Challenges of HPC Software Debugging Include

- Heterogeneity: hardware (CPUs, GPUs, …)
- Extreme scale: number of threads/cores
- Rapid evolution: new CPUs/GPUs/libraries
- Reality: High manual effort to annotate code
- Reality: No tools that collect enough debugging information per large-scale run with low overhead (Service Units or Core Hours get exhausted, precluding “second run”)

Prior Work (exemplars)

CommercialDebuggers

- Very good at detailed trace collection
- Good at minutely examining execution state
- Poor at handling scale
- Little help toward identifying the root cause
- Little help bridging concurrency models

Research Lab Tools

- Stack trace collection based
  - Often for MPI
  - Progress tracking
  - Often based on loop progress order
  - Example: STAT, AutomadeD, Protometer (LLNL), Dynoptic (UW)
- Do not exploit behavioral differences

Use of Coalesced Stack Trace Graphs

- Proven useful in large code base
- Summarizes stack nests
- Does not handle heterogeneity
- While overhead is low, it was not focused toward synchronizations across multiple concurrency models

Example use of Coalesced Stack Trace Graphs in detecting uninitialized variables in Uintah code base (University of Utah; see LCPC 2014)

Nondeterminism due to Uninitialized Variable (Poisson2 Example)

Largest Scale Tested

Other Case Studies Planned

- A Rigorous Global Optimizer for Floating-Point Precision Estimation
- Parallelized versions of a GPU Data Race Checker
- Using parallel execution frameworks to parallelize verification

Ongoing Work

Case Study: ILCS

- A heterogeneous concurrent program called the Iterative Local Champion Search (ILCS) has been chosen

ILCS combines three flavors of concurrency

- MPI
- OpenMP
- GPU

Execution Flow of ILCS

Anticipated Tools and Utilities

- Control tracing utilities for heterogeneous concurrency
- A graphical tool for querying collected control dependencies for debugging

Merit, Impact, Milestones, Students

Work in progress

1) CPU ↔ GPU control tracing methods
2) CPU ↔ XeonPhi control tracing methods
3) Binary Instrumentation Methods for Heterogeneous Trace Collection

Intellectual Advances, Broader Impact

- Ways to track “happens before” at scale
- Ways to mine the tracked information for finding the root causes of bugs
- Enabling science at scale
  - Achieving Extreme Scale requires the use of powerful debugging tools
  - An understanding of what information to collect, how collection scales, and how it facilitates debugging
  - Effective utilization of HPC resources
  - System heterogeneity is only bound to increase — impactful beyond HPC

Anticipated Tools and Utilities

- Control tracing utilities for heterogeneous concurrency
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Student Training

- Saeed Taheri, PhD
- Sindhu Devale, MS
- Kurstie Lenear (BS, graduated)