Production Cluster Visualization: Experiences and Challenges

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Why COTS Distributed Visualization Clusters?

- The realities of extreme dataset sizes (10TB+)
  - Stored with the compute platform
  - Cannot afford to copy the data
  - Co-resident visualization

- Track compute platform trends
  - Distributed infrastructure
  - Commodity hardware trends
  - Cost-effective solutions

- Migration of graphics leadership
  - The PC (Gamers) Desktops
  - Display technologies
    - HDR, resolution, stereo, tiled, etc
Production Visualization Requirements

- **Unique, aggressive I/O requirements**
  - Access patterns/performance

- **Generation of graphical primitives**
  - Graphics computation: primitive extraction/computation
  - Dataset decomposition (e.g. slabs vs chunks)

- **Rendering of primitives**
  - Aggregation of multiple rendering engines

- **Video displays**
  - Routing of digital or video tiles to displays (over distance)

- **Interactivity (not a render-farm!)**
  - Real-time imagery
  - Interaction devices, human in the loop (latency, prediction issues)

- **Scheduling**
  - Systems and people
Visualization Environment Architecture

- Raw data on platform disks/archive systems
- Data manipulation engine (direct access to raw data)
- Networking (data/primitives/images)
- Visualization/rendering engine
- Video & remotely rendered image delivery over distance
- Displays (office/PowerWalls)
Deployed Environment: MCR & PVC

MCR: 1,116 P4 Compute Nodes

PVC: 58 P4 “Render” nodes
6 “Display” nodes

1,152 Port QsNet Elan3

GbEnetFederated Switch

2 MetaData (fail-over) Servers
32 Gateway nodes @ 140 MB/s delivered Lustre I/O over 2x1GbE

Aggregated OSTs, single Lustre file system (90TB)

128 Port QsNet Elan3

Digital Desktop Displays

Video Switch

Analog Desktop Displays

2x2 PowerWall 5.2Mpixel

3x2 PowerWall 7.8Mpixel
MCR & PVC Success

- MCR+PVC, a prolific tandem…
- Effectively handling multi-TB datasets, many over 10TB
  - Examples: $1152^3$ 7 variables 1000 timesteps, billion atom
  - Custom data formats: wavelet compression, spacefilling curves
  - Excellent aggregate raw I/O rates (GBs/sec)
- Generating animations: 1/10 the time, 1/5 the resources
- Driving ~8Mpixel PowerWall (3x2)
  - Supporting interaction in a problem solving environment (PSE)
Challenges Remain…

- Fragile system components
- Data access
  - Cluster-wide parallel I/O systems can be fragile
  - Must optimize for viz access patterns
- The impedance mismatch problem
  - Smaller number of nodes for viz
    - Out of core processing
    - Improper data decomposition
- Scheduling complexity
  - Co-scheduling of multiple clusters
  - Combinations of parallel clients, servers, services and displays
- Increased Complexity
  - Increased fidelity
    - Spatial, temporal, higher-order
    - Complex & unique representations
- PSE Integration
  - Multiple data sources
  - Additional context
- Interpretation failure
  - Difficult visual interpretation
    - Artificial polygon limits (90M?)
  - Scalability
    - Failing, global algorithms
    - Fidelity issues
Idealized Visualization Environment

Compute Fabric
Storage Fabric

Composition Fabric
User Connect

Existing end user desktop nodes
Existing desktop displays

4 x 4 Tiled Power Wall

Virtual Compositor

Rendering Engines
Graphics
Graphics
Graphics
Graphics

Compositor
Compositor
Compositor
Compositor
Compositor
Compositor
Compositor

Graphics
Decompress

Graphics
Decompress

Graphics
Decompress

Workshop on Parallel Visualization and Graphics
Goal: Provide integrated, distributed parallel services for viz apps. Encourage new apps, increase portability & device transparency.

- Applications: VisIt, ParaView, EnSight, Blockbuster, etc.
- Toolkits – Parallel visualization algorithms, scene graphs, etc.
- DMX – Distributed X11 windowing and input devices
- Chromium – Parallel OpenGL rendering model
- PICA – Parallel image compositing API
- Merlot – Digital image delivery infrastructure
- Telepath – Visualization “session” control and scheduling
- Core “vendor” services - X11/OpenGL/compositors/NICs/Job control
Distributed OpenGL rendering pipeline. Provides a parallel OpenGL interface for an N to M rendering infrastructure based on a graphics stream processing model.

The Stream Processing Unit (SPU)
- “Filter” view OpenGL
- SPU interface is the OpenGL API
  - Render, modify, absorb…
- Allows direct OpenGL rendering
- Supports SPU inheritance
- Application “translucent”

Development:
- chromium.sourceforge.net
- RedHat/Tungsten Graphics ASCI PathForward
- Stanford, University of Virginia
- Stereo, Fragment/Vertex pgms, CRUT, dynamic caching
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Distributed multi-headed X server: DMX
Aggregates X11 servers
- “Server of servers” for X11
- Single X server interface
Accelerated graphics
- 2D via accelerated X server
  - Common extensions as well
- Back-side APIs for direct, local X11 server access
- OpenGL via ProxyGL/GLX (from SGI) or via Chromium SPU
Development:
- [dmx.sourceforge.net](http://dmx.sourceforge.net)
- RedHat ASCI PathForward contract
- Integrated with XFree86
Merlot is a framework for digital image delivery
- Transport layer abstraction, Codec interfaces, Device transparency

MIDAS: Merlot Image Delivery Application Service
- Indirect OpenGL rendering services for X11 environment
- Indirect window management
- Image stream transport

Development:
- Alpha released as OpenSource
- More apps and experimental hardware support
Applications

- Full-featured visualization
  - VisIt: www.llnl.gov/visit
    - VTK, client-server model
  - ParaView: www.paraview.org
    - Parallel VTK viz tool

- Specialty applications
  - Blockbuster
    - blockbuster.sourceforge.net
  - Scalable animations, DMX aware
  - TeraScale Browser/Xmovie/MIDAS
    - www.llnl.gov/icc/sdd/img/viz.shtml
The Road Ahead

- Improved data understanding and exploitation
  - Basic interactivity is pretty much a done deal
    - Plenty of workable, scalable approaches
  - Picking up to temporal (or other dimensional) challenge
  - Topological based representations
  - How far do we follow the terabyte to gigapixel path?

- Imminent progress
  - Bandwidth increases everywhere: Buses, interconnects, etc
  - Dedicated compositing hardware
  - Second generation digital video technologies: 10gigE, IB, etc

- On the near horizon…
  - Managing software longevity, software & hardware complexity
  - High dynamic range: data to rendering to display
  - The extreme FLOP approach
The nVidia NV30 Architecture
- 256MB+ RAM, 96 32bit IEEE FP units @ 500Mhz
- "Assembly language" for custom operations
- Streaming internal infrastructure

The PlayStation3 (patent application)
- Core component is a cell
  - 1 "PowerPC" CPU + 8 APUs ("vectorial" cpus)
  - 4GHz, 128K RAM, 256GFLOP/cell
  - Building block for multimedia framework
- Multiple cells
  - Four cell architecture (1TFLOP)
  - Central 64MB memory
  - Switched 1024 bit bus, optical links?

Effective streaming data access?
New rendering abstractions (are polygons dead?)
The Streaming Programming model

- Streaming exposes concurrency and latency at the system level as part of the programming target.
- Data moves through the system: exposed concurrency
  - Avoid global communication: prefer implicit models (e.g. Cr)
- Memory model: exposed latency/bandwidth
  - Scalable, must support very small footprints
  - Distributed, implicit flow between each operation
- A working model:
  - Computational elements + caching and bandwidth constraints
  - External “oracle” for system characterization and realization
- Goals:
  - Optimally trade off computation for critical bandwidth
  - Leverage traditionally “hidden” programmable elements
Modified visualization algorithms
- Cache oblivious: local, at the expense of computation
- “Non-graphical” algorithms, moving away from polygon primitives
- Digital, high dynamic range imagery from generation to display

Computation and memory caches everywhere
- NICs, Drive controllers, Switches, TFLOP GPUs + PCI express
- Utilizing them may require a disruptive programming shift
  - Exposed data staging and streaming issues

What are the appropriate abstractions?
- New languages with higher levels of abstractions?
  - Run-time “realization”, dynamic compilation and scheduling
- Glue languages: e.g. “shader” languages?
- Graphics or other API extensions/encapsulation?
- How do we preserve our largest investments, people & software?
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