Petascale Visualization: Approaches and Initial Results

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LA-UR- 08-07337

Questions about visualization in the petascale era

- What are our options for running our visualization software?
- Can we run our visualization software on the supercomputer?
- Do we need to a visualization cluster to support the supercomputer?

- Define supercomputer and visualization options
- Current approach and performance
- New approach
  - Ray-tracing for rendering

Trends in petascale supercomputing

- **Lots of compute cycles**
  - Multi-core revolution
- **Increasing latency from processor to memory, disk and network**
  - Many memory-only simulation results
- **Can compute significantly more data than can be saved to disk**
  - For example, on RR
    - To disk: 1 Gbyte/sec
    - Compute: 100 Gbytes on a triblade from Cells to Cell memory
- **Very expensive**

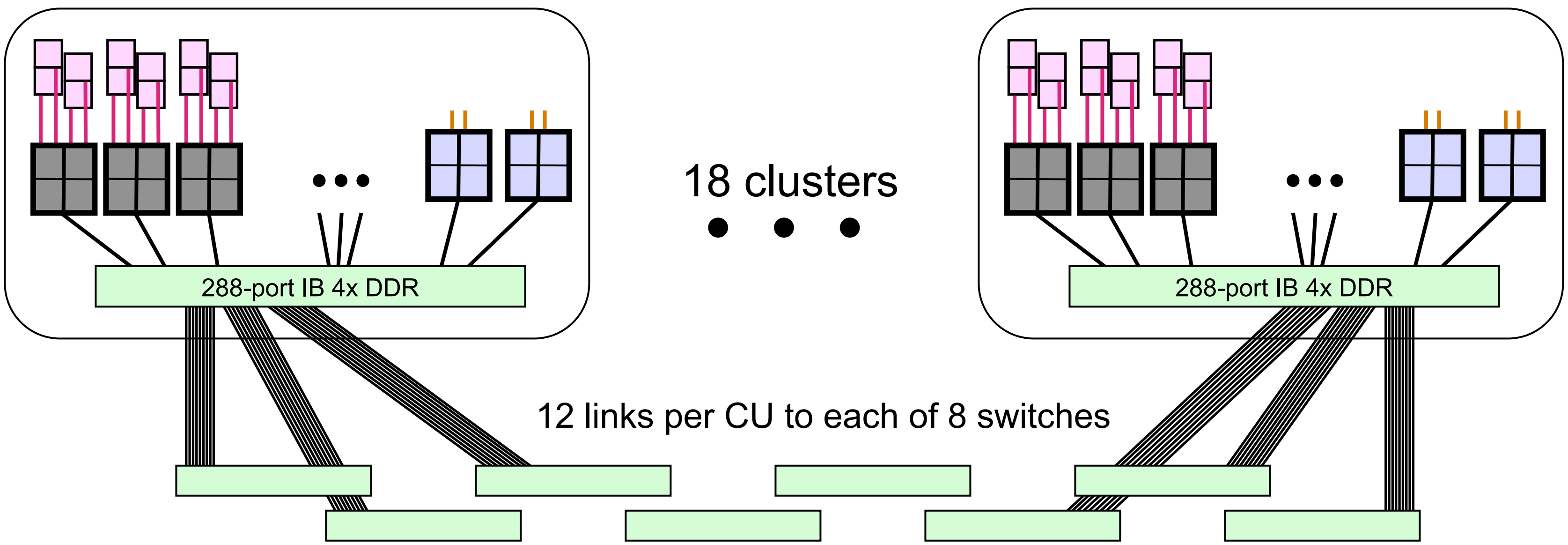
Supercomputing platforms

- **Definition of supercomputing platform**
  - Type of node
- **1. Co-processor architecture**
  - Example: Roadrunner
- **2. Multi-core processor**
  - Example: 16-way CPU (4 x 4 quad Opteron)

Roadrunner architectural overview

Connected Unit cluster
180 Triblade compute nodes w/ Cells
12 I/O nodes

6,480 dual-core Opterons ⇒ 23.3 Tflop/s (DP)
12,960 Cell eDP chips ⇒ 1.3 Pflop/s (DP)



Eight 2nd-stage 288-port IB 4X DDR switches

IBM Cell processors powers the Playstation

- **12960 Cell chips in Roadrunner!**
  - In Playstation – the Cell is used for physics processing – e.g. Little Big Planet
- **We plan to use the Cell for rendering…**

Can we efficiently run our visualization/rendering software on the supercomputer?

- **The data understanding process is composed of a number of activities:**
  - Analysis and statistics
  - Visualization
    - Map simulation data to a visual representation (i.e geometry)
  - Rendering
    - Map geometry to imagery on the screen
- **Already runs on the supercomputer**
  - Analysis, statistics and visualization
- **<u>Issue is rendering</u>**
- **Fast rendering for interactive exploration**
  - 5-10 fps minimum, 24-30 fps – HDTV, 60 fps - stereo
- **Typically provided by commodity graphics in a visualization cluster**

Related Work – Visualization hardware

- **SGIs (late 1998)**
  - SGI shared memory machine
  - “Blue Mountain ran Linpack, one of the computer industry's standard speed tests for big computers, at a fast 1.6 trillion operations per second (teraOps), giving it a claim to the coveted top spot on the TOP500 list, the supercomputer equivalent of the Indianapolis 500.”
  - Integrated Reality Engine graphics ($250K/each)
- **Commodity clusters (2004)**
  - Leverage commodity technology to replace SGI infrastructure
    - “Game” cards, PC-class nodes, Infiniband networks
- **What is next?**

Analysis of tradeoffs
Visualization/rendering on supercomputer or cluster

- **Visualization/rendering on the supercomputer**
  - Disadvantages
    - Cost to port rendering to the supercomputing platform
    - Allocate portion of supercomputer to analysis and visualization
  - Advantages
    - Scalable to supercomputer size
    - Access to “all” simulation results
- **Visualization/rendering on cluster**
  - Disadvantages
    - Cost of cluster and infrastructure to connect it
    - Less access to data – only data that is written to disk
  - Advantages
    - Independent resource devoted to visualization task
    - Very fast especially on smaller datasets

Standard parallel rendering solution
Sort-last parallel rendering of large data

- **Sort-last parallel rendering algorithms have two stages:**
  - 1. Rendering stage
    - The node renders its assigned geometry into a “distance/depth” buffer and image buffer
  - 2. Networking / compositing stage
    - These image buffers are composited together to create a complete result
- **Given there are two stages the performance is limited by the slower stage**
  - Assuming pipelining of the stages

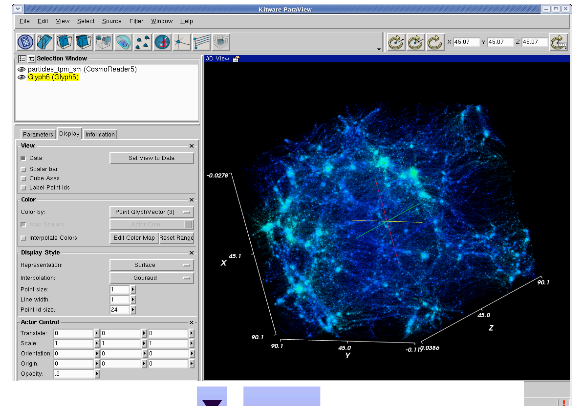
Performance study

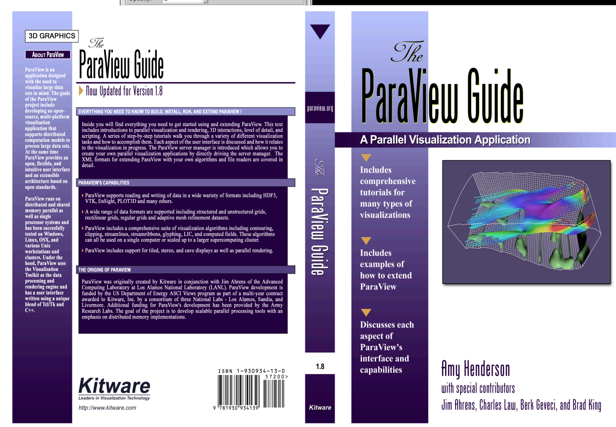
- **For real-world performance testing and to prepare for petascale visualization tasks…**
- **Incorporate rendering approaches into vtk/ParaView**
  - Vtk is open-source visualization library
  - Paraview (PV) is open-source parallel large-data visualization tool
- **Initially render on two types of nodes**
  - Multi-core node - 1, 2, 4, 8, 16 way
    - Mesa using multiple processes via parallel vtk
      - Data automatically partitioned and rendered by each process
      - On-node compositing to create final image
  - GPU
    - Standard OpenGL driver

Vtk and ParaView – Overview

- **Open source software**
- **Entities using/developing**
  - Laboratories
    - ANL, NCSA, EVL
    - LANL, LLNL, SNL
    - CEA, CHCH
    - ARL
  - Universities

    Stanford, UNC, Utah
  - Commercial companies
    - GE, DuPont
- **Agency funding**
  - NSF, NIH, DOE, DOD
- **Thousands of downloads / users**





ParaView features

- **Scalability**
  - Data parallelism and incremental processing
  - Visualized a **petabyte-sized** test problem in 2001
- **Serial and parallel portability**
  - Run on most serial and parallel platforms
    - Binaries for Windows, Linux, Mac
  - Distributed-memory execution
    - Commodity clusters
- **Advanced displays and rendering**
  - Stereo, Tiled walls, CAVE
  - Automatic level of detail rendering
  - Compression for remote data transfer
- **Remote visualization services**
  - Parallel data server
  - Parallel rendering server
  - Client
- **Advance application control**
  - Tracing
  - Scripting
  - Animation Editor

Vtk/PV rendering performance – standard approach

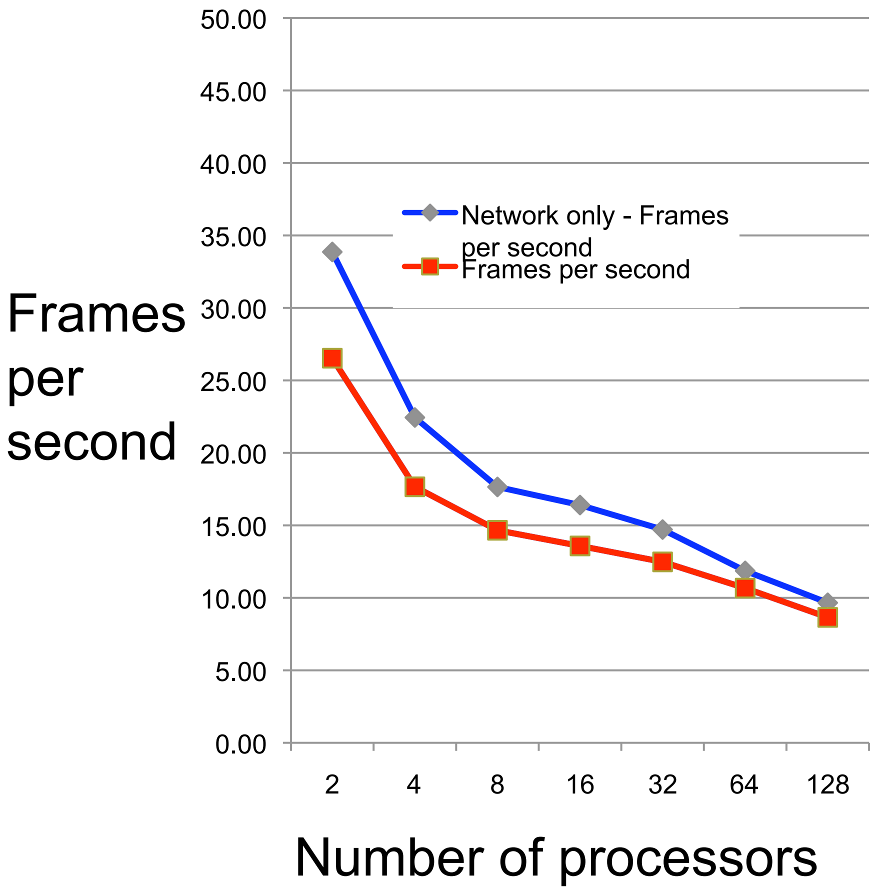
- **1 Million polygons rendering to a 1Kx1K image**

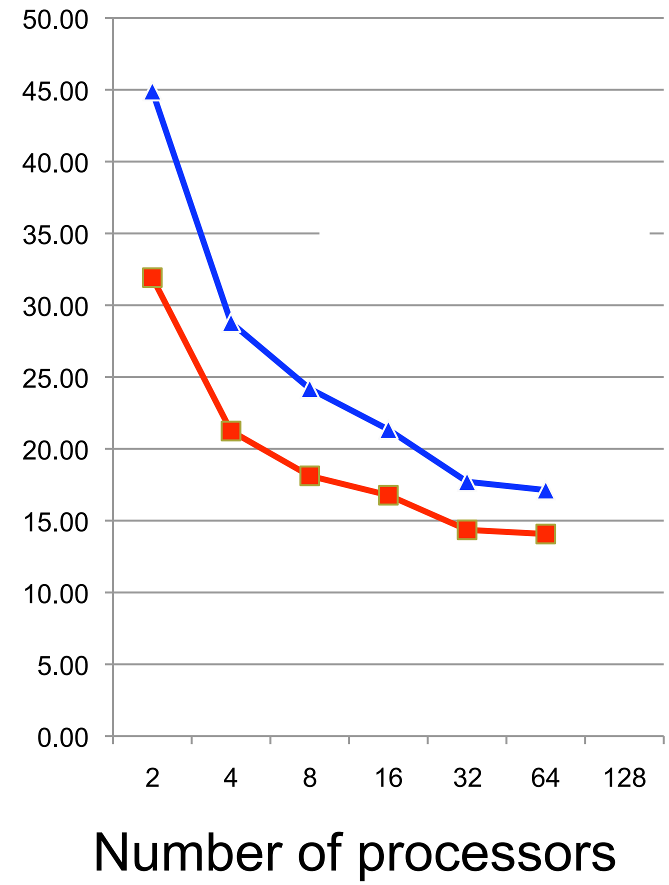
Rendering Type	Software	Architecture	Frames per second
Scan conversion	OpenGL	Nvidia Quadro FX 5600	18.6

1. Vtk GPU hardware rendering performance could be improved.

			Frames per second for # of cores				
Rendering Type	**Software**	**Architecture**	**1**	**2**	**4**	**8**	**16**
Scan conversion	Open GL Mesa	Multi-core (4 quad opt.)	0.7	1.2	2.0	3.2	4.6

Networking – IB-1, IB-2 compositing performance





Summary
Rendering and networking performance

- **10-15 frames per second on IB**

- **GPU-based**
  - 20 frames per second
- **CPU-based/supercomputer**
  - 5 frames per second with Mesa software rendering

- **This seems to suggest that visualization clusters are the right approach…**

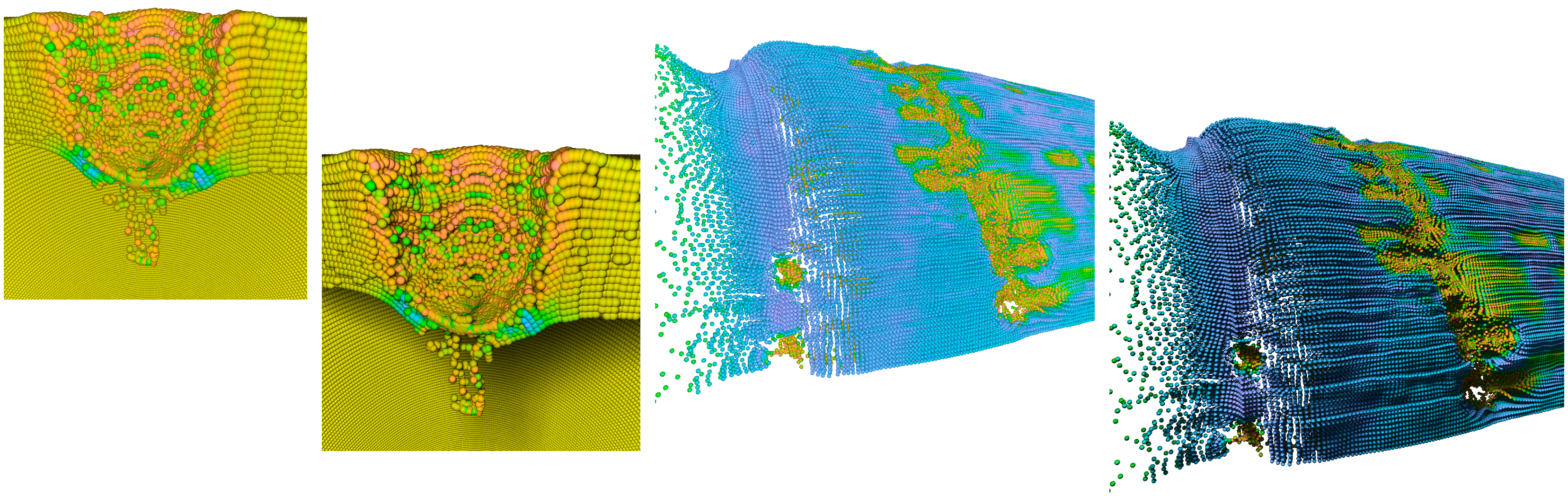
Another type of rendering

- **Scan conversion of polygons**
  - 1. OpenGL Software
    - Mesa - open-source
  - 2. OpenGL Hardware
    - Graphics cards – Nvidia

- **<u>Raytracing</u>**
  - Fast multi-core ready implementations
  - For RR - IBM's iRT software
    - Cell processor
  - . University of Utah – Manta software
    - Multi-core optimized, open-source

Why ray tracing?

- **Advanced rendering model**
  - More accurate lighting physics model
    - Shadows, reflections, refractions
  - Flexible software-based approach
  - Ability to integrate compute, analysis & rendering



Images courtesy Christiaan Gribble, Grove City College, PA (done while at Univ. of Utah)

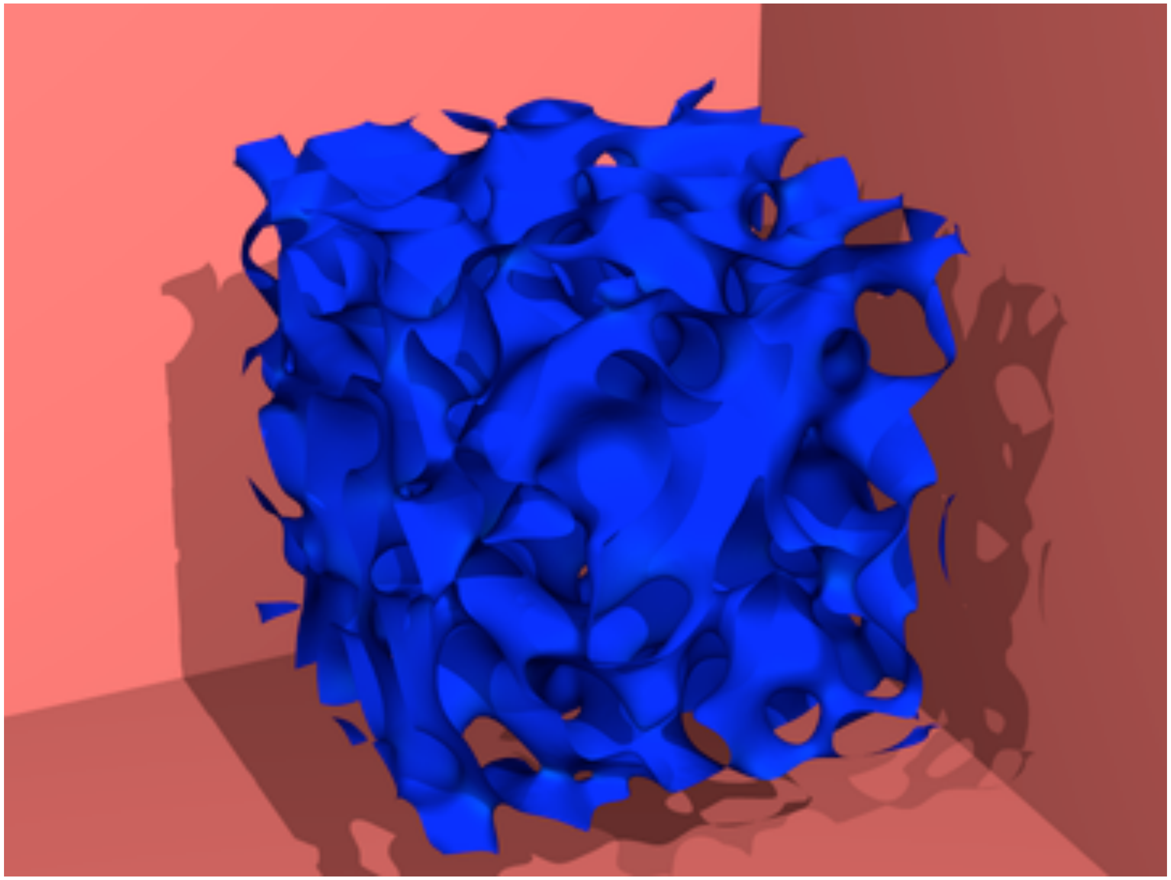
Using raytracing for rendering in vtk/PV

- **To be clear --**
- **Raytracing as a scan conversion/OpenGL replacement for parallel rendering**
  - Why? Optimized multi-core implementations available for ray-tracing
- **For this study, if there was an optimized multi-core OpenGL software we would use that:**
  - Aside - Tungsten Graphics is working on a Cell-based Mesa effort
    - Part of Gallium3D architecture
      - Their own rendering abstraction infrastructure

Using Manta raytracing for rendering in vtk/PV

- **Use vtk's rendering abstraction…**
- **Technical challenges**
  - Data representation
    - Mapping between representation of polygons in vtk and raytracer
      issues in 2D – points, lines
      - Scalar color mapping
  - Synchronization of control
    - Vtk runs in one thread and raytracer has many threads
    - Vtk and raytracer have their own event loop
      - Use callback mechanism in ray-tracer for synchronization

VtkManta serial rendering



Vtk/PV rendering performance

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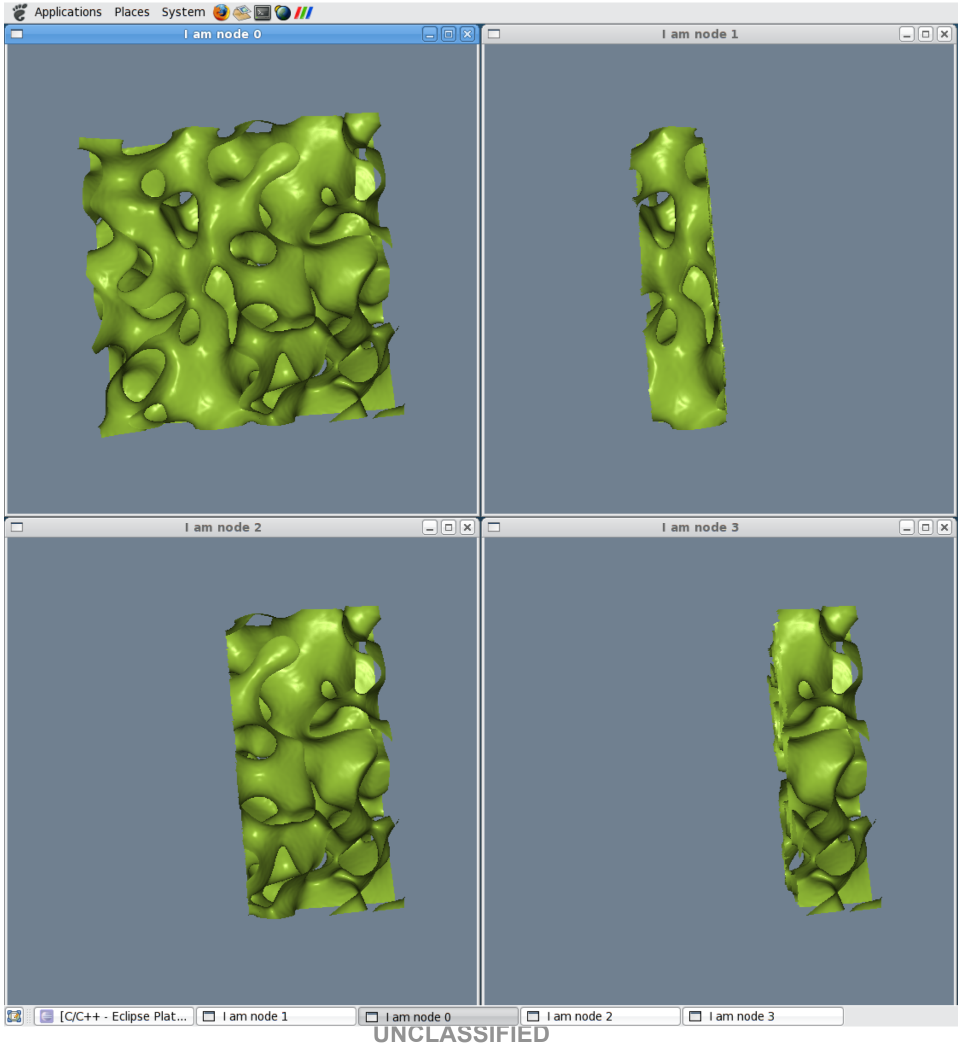
Raytracing	Manta	Multi-core (4 quad opt.)	1.6	2.8	5.6	10.9	19.4

Parallel rendering with raytracing

- Render with raytracer on each node
- Need a depth value for sort-last compositing

- Raytracer calculates distance from eye to polygon
- At each pixel can use this value as a depth value for sort-last compositing

Parallel rendering with Manta in ParaView



Summary
Rendering and networking performance

- **10-15 frames per second on IB**

- **GPU-based**
  - 20 frames per second
- **CPU-based / on supercomputer**
  - 20 frames per second with Manta raytracing (16-way multicore node)

- **This suggests trend is towards using the supercomputer and away from visualization cluster**

Future work

- iRT interface to vtk/PV in the works

- 1 Million polygons rendering to a 1Kx1K image - preliminary

Rendering Type	Software	Architecture	Frames per second
Raytracing	iRT	Cell blade (16 SPUs)	42

- Integration of IBM Cell-based ray-tracer into PV for visualization on RR platform

- Advanced ray-tracing

Conclusions

- **This preliminary study suggests that:**
  - Multi-core processors are starting to serve some of roles of traditional GPUs such as parallel rendering
  - Using fast software-based rendering methods may offer a path to utilizing our supercomputers for visualization