Evaluating Non-deterministic Multi-threaded Commercial Workloads

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Introduction

• Short measurements on real machines require multiple runs
  – Uncontrolled factors
  – Want to separate random from systematic effects

• Simulation measurements use a single run
  – Simulators are deterministic
  – No uncontrolled factors

• Wrong!
  – Multi-threaded workloads can be unstable
  – Small changes in timing cause large changes in results

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Introduction

• Instability may affect conclusions
  – Comparing Direct Mapped to Set-Associative Caches
Overview

• Introduction
• Methods
• Workloads
• Result I: Process scheduling
• Result II: Workload Variability
• Conclusion
• Future Work
Methods

• Real machine
  – Setup, tune, validate on a 16-processor Sun E6000
  – 8 – 16 X speed-up for each application

• Simulator
  – Simics, Full-system simulator running Solaris 8
  – Ruby, Memory timing simulator

• Experiments
  – Start from a warm checkpoint
  – Measure throughput (transactions completed / time)
Workloads

- **OLTP**
  - TPC-C-like benchmark using a 1 GB database
- **SPECjbb**
  - Server-side Java-based middleware workload
- **Apache**
  - Static web serving: Apache driven by SURGE
- **Slashcode**
  - Dynamic web serving message board, using code and data similar to slashdot.org
Why unstable?

- Different paths are executed
- Hypotheses
  - Process scheduling
  - Order of lock acquisition
Result I: Process scheduling

- Deterministic simulation of OLTP on *uniprocessor*
- Artificially injected misses to I-cache
  - Run1: 0, 100, 200 …
  - Run2: 50, 150, 250 …
- Measured equivalent to 3-5 seconds in real system
- Run time difference of 9%
- Is process scheduling a factor?
Result I: Process scheduling

- Traced process groups scheduled on CPU

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Methods, part II

- Pseudo-random perturbations
  - Run multiple runs from same checkpoint
  - All runs have same average memory latency
  - Misses to main memory perturbed by 0-4%
- Calculate mean, standard deviation
Result II: Variability

- **Variability**
  - 16-processor system running 8,000 OLTP transactions
  - 20 runs from same checkpoint
  - 12 – 20 seconds in real system
- 1 / Throughput (cycles per transaction)
Result II: Variability

- Miss rate (misses per transaction)
Result II: Variability

- Instructions executed (per transaction)
- Hypothesis
  - “Spin-waiting” hypothesis
  - Lock-acquisition, idle loop, device activity

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Result II: Variability
Conclusion

• Multi-threaded commercial workloads can be unstable even on uniprocessors
• Instability can affect conclusions in short runs
• Pseudo-random methodology can help
• Even within one workload variations exist
Future Work

- Root cause(s)?
- Methodology improvements
- Quantify instability further
Questions