CS-417
COMPUTER SYSTEMS MODELING

Spring Semester 2020

Batch: 2016-17

(LECTURE # 1)

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COURSE LEARNING OUTCOMES (CLOs)

	Course Learning Outcome (CLO)	Taxonomy Level	Program Learning Outcome (PLO)
CLO-1	Carry out reliability analysis of computer systems	Cognitive C3	PLO-1 Engineering Knowledge
CLO-2	Analyze uncertainty in computer systems using probabilistic models	Cognitive C4	PLO-2 Problem Analysis
CLO-3	Analyze performance of computer systems using mathematical models	Cognitive C4	PLO-4 Investigation

COURSE OUTLINE

S#	Topics	Week #
1.	Introduction to Performance Modeling & Evaluation of Computer Systems	1-2
2.	Measurement Techniques	2
3.	Review of Probability Theory	3
4.	Markov Reliability Modeling	4-5
5.	Fundamentals of Queuing Models	6
6.	Reliability & Availability Models	7
7.	Simulation Modeling	8
8.	PetriNet Modeling	9
9.	Performance Evaluation of Multi-processor Systems	10

List of Books

Title	Author(s)	Publisher
Computer System Performance Evaluation & Prediction	Paul J. Fortier Howard E. Michel	Digital Press
Measuring Computer Performance	David J. Lilja	Cambridge
Probability Models for Computer Science	S. M. Ross	Academic Press
The Art of Computer Systems Performance Analysis	Raj Jain	John Wiley & Sons
Probability and Statistics with Reliability, Queueing, and Computer Science Applications	K. S. Trivedi	John Wiley & Sons

SESSIONALS CRITERIA

Online Assignments
Online Questions/Answers Session
Online Presentations

Why are we studying this course??

- Motivation is to learn and improve mathematical reasoning skills to solve problems involving uncertainty.
- Application areas in CS includes AI, ML, Data Mining, NLP, Bio-informatics, web search, algorithm designs and much more.
- Examples of "*uncertainty*" are as follows:
  - Response time & throughput of a web server
  - Failure of components
  - # of database requests or queries a database server receives in a given period
  - Prices
  - Weather conditions

Chapter # 1

COMPUTER SYSTEMS PERFORMANCE MODELING AND EVALUATION

Computer Systems Performance Evaluation

Performance Evaluation is about quantifying the service delivered by a computer system

For Example:

- comparing the power consumption of several server farm configurations;
- knowing the response time experienced by a customer performing a reservation over the Internet;
- comparing compilers for a multiprocessor machine

Common Goals of Performance Evaluation

- Compare alternatives
- Impact analysis
- System Tuning
- Identify relative performance
- Performance Debugging
- Setting Expectations

MODEL

- A model is an abstraction of a real-world system used to gain insight into some critical aspect(s) of a system.

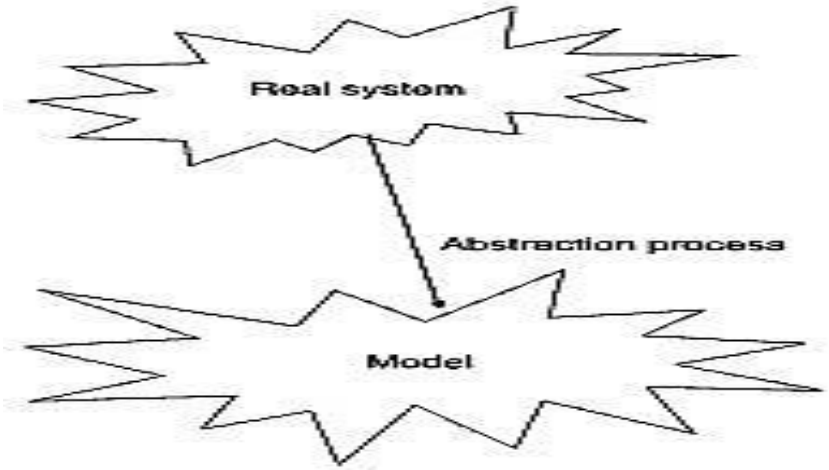


Fig 1: Modeling process

- They may have various forms:
  - physical models (scaled replicas),
  - mathematical equations and relations (abstractions), or
  - graphical representations

Motivation for Modeling

- Economic considerations

- Evaluating system performance under unusual scenarios
  - Upgrading a plant during operation
  - Modelled scenario to be avoided at any cost

- Predicting the performance of experimental design decisions

- Ranking multiple designs and analyzing their tradeoffs

Modeling Tools
(Techniques of Performance Evaluation)

1) Analytical
2) Simulation
3) Testbed
4) Operational Analysis

1) **Analytical Modeling Tools**

- Involves constructing a mathematical model of the system behavior (at the desired level of detail) and solving it.
- Works for simpler systems.
- For instance,
  - queuing models.
  - *Petri nets* for problem solving.
- A simple analytical model of the overall average memory-access time observed by an executing program is:

$$\mathbf{t_{avg} = h \,.\, t_c + (1\text{-}h) \,.\, t_m}$$

2) **Simulation Modeling Tools**

- It is a dynamic tool that uses a computer to imitate the operation of an entire process or system.
- A computer model with random elements and an underlying timeline is called Monte-Carlo Simulation.
- It involves development of model of systems, then experiments are conducted with an appropriate abstraction of *workload*.
- Simulation is a powerful technique for studying *memory-system behavior* due to its high degree of flexibility. For e.g. to study the impact on performance
  - the sizes of the cache and memory
  - the relative cache and memory delays
  - To study the effectiveness of pipelining in CPU.

COMPARISON BETWEEN ANALYTICAL MODELING & SIMULATION

- Suppose the example of distance travelled in particular time duration.
- Making simplifying assumptions, then the given analytical model is appropriate.

$$s = v * t$$

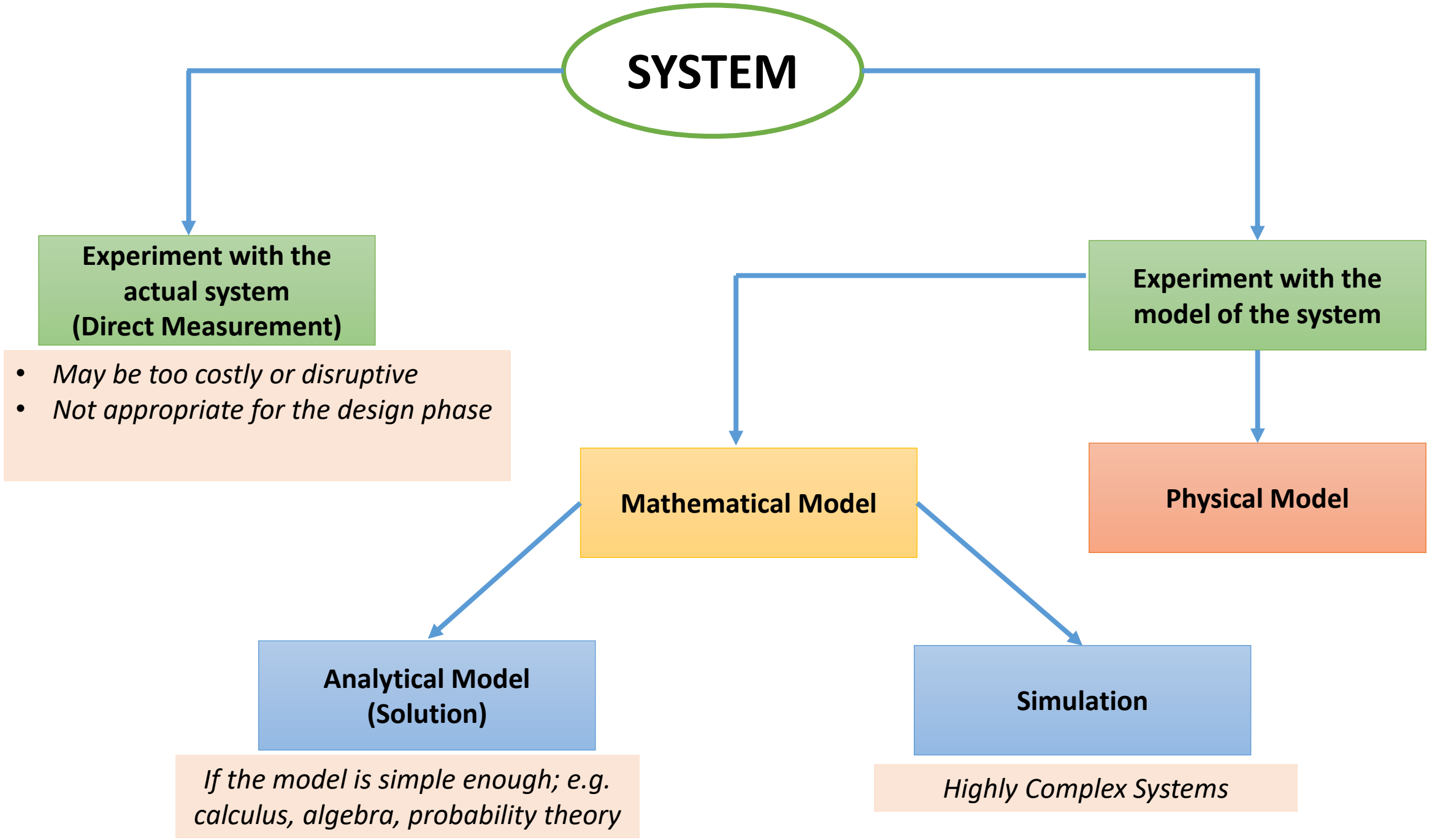
- Taking friction, acceleration and other factors into account, it will involve complex differential equations.
- Such equations are hard to solve analytically therefore simulation is preferred in this case.

3) **Testbeds**

- A realistic hardware-software environment for testing components without having the ultimate system.
- For e.g. New aircraft engines are fitted to a testbed aircraft for flight testing.
- *Important feature*: only focuses on a subset of the total system.
- Testbed examples in the context of software development and computer networks.
- Testbed is made up of three components:
  - Experimental Subsystem
  - Monitoring Subsystem
  - Simulation - Stimulation Subsystem

4) **Operational Analysis (Direct Measurement)**

- It is the measurement and evaluation of an actual system in operation.
- Also used to develop projections about the system's future operations.
- Involves instrumenting the system to extract the information.
- In an actual system, it may be very difficult (or impossible) to change the parameters.
- It can be very time consuming and costly.


SYSTEM
Experiment with the actual system (Direct Measurement)
May be too costly or disruptive
Not appropriate for the design phase
Experiment with the model of the system
Mathematical Model
Physical Model
Analytical Model (Solution)
If the model is simple enough; e.g. calculus, algebra, probability theory
Simulation
Highly Complex Systems

Key differences among the various Modeling Techniques

Solution Techniques				
Characteristics	**Analytical Modeling**	**Simulation**	**Testbed**	**Direct Measurement**
Flexibility	High	High/Medium	Medium/Low	Low
Cost	Low	Medium	Medium/High	High
Believability	Low	Medium	Medium/High	High
Accuracy	Low	Medium	Varies	High
Time Required	Small	Medium	Varies	Varies

Emulation

- An **emulator** is hardware or software that enables one computer system (called the *host*) to behave like another computer system (called the *guest*). An emulator typically enables the host system to run software or use peripheral devices designed for the guest system.

- Emulation allows program to run on the platform other than the one for which they were originally developed.

- For Example
  - Android Emulator
  - DOSBox emulates the command-line interface of DOS