CSC 508:
System Modeling and Simulation

- This Lecture:
  - Basics of Modeling
  - Computer Systems Performance Evaluation
  - Simulation Modeling Example

The purpose is to learn the basics of systems modeling, discrete-event simulation, and computer systems performance evaluation

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., Money value, energy requirements)

- Performance evaluation is a well-defined sub-domain of computer science that has been around for over 50 years
- 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:

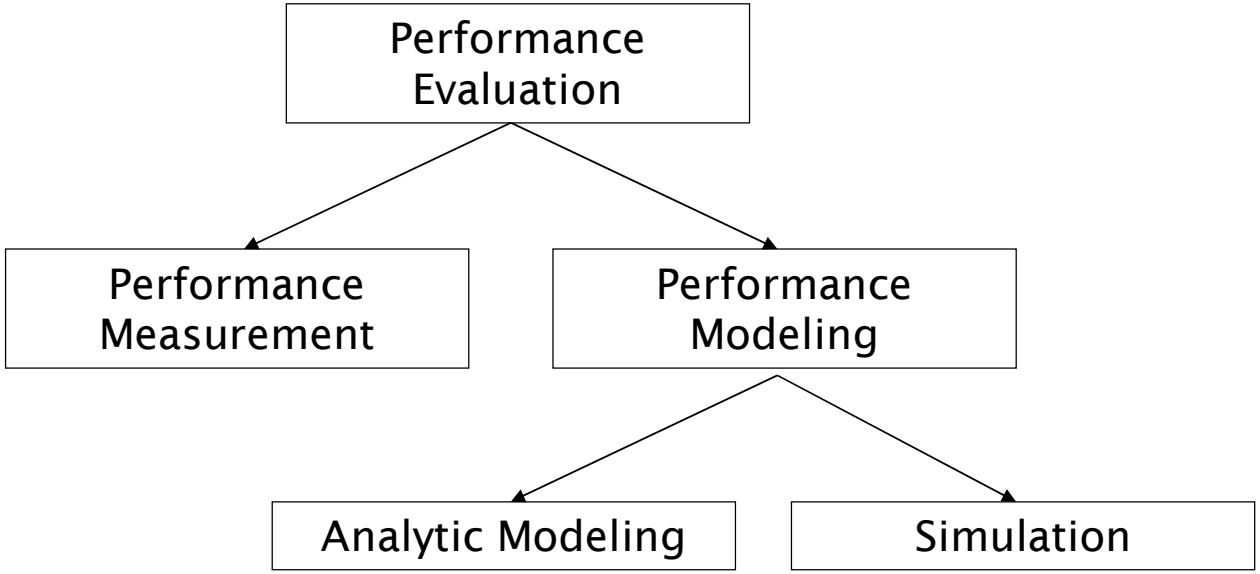
- Evaluating alternative system designs/configurations
  - e.g., should our Web site run on one server or two servers?
  - e.g., should Web server software be Apache, IIS, or nginx?
- Predicting system performance for a given set of inputs
  - e.g., predict the mean response time of a Web server when 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!