Visual Performance Analysis for the Exascale Era

Peer-Timo Bremer
Center for Applied Scientific Research, LLNL
Associate Director of Research,
Center for Extreme Data Management,
Analysis and Visualization, University of Utah.

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Massive Parallelism has made Performance Analysis Data-Rich but Tools are Missing to Interpret the Data

- We can collect data at scale, but data volume is overwhelming
  - Too many variables to measure
  - Difficult to write out data from 1 billion cores
- Information is highly categorical, discontinuous
  - Profiles, traces
  - Hardware Performance Counters
    - FP counts, cache misses, network traffic
  - Counts map to particular cores
- MPI Process ID space is often unintuitive
  - Rank offers little insight into underlying network

MPI Trace Data from runs with 16 and 34 processes

Floating Point Instruction Counts
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**It is difficult to apply analysis techniques because this data lacks structure**
Mapping Data into an Appropriate Contexts Enables more Holistic Analysis and Intuitive Visualization

- Data is typically collected, presented, and analyzed in its native context:
  - Hardware counters
  - Communication traces
  - Code profiles

- Mapping data between contexts provides Opportunities for
  - More holistic, interconnected analysis
  - Exploit intuitive visual encodings that exist for some contexts
Case Study 1: Map Performance Data of Multi-Physics Code onto its Application Domain

Aluminum distribution

Velocity distribution

Floating point operations

L1 cache misses
What’s going on with L1 misses?

- One core on each socket has more L1 misses
What’s going on with L1 misses?

- One core on each socket has more L1 misses
- Caused by execution of MPI collective operations
- Need for different perspectives to disambiguate causes
Compensating for MPI Processing Leads to More Interesting Secondary Hypotheses

Same data with linear color map

L1 Cache Misses

FP Operations
Compensating for MPI Processing Leads to More Interesting Secondary Hypotheses

Same data with linear color map

L1 Cache Misses with MPI worker filtered

FP Operations

L1 Misses per FP operation: Coarse measure of efficiency
Case Study 2: Understanding Communication Bottle Necks in an AMR Load Balancing

- Case study: SAMRAI, structured adaptive mesh refinement
  - Blue Gene/P at Argonne (256 to 128K cores)
Timings in MPI Rank Space Show Large Imbalances but Provide Little Insight into the Root Causes

Different phases of load balancing (256 cores)
Projecting Information onto the Internal Tree Communication Graph Highlights the Problem

Load on 16k cores
Wait time for box distribution
Wait time with flow information
We are Developing the Boxfish Tool to Collect Context Dependent Visualizations and (Semi-)Automatic Mappings

Grid layout to highlight planes in the 2D view with mouse over. The 2D view also supports interactions like zooming and translations.

Overview Minimaps for giving context once user zooms in. Color based on mean link values for the links in that plane. Three different orientation options as user can look into the 3D view in the X, Y or Z directions. These views also give an overview of the communication behavior.

Interactive legend for selecting range of values to be viewed. Axes showing current orientation of the view. Clicking on any of the directions shows links in only that direction.

The 2D view can display all nodes without any occlusion. Only half of X links and half of Y links and all of Z links are shown. The Z links are along the diagonals.

3D view supports interactions like zooming, rotation and translation.
2D Visualization of Network Traffic in a 3D Torus Network Reveals Impact of Node Mappings
The Same Tools Allows Visualizing the Effects of Job Placements on Cray Machines
Organizing the Data into Contexts and Mappings Provides a Flexible and Constructive Framework

- Mappings between contexts allows analyzing new correlations
- Context specific analysis and visualization techniques lead to modular algorithms and tools
- We keep refining these ideas and concepts to
  - Develop more advanced performance analysis techniques
  - Connect to other communities such as visualization, machine learning, etc.

Dagstuhl Perspectives Workshop on Connecting Performance Analysis and Visualization to Advance Extreme Scale Computing