CPSC 531: System Modeling and Simulation

Carey Williamson
Department of Computer Science
University of Calgary
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Agenda

- Welcome!
- Course Overview
- Learning Outcomes
- Administrative Details
- Expectations
- Q&A

- Today's Lecture Material:
  - Basics of Modeling
  - Computer Systems Performance Evaluation
  - Simulation Modeling Example

Course Overview

- The purpose of this course is to learn the basics of systems modeling, discrete-event simulation, and computer systems performance evaluation.
- Syllabus:
  - Intro to modeling and simulation (1 week)
  - Random numbers and Monte Carlo simulation (1 week)
  - Probability models: discrete and continuous (2 weeks)
  - Discrete-event simulation methods (2 weeks)
  - Simulation output analysis (2 weeks)
  - Simulation input analysis (2 weeks)
  - Queueing theory and Markov chains (2 weeks)

Learning Outcomes

- Classify/describe different types of simulations.
- Solve simple problems using Monte Carlo methods.
- Develop discrete-event simulation models.
- Generate random variates using inverse transforms.
- Understand differences between transient and steady-state behaviour of a system.
- Compute confidence intervals from simulation data.
- Conduct goodness of fit tests for input data models.
- Use basic queueing theory for simple system models.

Administrative Details

- Course Web Site: http://www.cpsc.ucalgary.ca/~carey/CPSC531
- D2L Site: site exists, with actual content coming soon!
- Lectures: Tue/Thur 9:30am-10:45am MS 211
- Instructor: Carey Williamson
- Tutorials: Tue/Thur 1:00pm-1:50pm SS 006
- TA: Jonathan Hudson (tutorials start week of Sept 18)
- Textbook: Discrete-Event Simulation: A First Course
- Grading:
  - Assignments (40%) - four programming assignments
  - Midterm Exam (20%) - in-class on Thursday, October 26
  - Final Exam (40%) - two-hour closed book exam
- Grading Scheme: threshold-based step-function

Instructor

- Professor: Carey Williamson
- Department: Computer Science
- Office: ICT 736
- Office Hours: Mondays (1:00pm-3:00pm) or by appt
- Phone: (403) 220-6780
- Email: carey@cpsc.ucalgary.ca (any time!)
- Web Site: http://www.cpsc.ucalgary.ca/~carey
- Research Interests: Computer networks, Computer systems performance evaluation, Network simulation
- Hobbies: Golf, curling, hiking, travel, cooking, family

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Basics of Modeling

- What is a model?
  - An abstract representation of a (real) system that captures the essential characteristics or properties of the system
  - Often requires making simplifying assumptions about how the system actually works
- Examples:
  - Model airplane; molecular model; performance model

- Modeling is an essential tool in computer system performance evaluation (as we will see shortly)
- Note that modeling is both an ‘art’ and a ‘science’

Modeling: A Reality Check

- A famous quote:

"All models are wrong; some models are useful."

- George Box, 1976

- Models are useful when they provide critical insights into the system behaviour (e.g., its performance)
- Models are especially valuable when they are simple, elegant, and computationally fast

Computer Systems Performance Evaluation

- Performance is a key consideration in the design, procurement, and use of computer systems.
- The typical goal is to get the highest possible performance for a given cost (e.g., dollars, energy)

- Performance evaluation is a well-defined sub-domain of computer science that has been around for 40 yrs
- Need basic knowledge of the tools and techniques of computer systems performance evaluation
  - What are the performance requirements?
  - How to compare different system alternatives?

Objectives of Performance Evaluation

Establish a quantitative understanding of system behaviour

This understanding should be sufficient for:

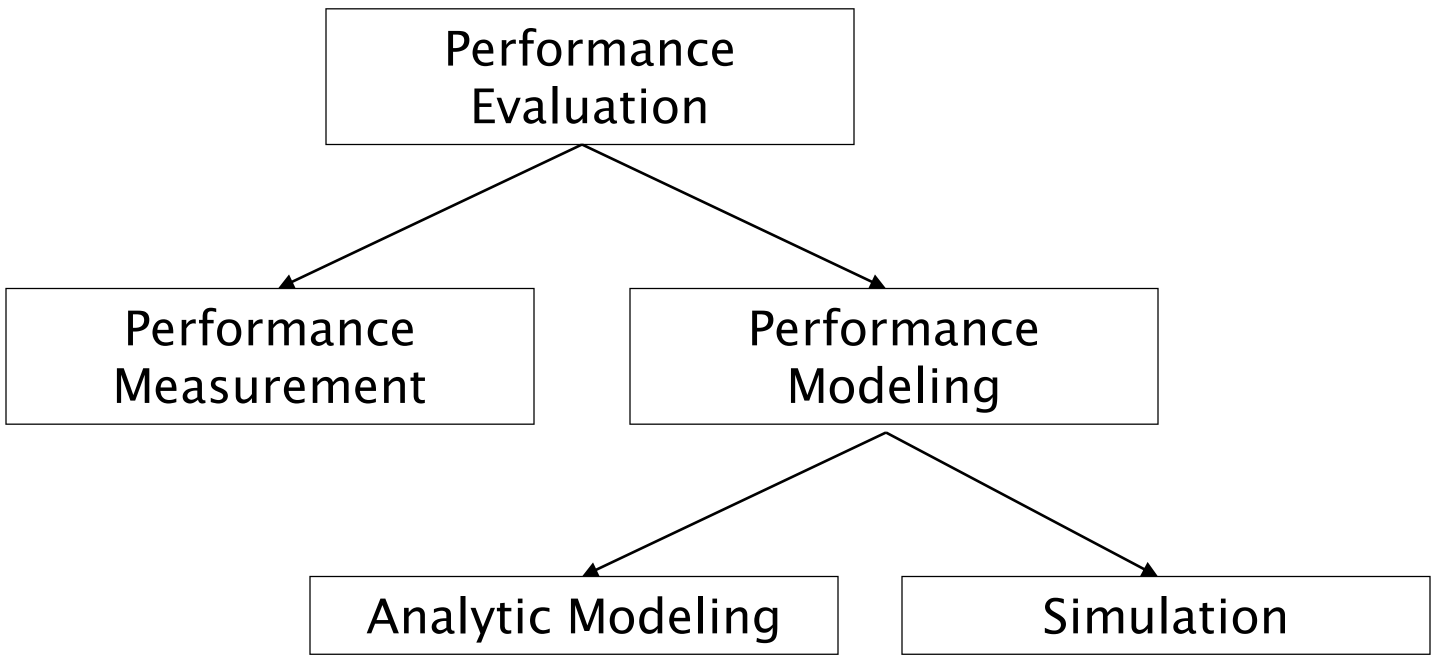
- Evaluating alternative system designs/configurations
  – e.g., should our Web site run on one server or two servers?
  – e.g., should Web server software be Apache, IIS, or nginx?
- Predicting system performance for a given set of inputs
  – e.g., predict the mean response time of a Web server when the number of users is increased
- Performance debugging and system tuning
  – e.g., identify/remove bottlenecks, optimize configuration
  – e.g., why is D2L so slow? is it the server, or the network?

Approaches to Performance Evaluation

Three main approaches:

1. Experimental
   - Obtain measurement data by observing the events and activities on an existing system; evaluate new algorithms or designs by implementing and comparing them in a real system
2. Simulation modeling
   - Develop a computer program that implements an abstracted model of the physical system; manipulate the model and/or its inputs to estimate the system performance (e.g., randomization)
3. Analytical modeling
   - Represent the system by an abstract mathematical model of the physical system (e.g., formula); manipulate parameters of the model to obtain information about system performance

High Level Overview



Performance Measurement

- Measure the performance directly on a system
- Need to characterize the workload placed on the system during measurement
- Generally provides the most valid results
- Nevertheless, not very flexible
  - May be difficult (or even impossible) to vary some workload parameters

Performance Modeling

- Construct a model
  - An abstracted representation of a system obtained by making assumptions about how the system works
  - Captures the most salient characteristics of the system
- Reasons for using models
  - Experimenting with the real system may be
    - too costly
    - too risky, or
    - too disruptive to system operation
  - System may not even exist yet (e.g., planning stage)

Analytic Modeling

- Mathematical methods are used to obtain solutions to the performance measures of interest
- Examples: queueing models for computer systems or computer communication networks
- Numerical results are easy to compute if a simple analytic solution is available
- Useful approach when one only needs rough estimates of performance measures
- Solutions to complex models may be difficult to obtain

Simulation Modeling

- Develop a simulation program that implements the model
- Run the simulation program and use the data collected to estimate the performance measures of interest (typically using randomization)
- A system can be studied at an arbitrary level of detail
- It may be costly to develop and run the simulation program

Advantages of Simulation

- New policies and procedures can be explored without disrupting the ongoing operation of the real system
- New designs can be tested without committing resources for their acquisition
- Time can be compressed or expanded to allow for a speed-up or slow-down of the phenomenon under study
- Insight can be obtained about the interactions of variables, and which ones have the most impact on system performance
- Can obtain answers to “What if…” questions

Areas of Application for Simulation

- Manufacturing applications
- Financial markets
- Military applications
- Logistics and supply chain management
- Transportation modes and traffic
- Business process simulation
- Health care optimization
- Facility placement problems
- Communication networks
- And many more!

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Simulation Example

- Hair salon (e.g., Witchcraft)
- Two stylists (one fast, one slow)
- Limited size waiting room (N chairs)
- Customers arrive at random times (no appts)
- Customers are impatient (don’t like waiting long)

- Question: How many customers do you lose by not having enough chairs in the waiting room?

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