Visualizing Heterogeneous Performance Tested on MPI+CUDA Gigapixel Panorama Stitching

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Performance Analysis of Large Scale Simulations

- The Challenges:
  - Hundreds and thousands of interacting nodes in supercomputers
  - Each node consists of multicore CPUs and GPUs
  - Several hardware counters/events for each component
  - Data collected from all these components
  - Add to this communication data
- Overall data is complex and large

Types of Performance Data

- Data from the compute devices
  - Data at cluster level
    - Time taken by entire node to complete a task
    - Average/aggregate hardware counter values for the entire node
    - Communication packet counters for each node
  - Data at Node level
    - Data from multiple CPU cores
    - Data from multiple GPUs
  - Data at CPU/GPU level
    - Data from a particular CPU core
    - Data from a particular GPU

Hardware Domain

Types of Performance Data

- Data obtained from logical data transfers
  - Sizes of message exchanges between processes
  - Communication graphs of interacting processes
  - Message traces

Communication Domain

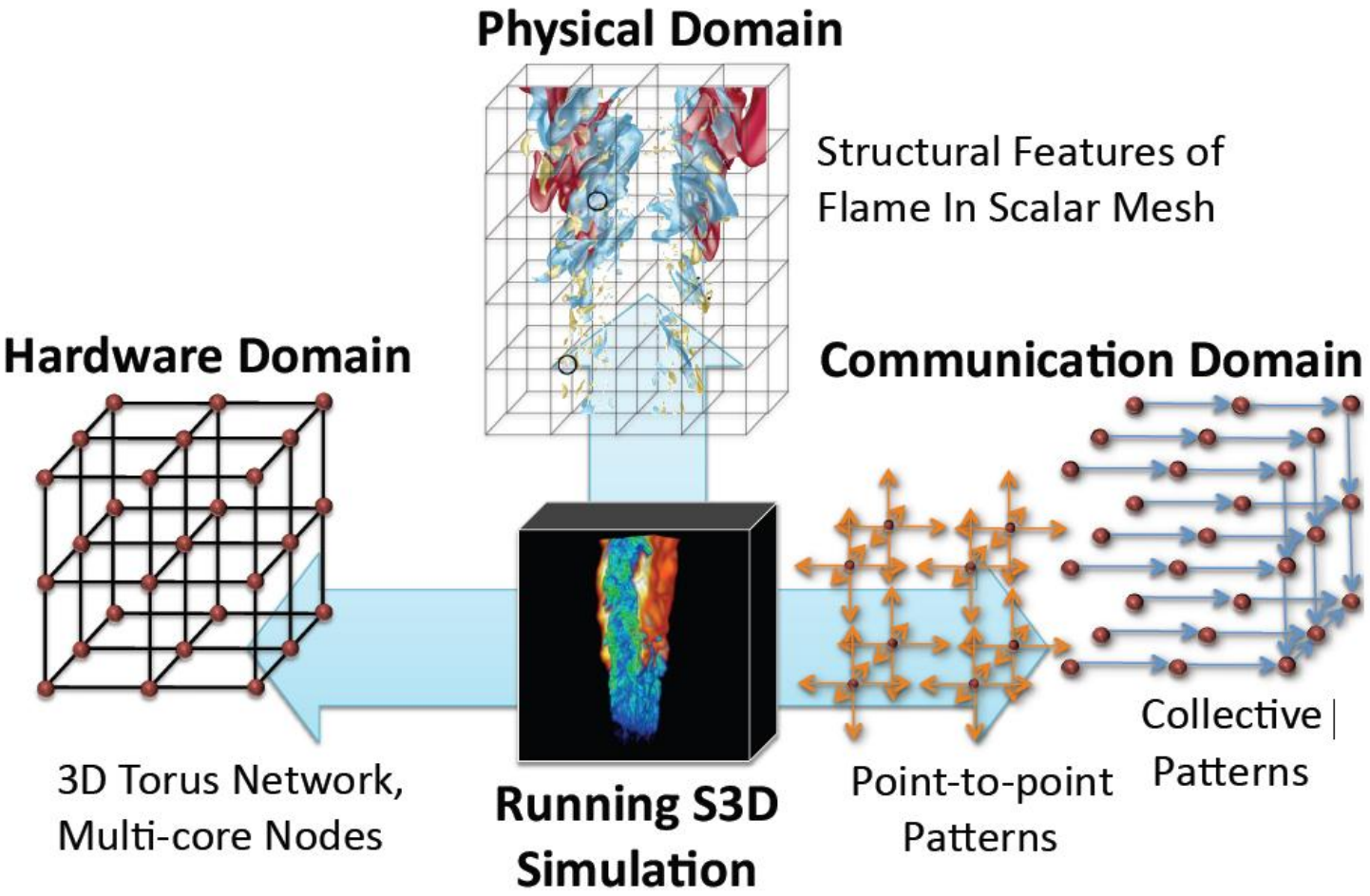
Current Techniques

- Focused on independent analysis of:
  - Hardware domain:
    - 2D/3D plots and graphs
    - 3D views representing topology of the system
  - Communication domain:
    - MPI traces
    - Communication graphs
- These techniques are unintuitive while dealing with large scale simulations

Application Domain

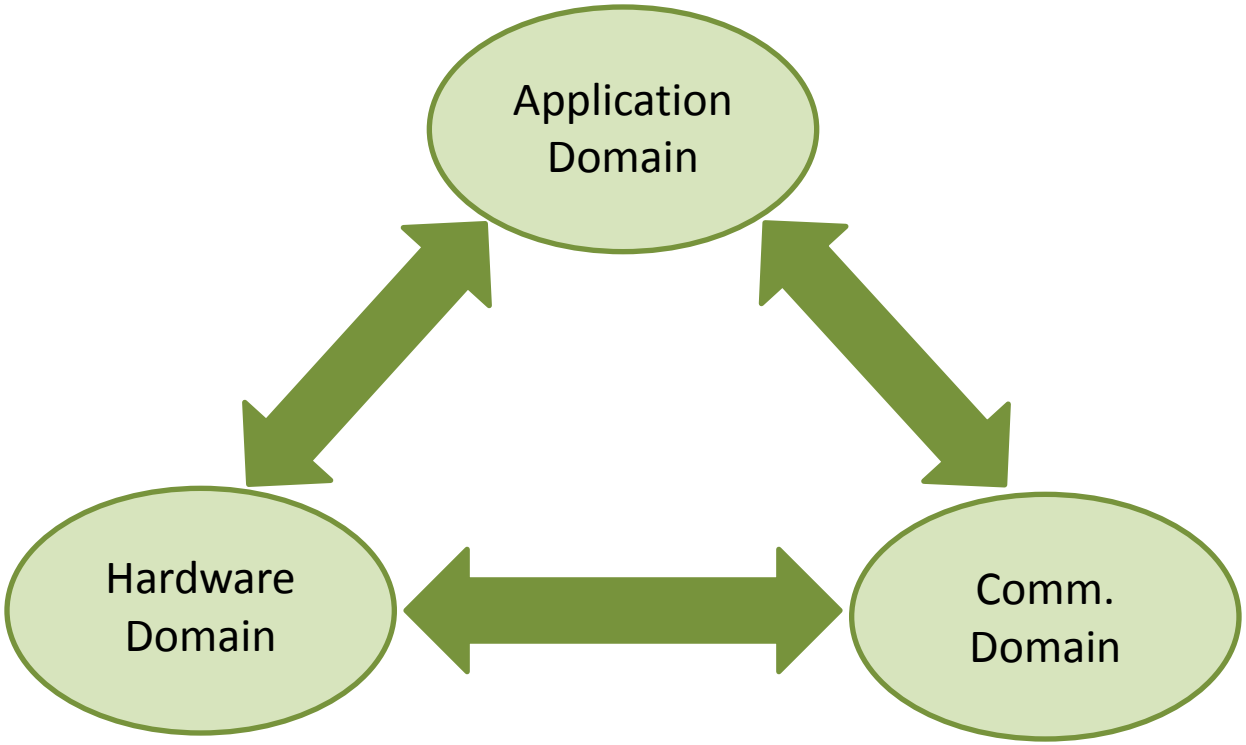
- Representation of the problem as a mesh, large matrices or graphs
- Provides the mental reference frame while code design
- Most familiar to application scientists

The Three Domains

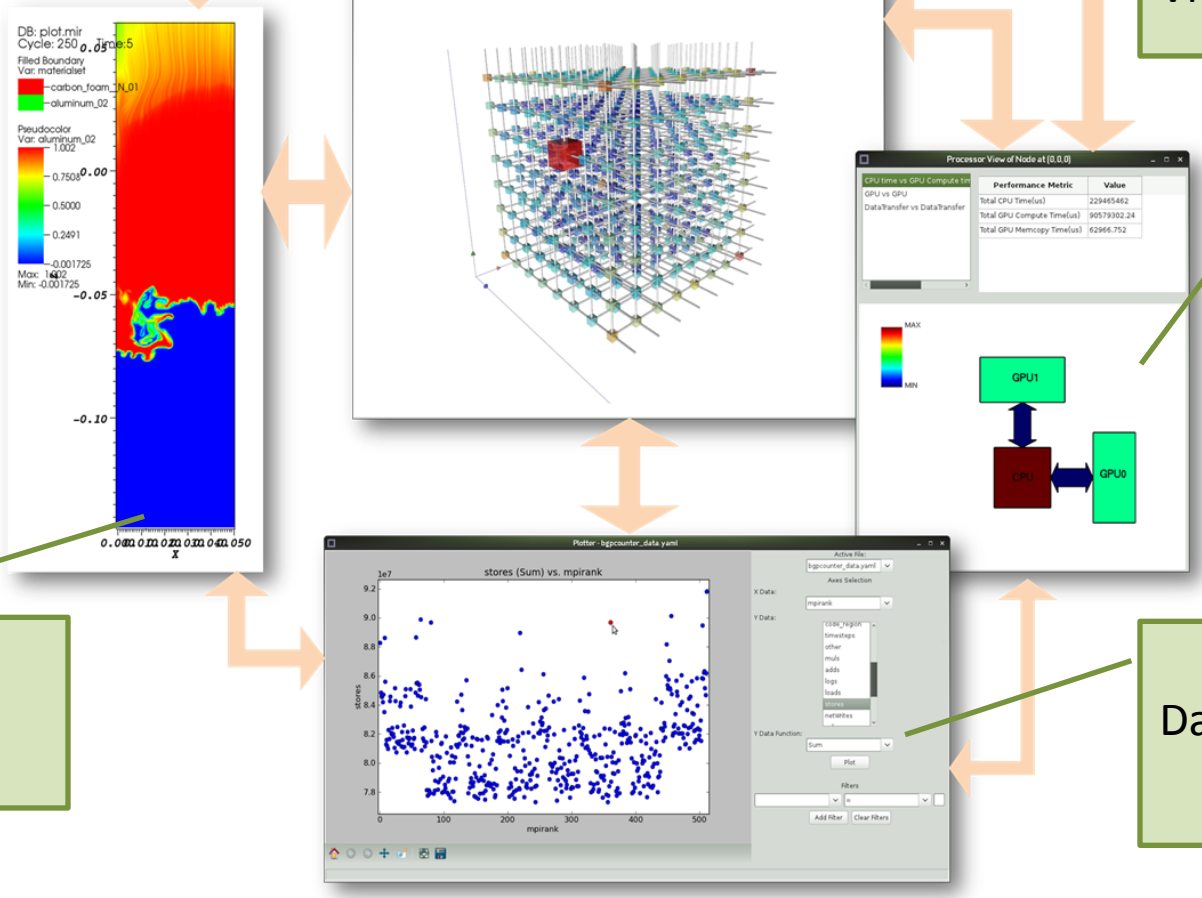


The HAC Model

Mapping between domains



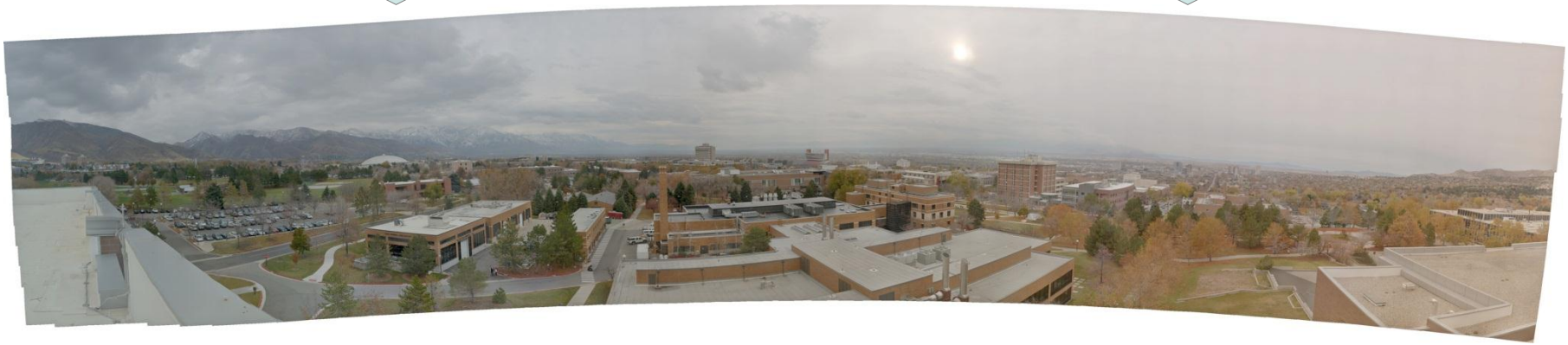
Interactive Linked Views



Case Study - Seamless Panorama Stitching

3.2 Gigapixel Image

Gradient Domain Blending



Gradient Domain Image Processing

Gradient

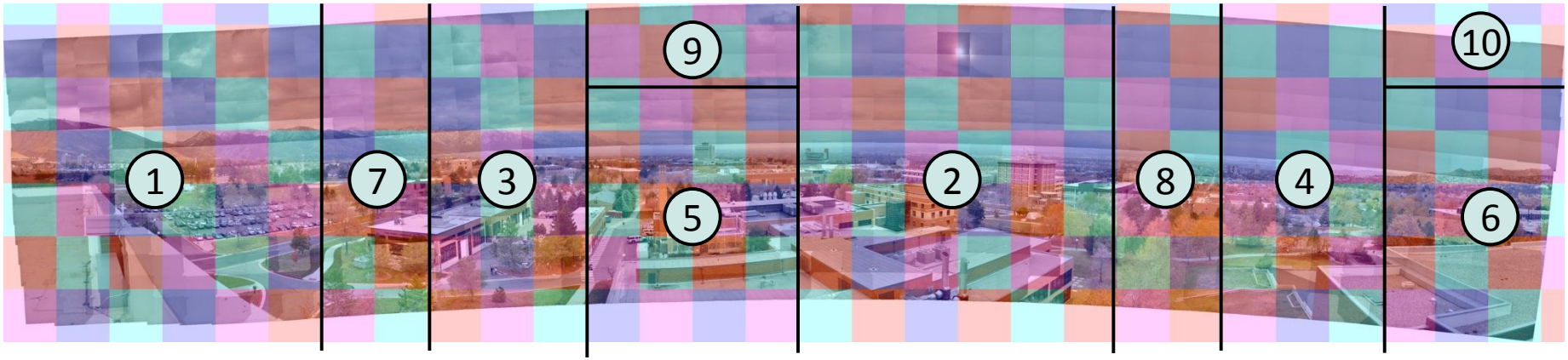
Process

Solve

Hybrid Parallel Scheduling

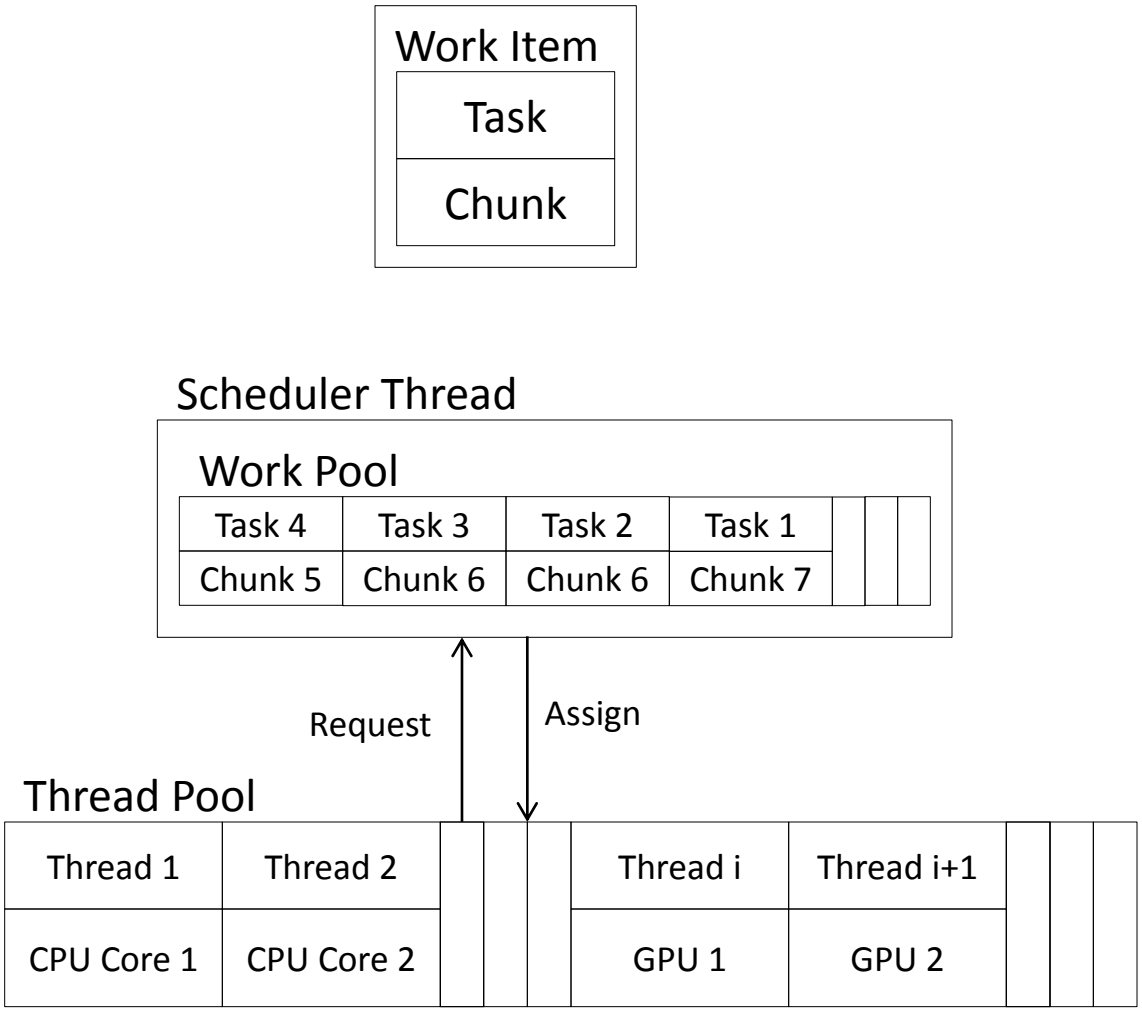
Divide the image into tiles and solve the tiles independently and in parallel:

Static scheduling among nodes of a cluster:



Hybrid Parallel Scheduling

Intra-node Scheduler:



Hybrid Parallel Scheduling

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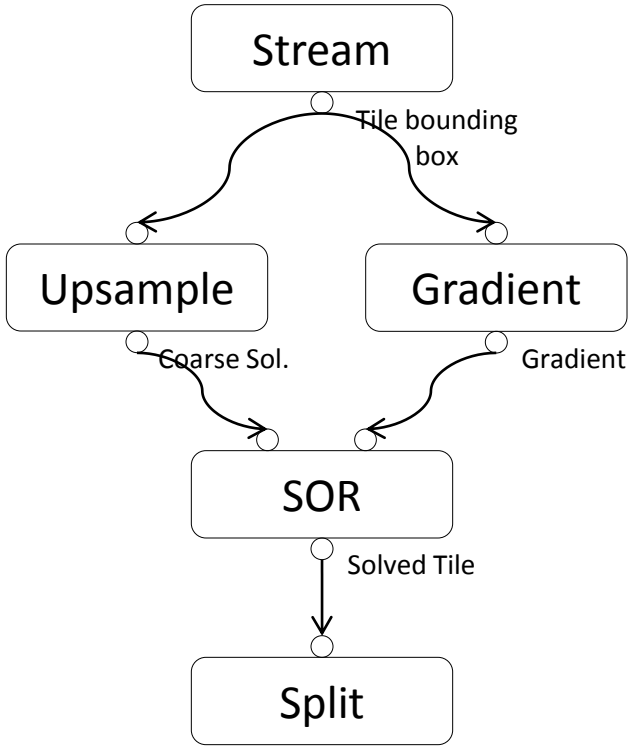
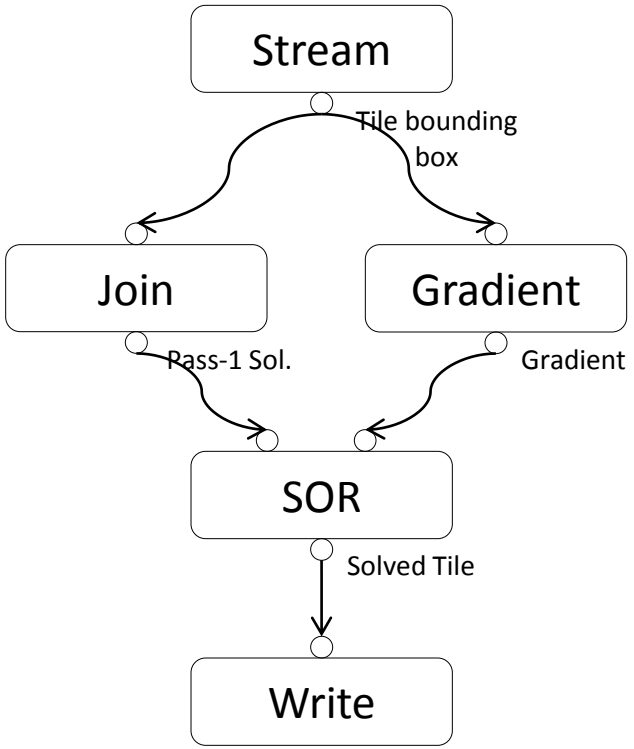


Pass 1 Task Graph



Pass 2 Task Graph

Results

Fall Panorama – 126,826 x 29633, 3.27 gigapixel

Application Setup

- Test Setup:
  - Tile size of 1024 x 1024 was chosen
  - Fall data has 124 x 29 tiles
  - Tests were on the following system:
    - **HP Cluster:** 2.67 GHz Xeon X5550 (8 cores), 24 GB RAM, 2 NVIDIA Tesla T10 GPUs per node.
- Data Collection:
  - Using PAPI for CPUs and CUPTI for NVIDIA GPUs

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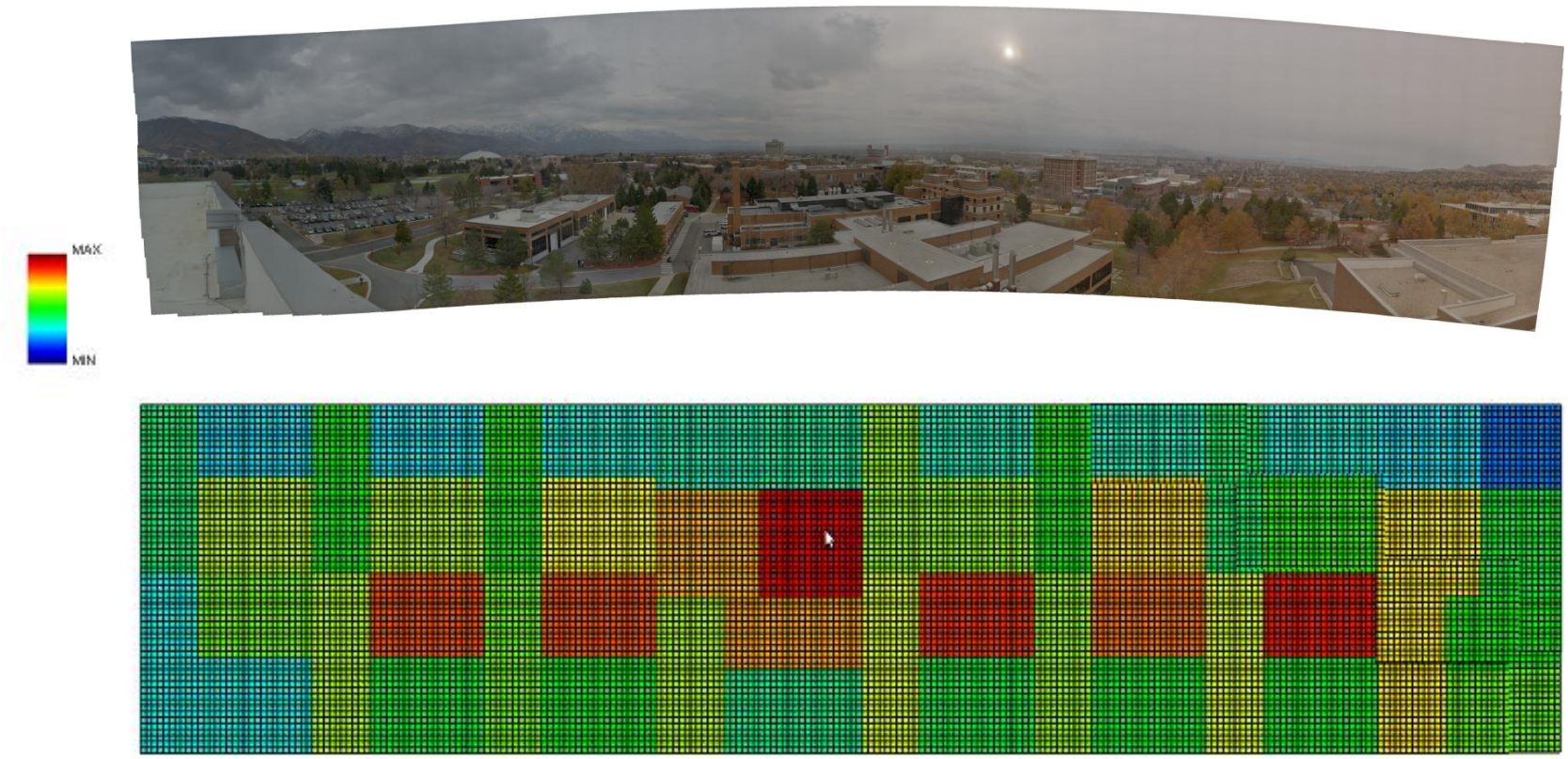
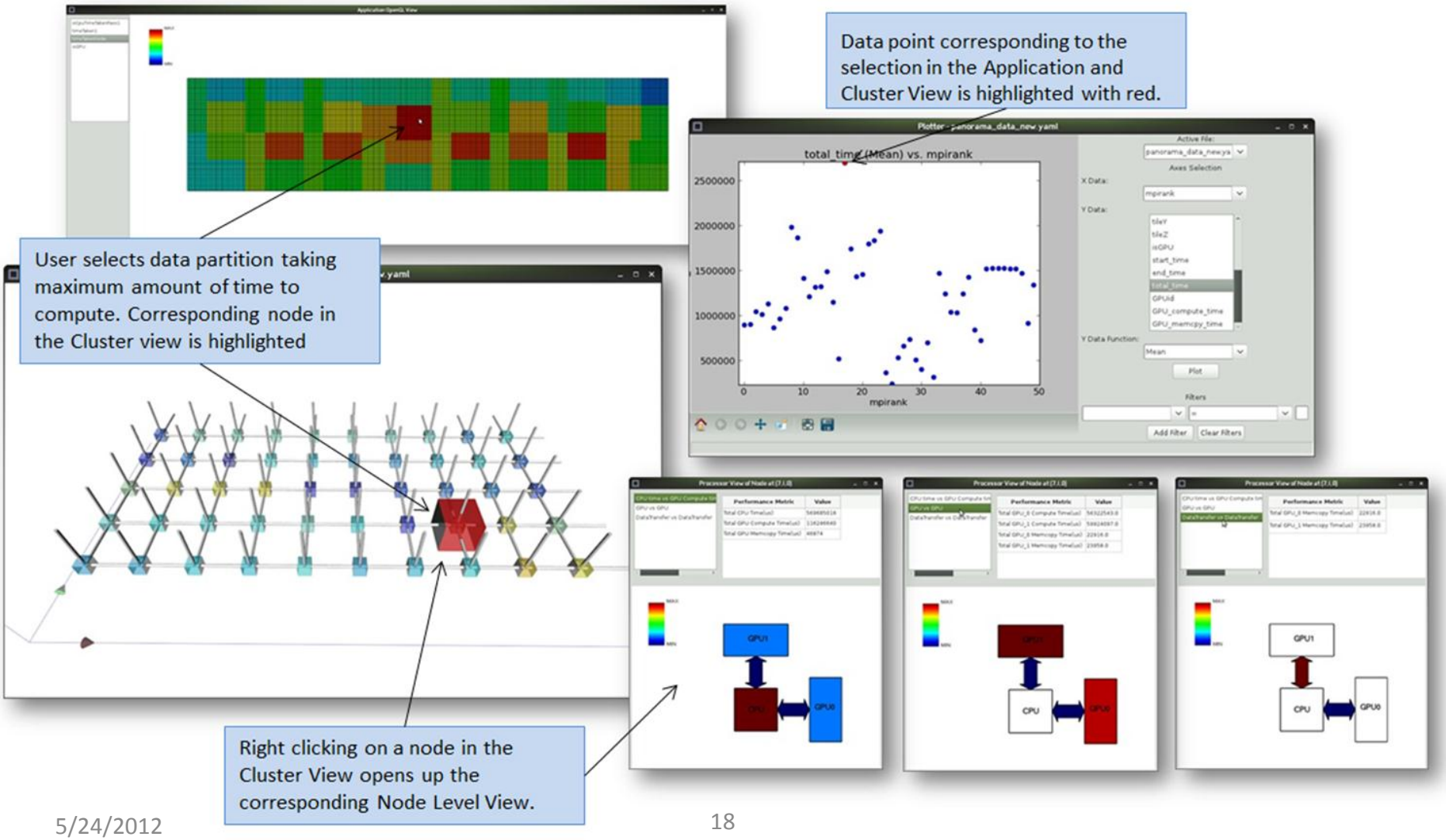
Hardware to Application Mapping

Insight into load balancing

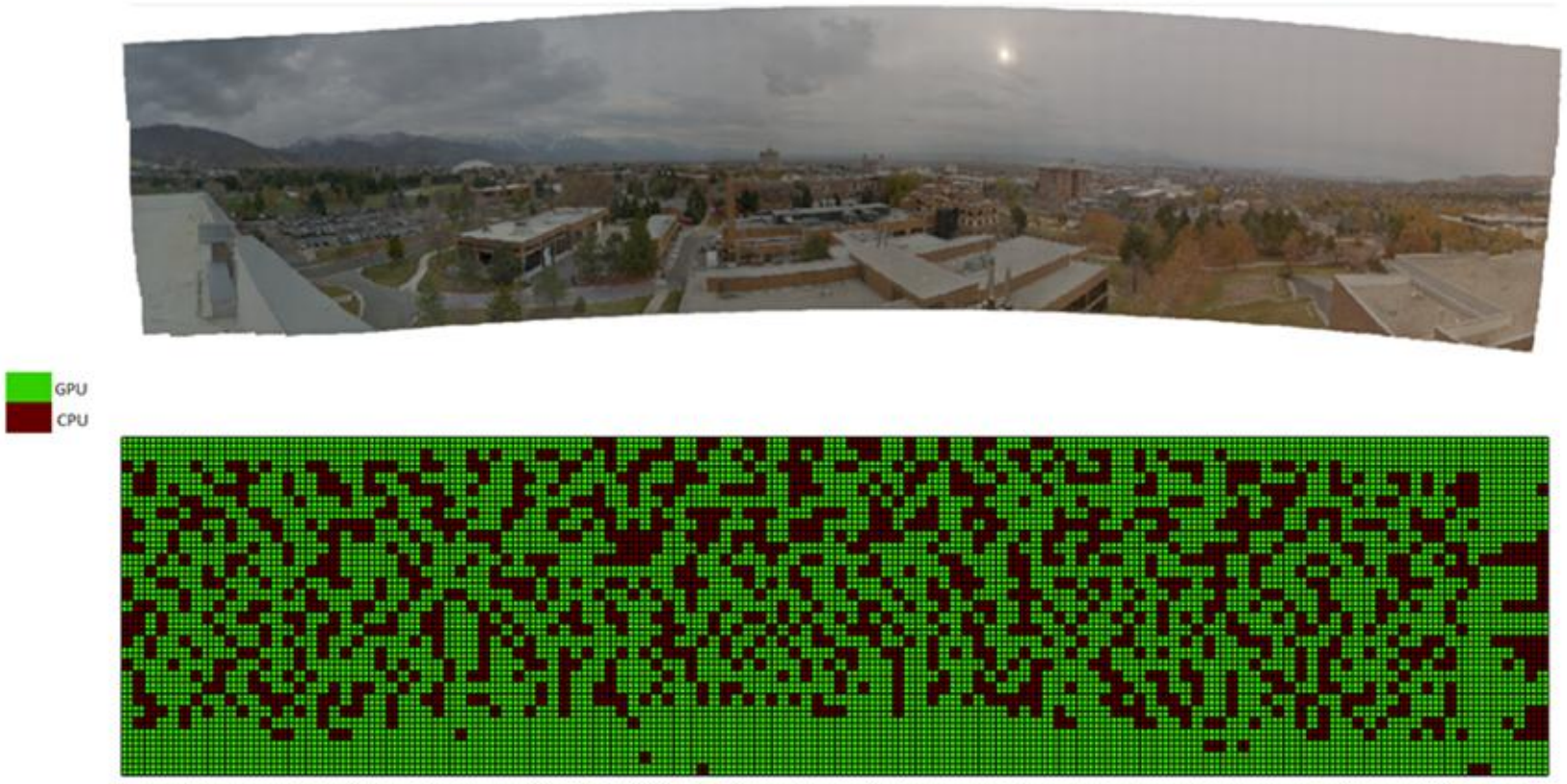


Interaction between Views



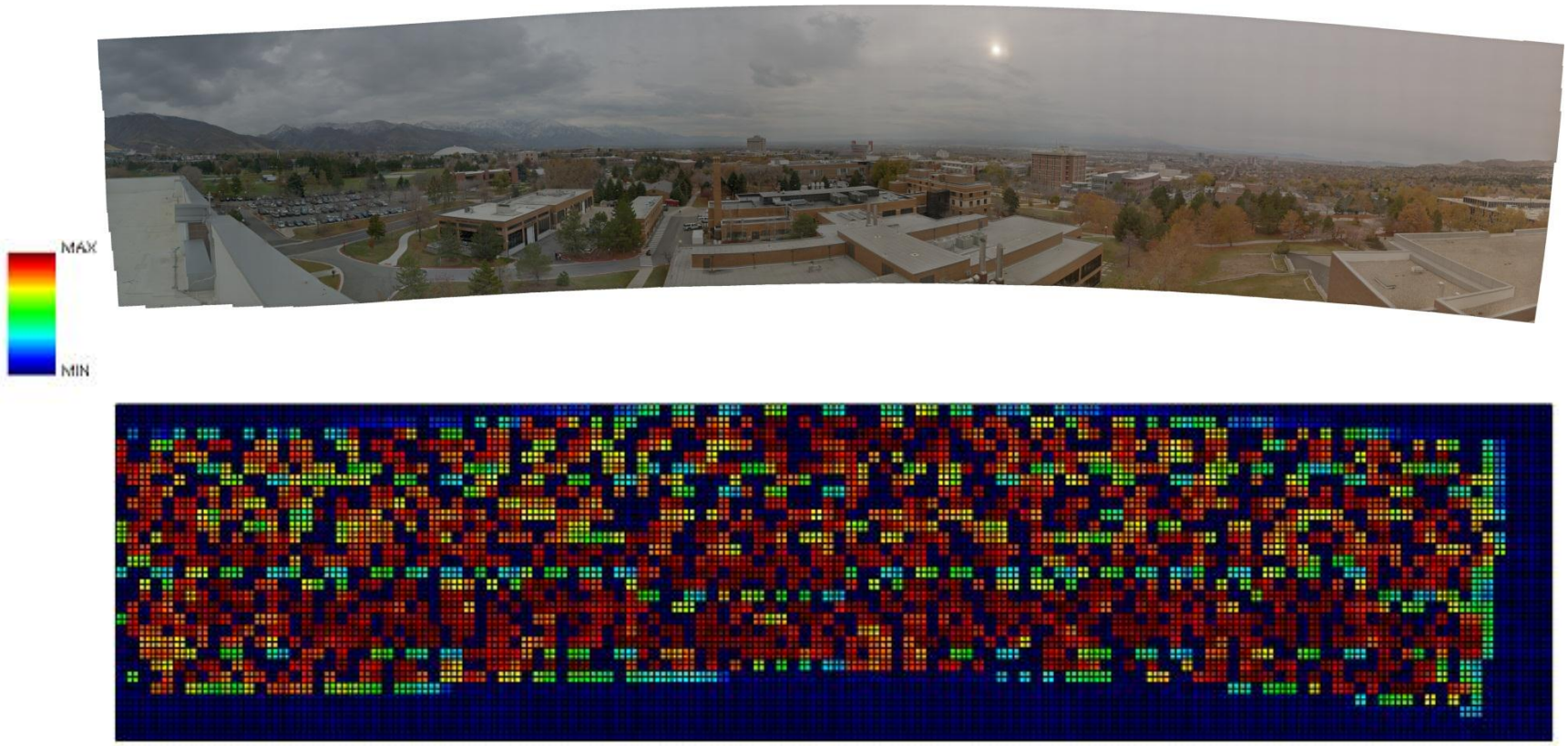
Hardware to Application Mapping

Insight into GPU utilization

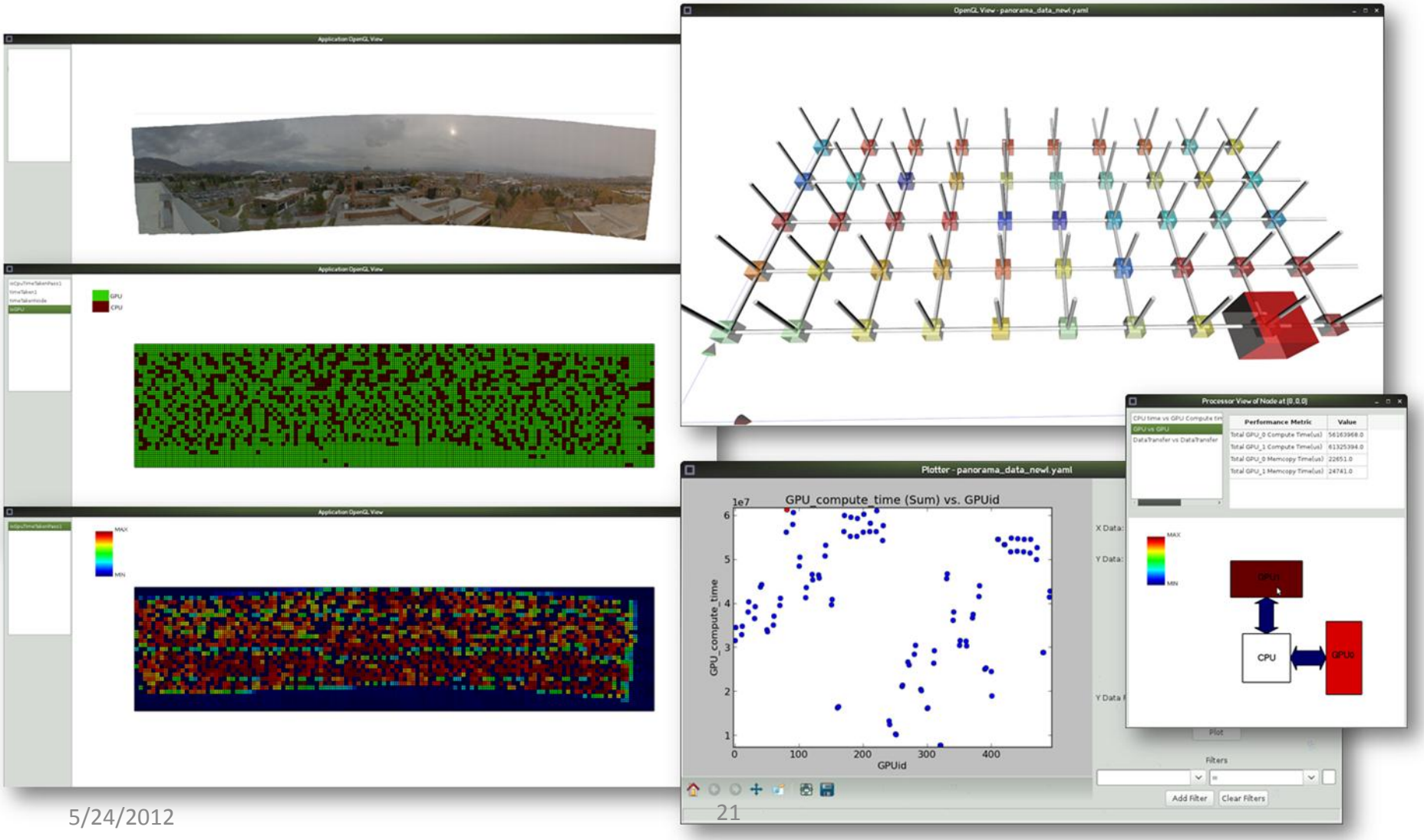


Hardware to Application Mapping

Time taken by each tile when processed on GPU



Interaction between Views



Summary

- A new approach for performance visualization of heterogeneous supercomputers using the HAC model
- An interactive linked views based tool for visualizing performance
- A more intuitive and insightful way of looking at application performance run on supercomputers

Future Work

- Right now support for only 2D structured data, add support for 3D data
- Create clean and user friendly APIs for data collection
- Help show application topology on hardware domain
- Use various data analysis techniques on the performance data once mapped onto app domain
- Allow fine grained perf analysis visualization for data on a single GPU
- Generate views for the communication domain

References

- M. Schulz, J. A. Levine, P-T Bremer, T. Gamblin, and V. Pascucci. **Interpreting performance data across intuitive domains.** International Conference Parallel Processing, Sept. 2011

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- S. Philip, B. Summa, P-T Bremer, V. Pascucci. **"Hybrid CPU-GPU Solver for Gradient Domain Processing of Massive Images,"** In *Proceedings of 2011 International Conference on Parallel and Distributed Systems*, pp. (accepted). 2011.

Acknowledgments

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Implementation Overview

(1) Global and large scale trends in the image are missed: