd with collaborators! Don’t use login passwd!!
1. Allocate set of nodes on visualization system. This will start a VNC server on one node, which you will connect.
Start VNC session on Stampede

- Stampede provides convenient job script
  - sbatch /share/doc/slurm/job.vnc

- Control node allocation via SLURM params
  - sbatch -N 8 -A MY_ACCOUNT /share/doc/slurm/job.vnc

- VNC desktop runs on compute node, private vnc port opened on login nodes just for you

  local (compute node) VNC port is 5901
  got login node VNC port 15754
  Created reverse ports on Stampede logins
  Your VNC server is now running!
  To connect via VNC client:
  SSH tunnel port 15754 to stampede.tacc.utexas.edu:15754
  Then connect to localhost::15754
2. From that desktop, launch the PV or VisIt Client App
Visualization Session

3. Start Paraview or VisIt Server Processes
   (Paraview and Visit can do this automatically, with the right configuration)
Launching Vis Applications

- Applications using OpenGL (i.e. all visualization apps) need to be wrapped with `vglrun <app>`
  - This is a workaround for the fact that vnc servers do not support OpenGL natively
- This starts the visualization GUI only.
  - Parallel backends are launched on-demand by visualization app, or manually by user
  - If not using parallel mode, then you’re done!
- Visit simply asks if you want parallel or serial mode
  - Params automatically determined by session params
- Paraview needs to be told to run backend processes via `ibrun`
Visualization Session

4. Multiple processes/node to take advantage of multiple cores/node -- wayness