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

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

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

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