Data-Intensive Applications on Numerically-Intensive Supercomputers

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Interactive visualization of a billion-cell plasma physics simulation
VPIC – A case study of visualization on a supercomputing platform

• Goal: Running simulation on 4096 ASC Roadrunner processors
  — Computing an 8192x512x512 problem = 2 billion cell problem
  — VPIC per processor dump files = 100s of GB per time step
• Data reduction, prioritization and visualization on the supercomputer combines will help this science team be successful
The RoadRunner Universe project

• First Petascale Cosmology Simulations
  – New scalable hybrid code designed for heterogeneous architectures
  – New algorithmic ideas for high performance
    • Domain overloading with particle caches
    • Digital filtering to reduce communication across Opteron/Cell layer
    • >50 times speed-up over conventional codes

• The RoadRunner Universe Data Challenge
  – Individual trillion particle runs generate 100s of TB of raw data

• Must carry out “on the fly” analysis
  – KD tree-based halo finder parallelized with particle overloading
Visualization tools provide a high-level data-oriented programming model

- Visualization tools are programmable
  - Uses a data-flow program graph...
- Visualization tools provide their own run-time system

- Optimize access to numerically-intensive architecture
  - Multi-resolution out-of-core data visualization
Multi-resolution out-of-core visualization
Multi-resolution out-of-core visualization
Impact: Using a data-oriented programming model we can directly address the fundamental massive scale visualization challenge

- Supports an approach for the massive data visualization problem
  - Data reduction, prioritization, multi-resolution and out-of-core processing

### Performance comparison

<table>
<thead>
<tr>
<th></th>
<th>seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>full data (1 GB)</td>
<td>7.80</td>
</tr>
<tr>
<td>low res data (1 MB)</td>
<td>0.14</td>
</tr>
<tr>
<td>multi-res data (38 MB)</td>
<td>0.84</td>
</tr>
<tr>
<td>one time mesh</td>
<td>0.04</td>
</tr>
<tr>
<td>one time read</td>
<td>0.00</td>
</tr>
</tbody>
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### Time vs. image quality

- normalized RMS CIELUV error vs. seconds
- 0 seconds to 30 seconds
- 0 to 1 normalized RMS CIELUV error
There is a “Middle Way” between numerically-intensive and data-intensive supercomputing

- Numerically-intensive supercomputing approach – Massive FLOPS
- Data-intensive supercomputing (DISC) approach – Massive data
- We are exploring this “Middle Way” by necessity for interactive scientific analysis and visualization of massive data
- DISC using a traditional HPC platform (compare Bryant)
  - 1. Data as first-class citizen
    - In-situ analysis for Roadrunner Universe application
  - 2. High-level data oriented programming model
    - Programmable visualization tools
    - Multi-resolution out-of-core visualization
  - 3. Interactive access – human in the loop
    - Visualization on the supercomputing platform
  - 4. Reliability
Non-Traditional Programming Models for High-Performance Computing

This year's LACSS will focus on Data-Intensive Architectures and Applications. The similarities and differences with "traditional" HPC will be explored. Other non-traditional HPC themes may be added.

Attendance open to all. Speakers likely by invitation only but contact Al McPherson <mcpherson@lanl.gov> if you are interested.