Profiling with Rice HPCToolkit

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http://hpctoolkit.org

HPCToolkit Basic Features

- **Run application natively and every 100-200 times per second, interrupt program and record snapshot of call stack and then combine these into a calling context tree (CCT).**
- **Combine sampling data with a static analysis of the program structure: loops, inline functions, etc.**
- **Present top-down, bottom-up and flat views of calling context tree (CCT) and time-sequence trace view. Metrics are displayed per source line in the context of their call path.**
- **Can sample on Wallclock (itimer), POSIX timers and Hardware Performance Counter Events (PAPI preset and native events): cycles, flops, cache misses, etc.**

HPCToolkit Advanced Features

- **Finely-tuned unwinder to handle multi-lingual, fully-optimized code, no frame pointers, broken return pointers, stack trolling, etc.**
- **Derived metrics -- compute flops per cycle, or flops per memory reads, etc. and attribute to lines in source code.**
- **Compute strong and weak scaling loss, for example:**

strong: 8 * (time at 8K cores) - (time at 1K cores)

weak: (time at 8K cores and 8x size) - (time at 1K cores)

- **Load imbalance -- display distribution and variance in metrics across processes and threads.**
- **Blame shifting -- when thread is idle or waiting on a lock, blame the working threads or holder of lock.**

The Good and the Not Quite So Good

- **What we do well**
  - — core events tied to specific process/thread: cycles, flops, cache misses via hardware performance counters
  - — attribute events to source code, function calls and loops
- **What we do not so well**
  - — system-wide events: network and I/O latency, throughput, congestion, shared cache (L2 on BG/Q)
  - — scaling issues to 1,000,000 cores

Where to find HPCToolkit

- Home site: user's manual, build instructions, links to source code, download viewers:

  http://hpctoolkit.org/

- On mira, cetus, tukey:

  /projects/Tools/hpctoolkit/pkgs-mira/hpctoolkit/bin

  /projects/Tools/hpctoolkit/pkgs-tukey/hpctoolkit/bin

- Source code via anonymous svn checkout:

  http://code.google.com/p/hpctoolkit/

- Send questions to:

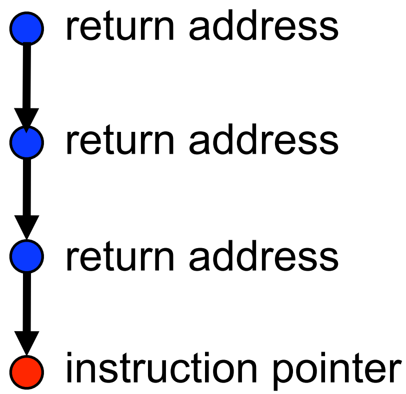
  hpctoolkit-forum at mailman.rice.edu

Call Path Profiling

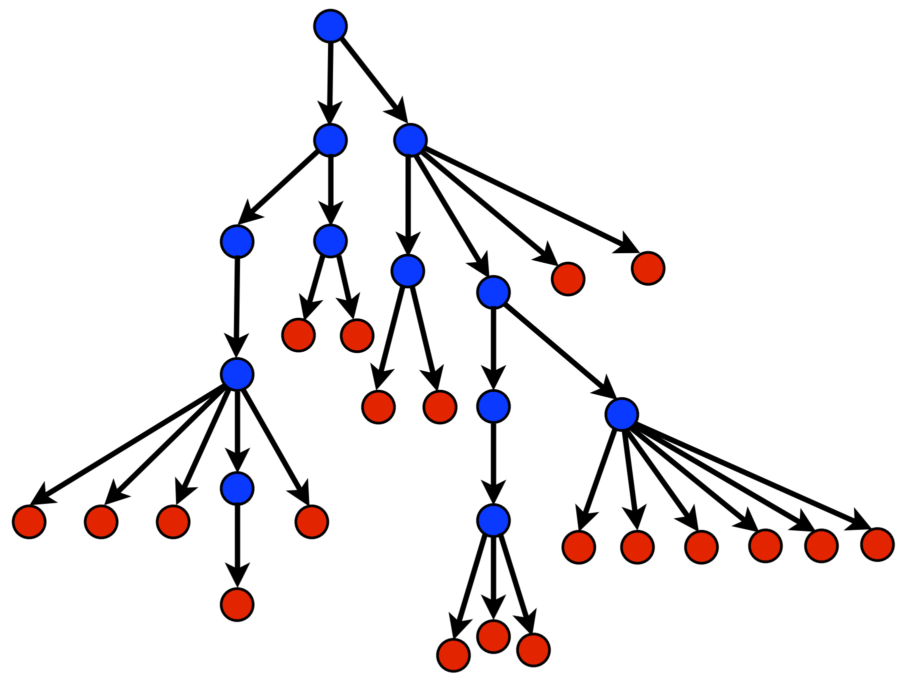
Measure and attribute costs in context

- **sample timer or hardware counter overflows**
- **gather calling context using stack unwinding**

Call path sample



Calling context tree

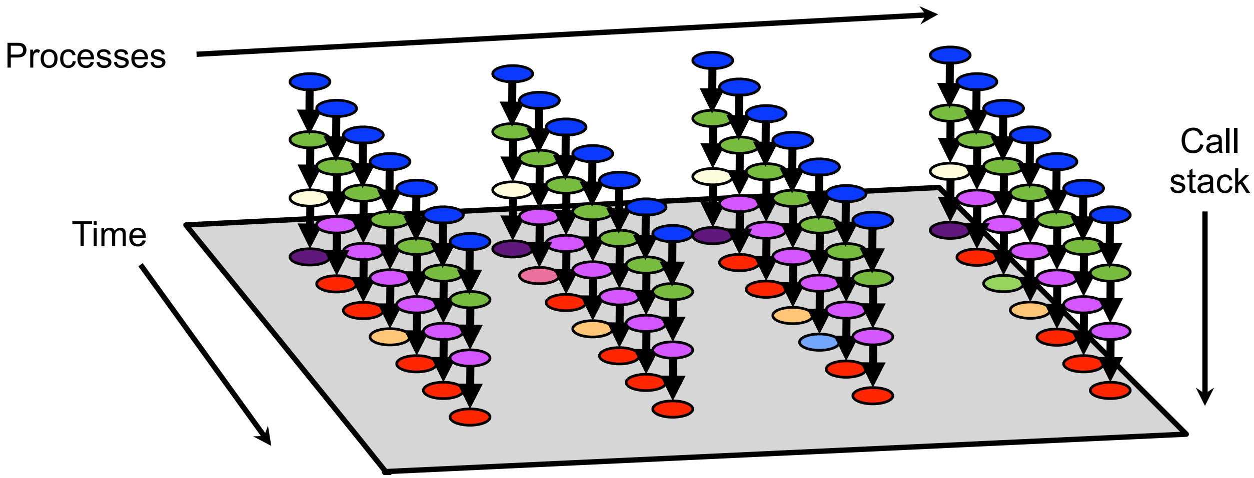


Overhead proportional to sampling frequency...
...not call frequency

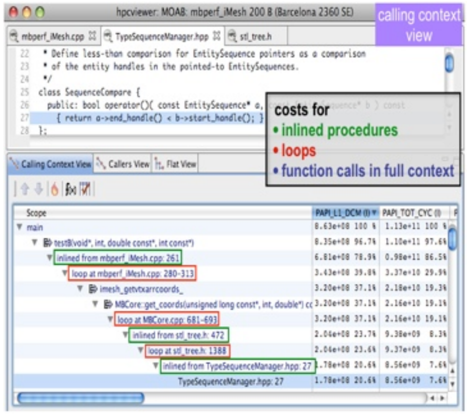
Understanding Temporal Behavior

- **Profiling compresses out the temporal dimension**
  - —temporal patterns, e.g. serialization, are invisible in profiles
- **What can we do? Trace call path samples**
  - —sketch:
    - – N times per second, take a call path sample of each thread
    - – organize the samples for each thread along a time line
    - – view how the execution evolves left to right
    - – what do we view?

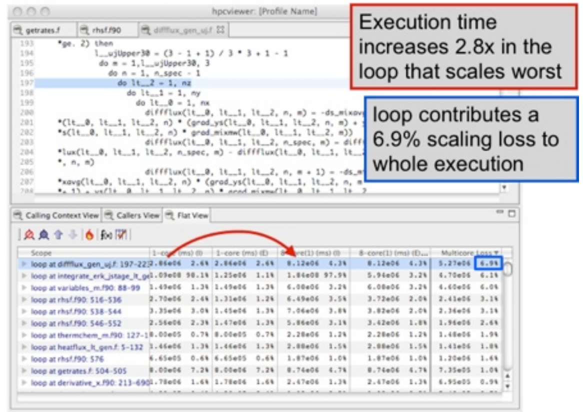
      assign each procedure a color; view a depth slice of an execution



HPCToolkit Capabilities at a Glance

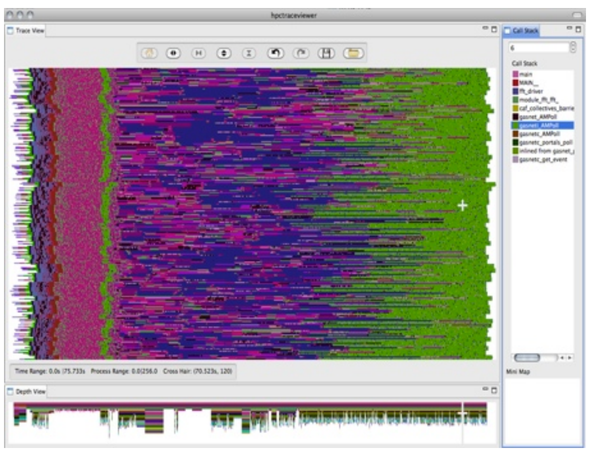


Attribute Costs to Code

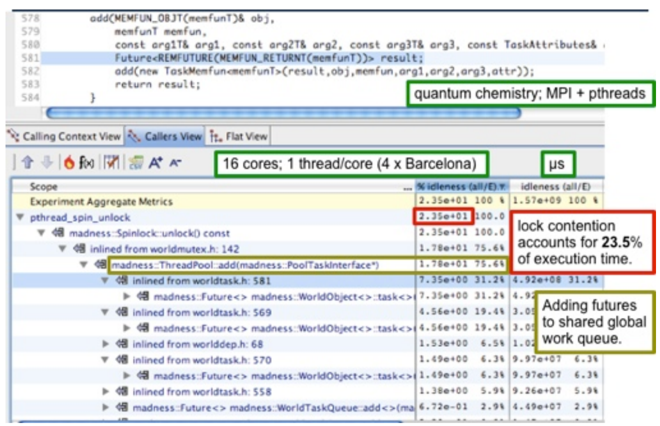


Pinpoint & Quantify Scaling Bottlenecks

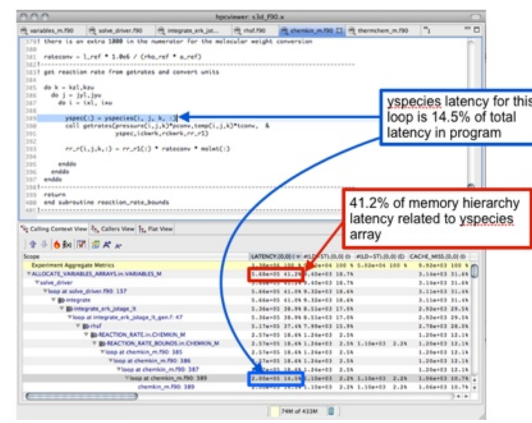
Assess Imbalance and Variability



Analyze Behavior over Time



Shift Blame from Symptoms to Causes



Associate Costs with Data

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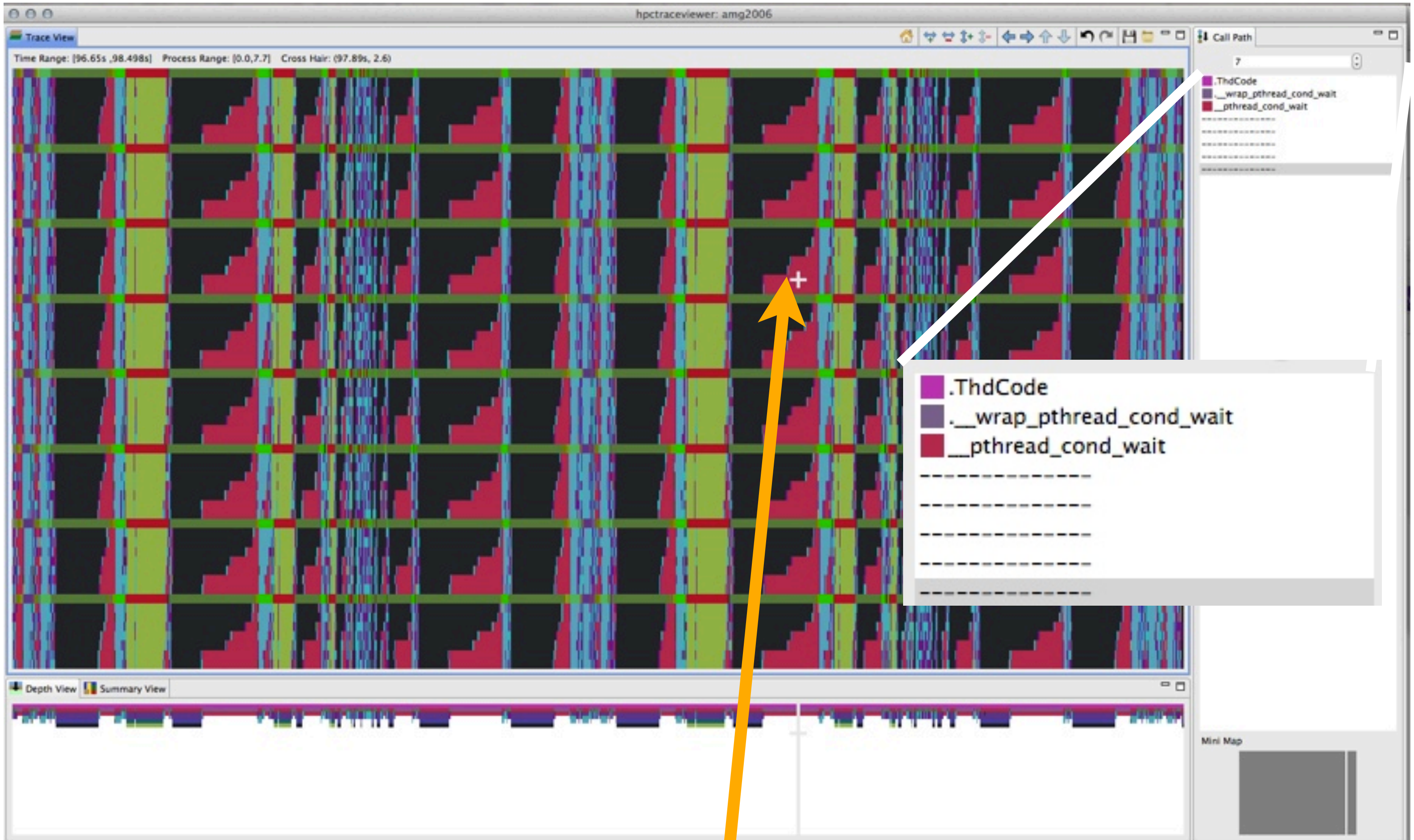
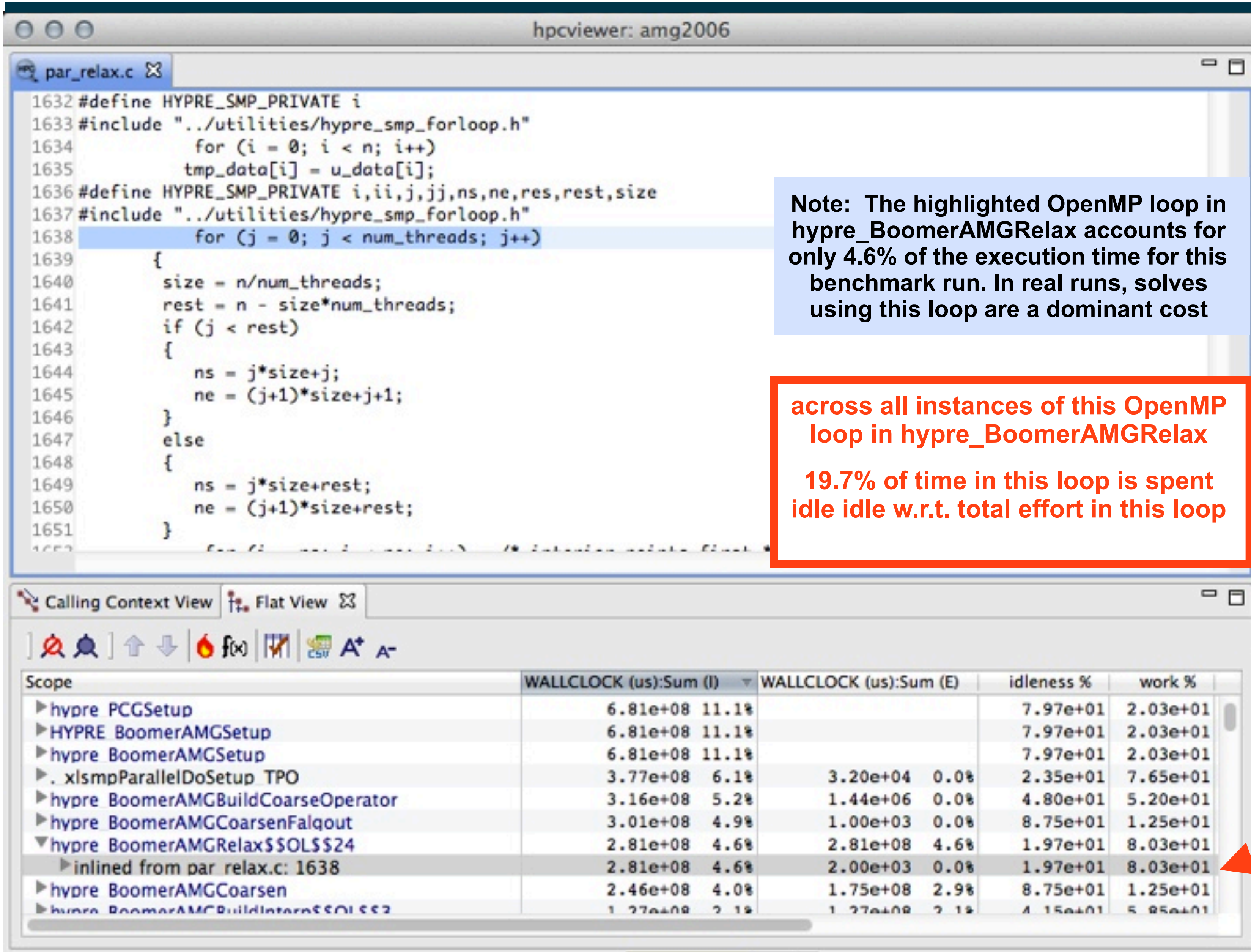
AMG2006: 8PE x 8 OMP Threads



OpenMP loop in `hypre_BoomerAMGRelax` using static scheduling has load imbalance; threads idle for a significant fraction of their time

Code-centric view: `hypre_BoomerAMGRelax`

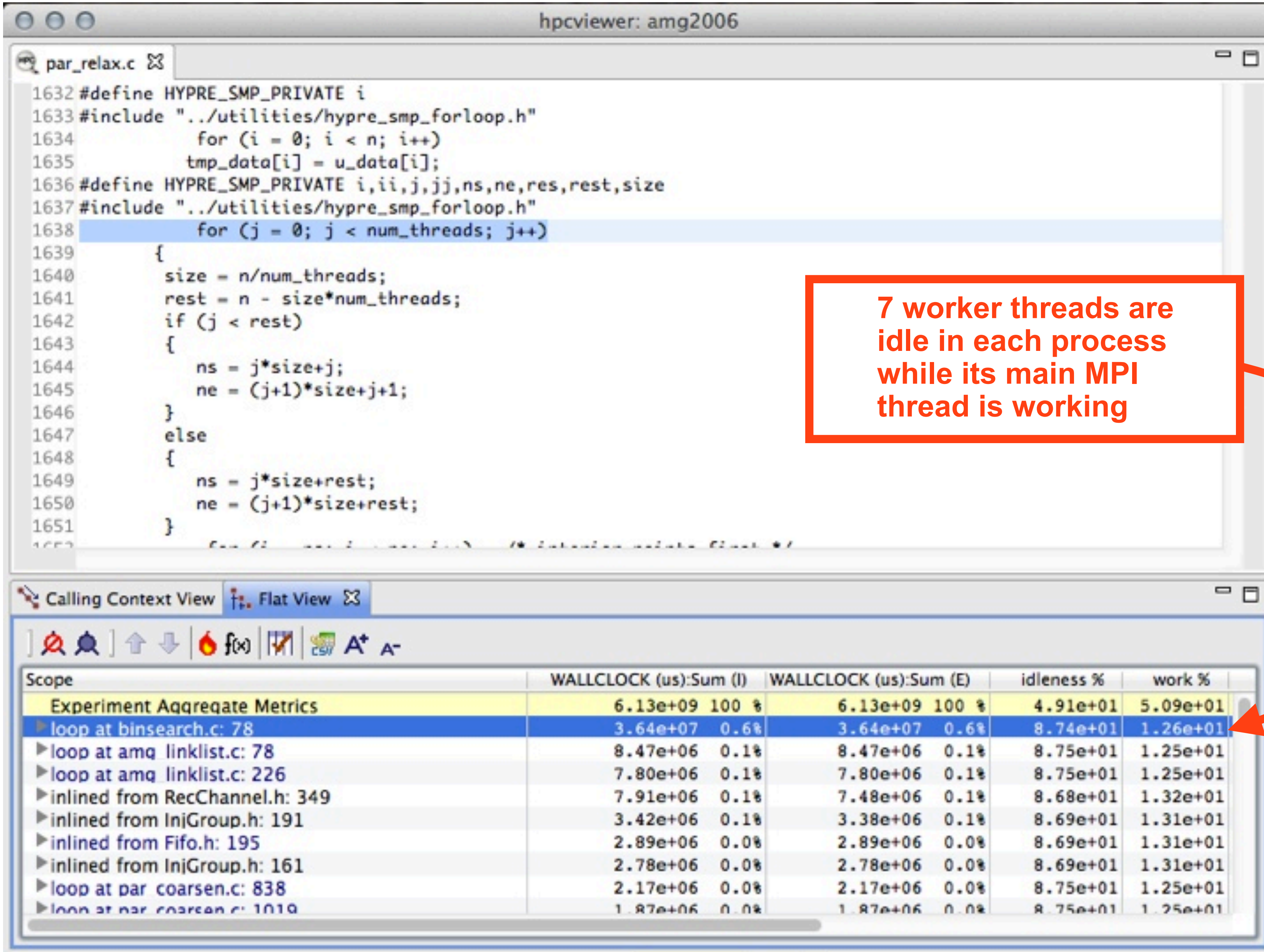


Note: The highlighted OpenMP loop in hypre_BoomerAMGRelax accounts for only 4.6% of the execution time for this benchmark run. In real runs, solves using this loop are a dominant cost

across all instances of this OpenMP loop in hypre_BoomerAMGRelax

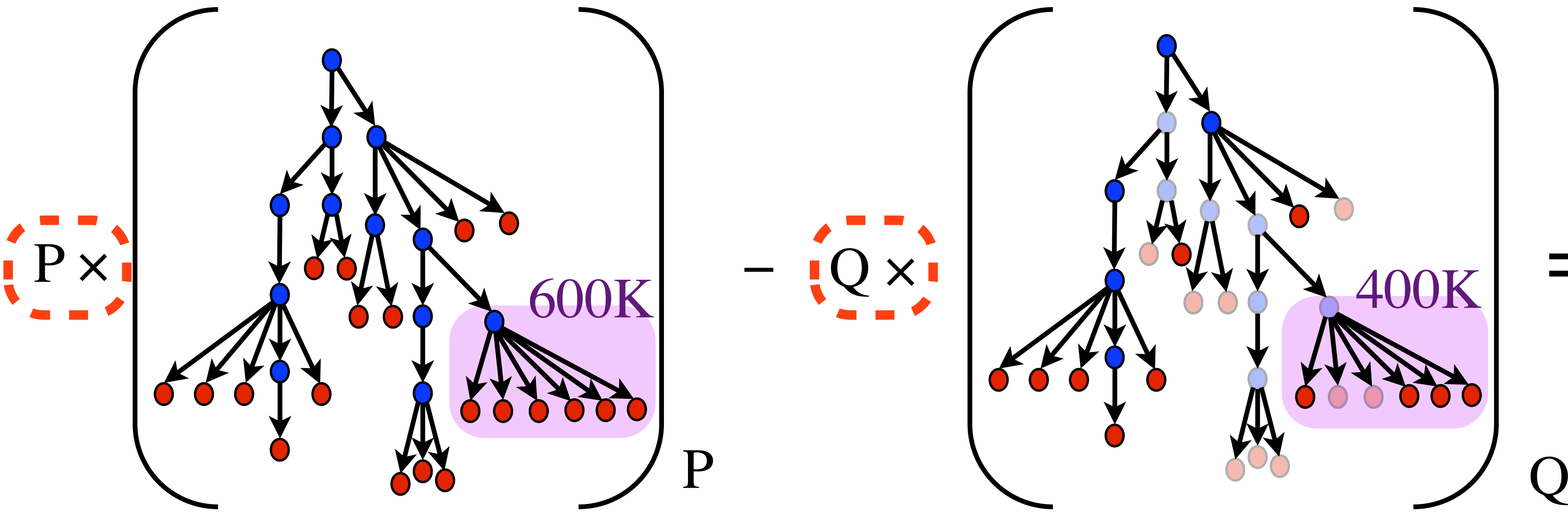
19.7% of time in this loop is spent idle idle w.r.t. total effort in this loop

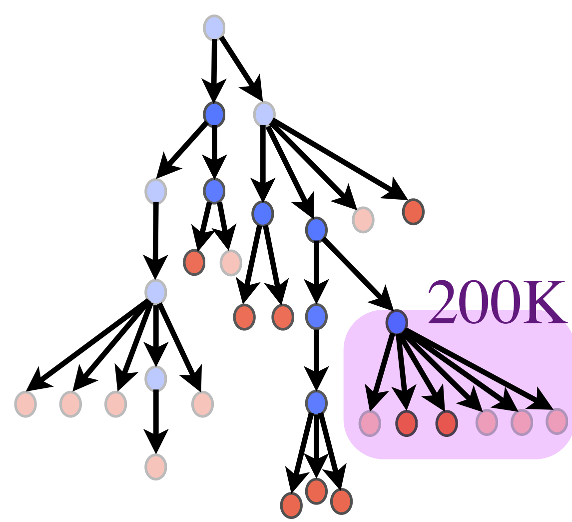
Serial Code in AMG2006 8 PE, 8 Threads



7 worker threads are idle in each process while its main MPI thread is working

Pinpointing and Quantifying Scalability Bottlenecks





coefficients for analysis of strong scaling