Analysis of Simulation Results

Computer Systems Performance Modeling and Evaluation

Department of Electrical and Computer Engineering
Shiraz University
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Reza Azimi
[Some of the Slides are based on Raj Jain’s]

Overview

- Model Verification
- Model Validation
- Transient Removal
- When to Stop Simulation
Model Verification

- Goal: To verify that the simulation software is actually implementing the model correctly.

- Basic Techniques
  - Debugging and Testing
  - Deterministic Models
  - Collecting Traces

Debugging and Testing

- Conventional Debugging
- Continuity Tests
- Consistency Tests
Conventional Debugging

- Modular Design
  - Helps isolate and contain bugs

- Code Walkthrough

- Simple Test Cases
  - Example: one packet in the system, one job in the system, etc.

- Corner (Extreme) Cases
  - also known as “boundary conditions”
  - Examples: very high network latency, very high CPU service time, a disk with the capacity of only one block, etc.

Conventional Debugging (cntd.)

- Anti-bugging
  - Explicitly instrumenting simulation code with
    - model assumptions
    - program checks
  - Examples:
    - Sum of probabilities should be 1
    - Number of packets in the system = number of packets arrived – number of packets left
    - Number of alive nodes in a cluster < Total number of nodes
Continuity Tests

- Run simulation for different input values:
- A small change in the input should result in a small change in the output.
- Generally true, but not all the time.

Figure from: C. Bienia et al., The PARSEC Benchmark Suite: Characterization and Architectural Implications, in PACT08.

Consistency Tests

- There should not be any contradictions in the simulation results:
  - Examples:
    - Doubling the number of users in the system should increase the load (arrival of the requests), but it does not.
    - Increasing cache size should either improve hit rate or leave it unaffected, but it decreases hit rate.
    - Increasing the number of CPUs from 2 to 4 increases application performance, but from 1 to 4 decreases it.
Deterministic Model

- Random input => different output

- Removing Randomness
  - Allow user to specify the values for random variables (constant values)
  - Check whether the output for the specific input values is correct or not

- Example:
  - An LRU page replacement policy for a sequential access pattern should generate miss on every access

Collecting Traces

- Trace: a time-ordered list of events in the system.

- Key Idea: every repetition of the simulation would result in different set of events in different order at different time (due to the random nature of the input)
  - Debugging is hard without exact reproduction of the bugs

- Collecting a trace helps understanding what exactly has happened during a simulation.
Model Validation

- **What to Validate**
  - Assumptions
  - Input parameter distribution
  - Output values and conclusions

- **How**
  - Expert Intuition
  - Real System Measurement
  - Theoretical Results

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Expert Intuition

- **Experts**
  - Analysts
  - System Designers
  - Developers
  - Managers
  - Administrators/Technical Support

- The assumptions, input, and output of the model must be clearly presented.
Real System Measurement

- Compare simulation results against measurement of a real system

- Advantage: real and reliable

- Disadvantage: not always possible
  - No real system is available
  - The measurements are done only for a small number of cases

Theoretical Results

- The simulation result must be compliant with those of an analytical modeling

- Advantage: mutual validation!

- Disadvantage: both models can be wrong!
Verification vs. Validation

- Verification □ Program Correctness
- Validation □ Model Correctness

Four Possibilities:
- Unverified Simulation, Invalid Model
- Unverified Simulation, Valid Model
- Verified Simulation, Invalid Model
- Verified Simulation, Valid Model

Transient Removal

- Generally steady state performance is interesting
- Remove the initial part
- No exact definition => Heuristics:
  - Long Runs
  - Proper Initialization
  - Initial Data Deletion
Terminating Simulation

- There is no steady state
- Transient state is of interest
  - System shutdown
  - TCP Congestion

When to Stop Simulation

- If a simulation is too short the results may be highly variable from run to run.
- Too long simulation may require too much time and resources
- Variance Estimation
  - The variance between runs
  - The variance between sub-intervals of the same run
Common Mistakes in Simulation

- Inappropriate Level of Detail
- Unverified Models
- Invalid Models
- Too Short Simulation
- Poor Random Number Generation