Chapter 1 **Introduction to Simulation**

Banks, Carson, Nelson & Nicol

Discrete-Event System Simulation

Outline

- When Simulation Is the Appropriate Tool
- When Simulation Is Not Appropriate
- Advantages and Disadvantages of Simulation
- Areas of Application
- Systems and System Environment
- Components of a System
- Discrete and Continuous Systems
- Model of a System
- Types of Models
- Discrete-Event System Simulation
- Steps in a Simulation Study

Definition

- A *simulation* is the imitation of the operation of real-world process or system over time.
  - Generation of artificial history and observation of that observation history
- A *model* construct a conceptual framework that describes a system
- The behavior of a system that evolves over time is studied by developing a simulation *model*.
- The model takes a set of expressed assumptions:
  - Mathematical, logical
  - Symbolic relationship between the *entities*

Goal of modeling and simulation

- A model can be used to investigate a wide verity of “what if” questions about real-world system.
  - Potential changes to the system can be simulated and predicate their impact on the system.
  - Find adequate parameters before implementation
- So simulation can be used as
  - Analysis tool for predicating the effect of changes
  - Design tool to predicate the performance of new system
- It is better to do simulation before Implementation.

How a model can be developed?

- Mathematical Methods
  - Probability theory, algebraic method ,…
  - Their results are accurate
  - They have a few Number of parameters
  - It is impossible for complex systems
- Numerical computer-based simulation
  - It is simple
  - It is useful for complex system

When Simulation Is the Appropriate Tool

- Simulation enable the study of internal interaction of a subsystem with complex system
- Informational, organizational and environmental changes can be simulated and find their effects
- A simulation model help us to gain knowledge about improvement of system
- Finding important input parameters with changing simulation inputs
- Simulation can be used with new design and policies before implementation
- Simulating different capabilities for a machine can help determine the requirement
- Simulation models designed for training make learning possible without the cost disruption
- A plan can be visualized with animated simulation
- The modern system (factory, wafer fabrication plant, service organization) is too complex that its internal interaction can be treated only by simulation

When Simulation Is Not Appropriate

- When the problem can be solved by common sense.
- When the problem can be solved analytically.
- If it is easier to perform direct experiments.
- If cost exceed savings.
- If resource or time are not available.
- If system behavior is too complex.
  - Like human behavior

Advantages and disadvantages of simulation

- In contrast to optimization models, simulation models are “run” rather than solved.
  - Given as a set of inputs and model characteristics the model is run and the simulated behavior is observed

Advantages of simulation

- New policies, operating procedures, information flows and son on can be explored without disrupting ongoing operation of the real system.
- New hardware designs, physical layouts, transportation systems and … 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(clock is self-control).
- Insight can be obtained about interaction of variables and important variables to the performance.
- Bottleneck analysis can be performed to discover where work in process, the system is delayed.
- A simulation study can help in understanding how the system operates.
- “What if” questions can be answered.

Disadvantages of simulation

- Model building requires special training.
  - Vendors of simulation software have been actively developing packages that contain models that only need input (templates).
- Simulation results can be difficult to interpret.
- Simulation modeling and analysis can be time consuming and expensive.
  - Many simulation software have output-analysis.

Areas of application

- Manufacturing Applications
- Semiconductor Manufacturing
- Construction Engineering and project management
- Military application
- Logistics, Supply chain and distribution application
- Transportation modes and Traffic
- Business Process Simulation
- Health Care
- Automated Material Handling System (AMHS)
  - Test beds for functional testing of control-system software
- Risk analysis
  - Insurance, portfolio,...
- Computer Simulation
  - CPU, Memory,…
- Network simulation
  - Internet backbone, LAN (Switch/Router), Wireless, PSTN (call center),...

Systems and System Environment

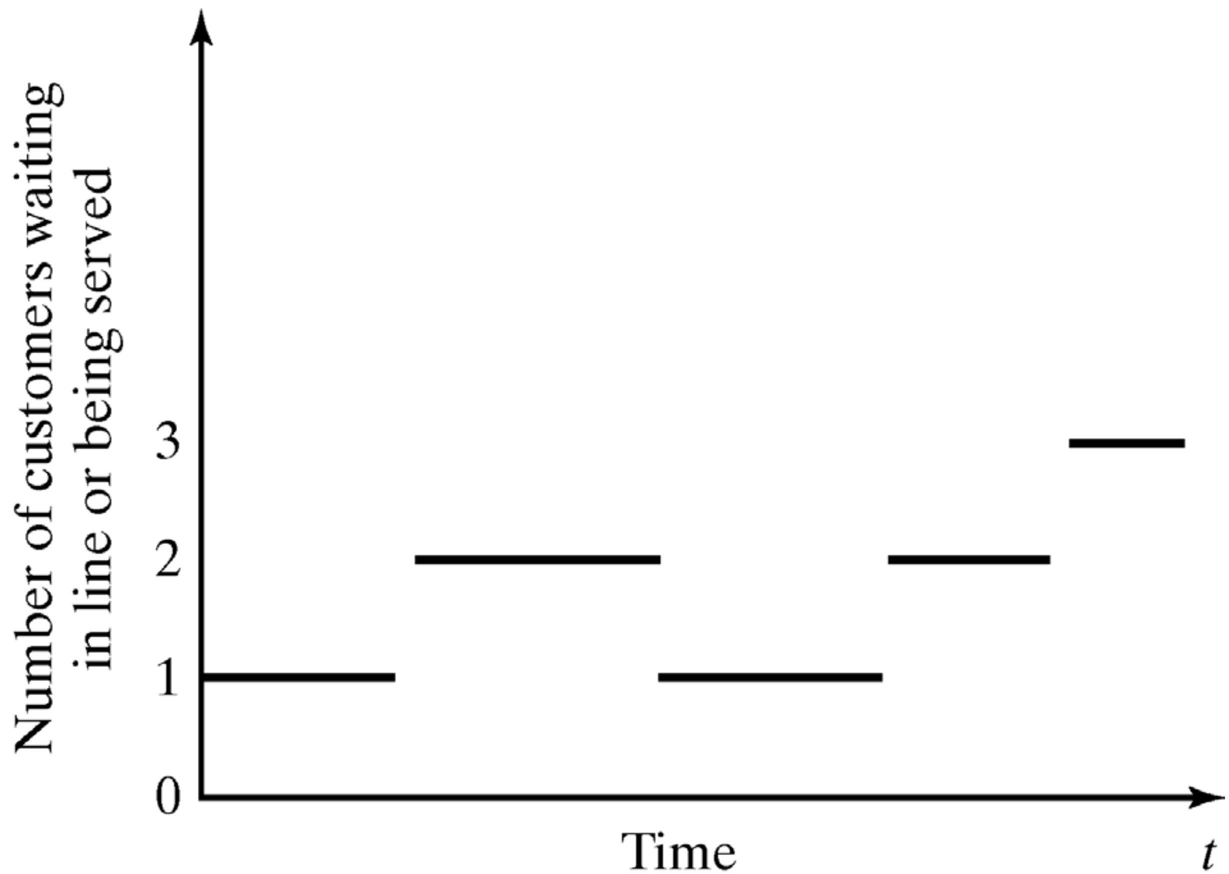
- A *system* is defined as a groups of objects that are joined together in some regular interaction toward the accomplishment of some purpose.
  - An automobile factory: Machines, components parts and workers operate jointly along assembly line
- A system is often affected by changes occurring outside the system: system environment.
  - Factory : Arrival orders
    - Effect of supply on demand : relationship between factory output and arrival (activity of system)
  - Banks : arrival of customers

Components of system

- Entity
  - An object of interest in the system : Machines in factory
- Attribute
  - The property of an entity : speed, capacity
- Activity
  - A time period of specified length :welding, stamping
- State
  - A collection of variables that describe the system in any time : status of machine (busy, idle, down,…)
- Event
  - A instantaneous occurrence that might change the state of the system: breakdown
- Endogenous
  - Activities and events occurring with the system
- Exogenous
  - Activities and events occurring with the environment

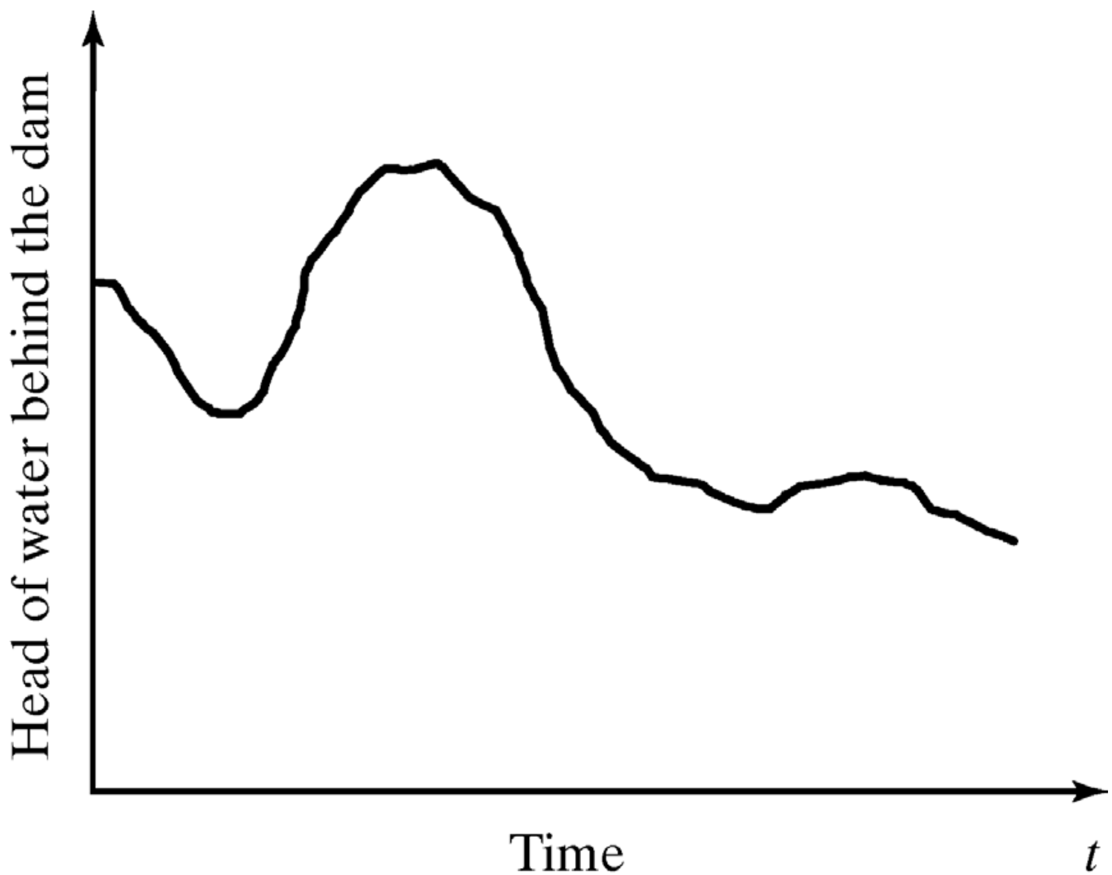
Discrete and Continues Systems

- A discrete system is one in which the state variables change only at a discrete set of points in time : Bank example



Discrete and Continues Systems (cont.)

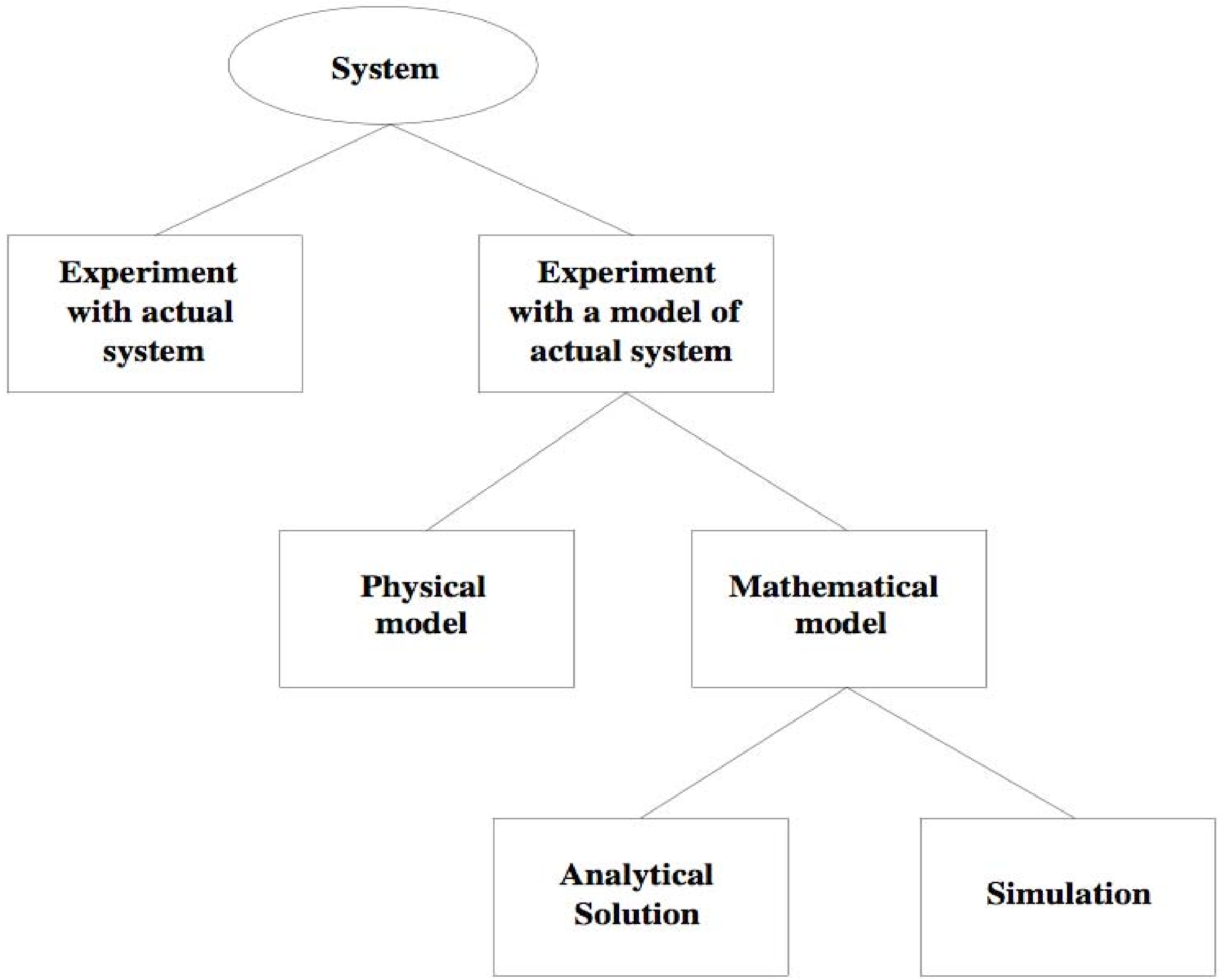
- A continues system is one in which the state variables change continuously over time: Head of water behind the dam



Model of a System

- To study the system
  - it is sometimes possible to experiments with system
    - This is not always possible (bank, factory,…)
    - A new system may not yet exist
- Model: construct a conceptual framework that describes a system
  - It is necessary to consider those accepts of systems that affect the problem under investigation (unnecessary details must remove)

Types of Models



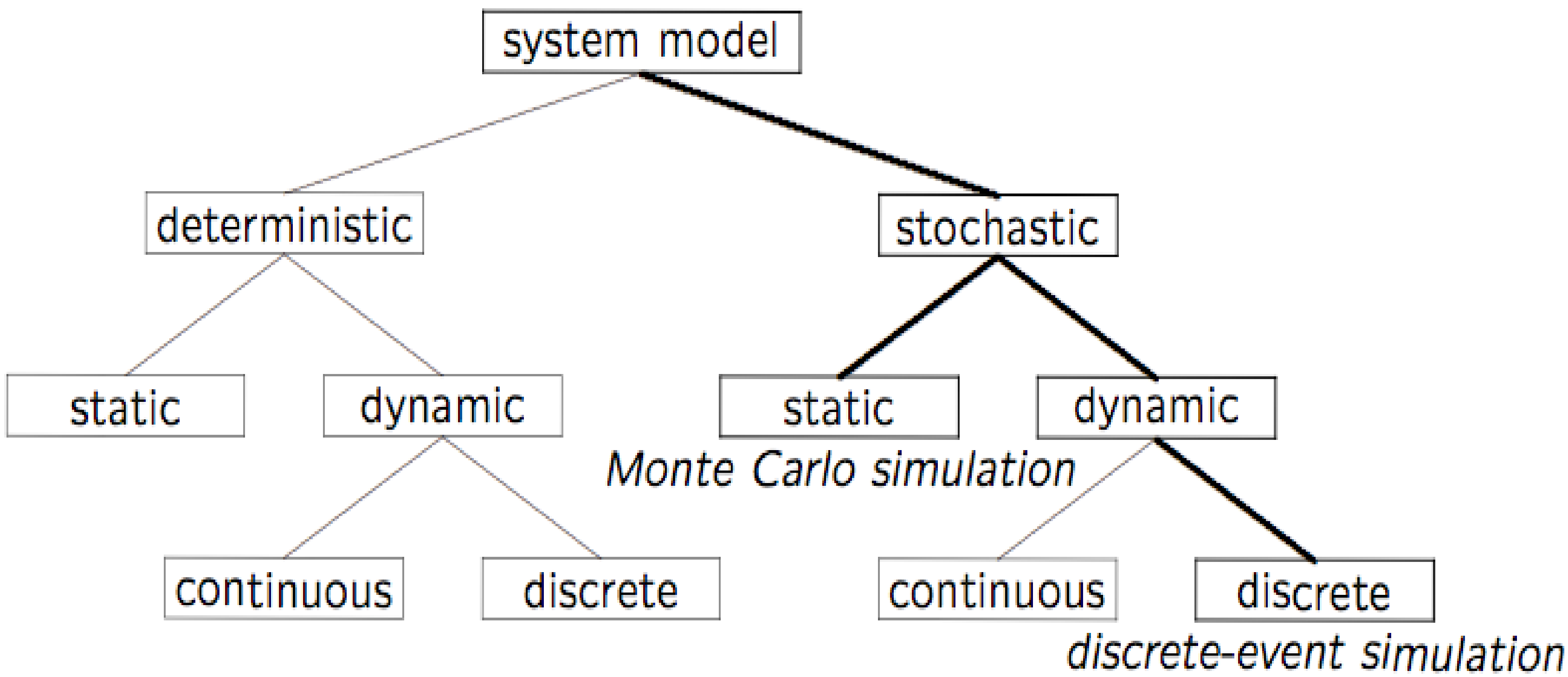
Characterizing a Simulation Model

- Deterministic or Stochastic
  - Does the model contain stochastic components?
  - Randomness is easy to add to a DES
- Static or Dynamic
  - Is time a significant variable?
- Continuous or Discrete
  - Does the system state evolve continuously or only at discrete points in time?
  - Continuous: classical mechanics
  - Discrete: queuing, inventory, machine shop models

Discrete-Event Simulation Model

- Stochastic: some state variables are random
- *Dynamic*: time evolution is important
- *Discrete-Event*: significant changes occur at discrete time instances

Model Taxonomy



DES Model Development

How to develop a model:

1) Determine the goals and objectives
2) Build a ***conceptual*** model
3) Convert into a ***specification*** model
4) Convert into a ***computational*** model
5) Verify
6) Validate

Typically an iterative process

Three Model Levels

- Conceptual
  - Very high level
  - How comprehensive should the model be?
  - What are the *state variables,* which are dynamic, and which are important?
- Specification
  - On paper
  - May involve equations, pseudocode, etc.
  - How will the model receive input?
- Computational
  - A computer program
  - General-purpose PL or simulation language?

Verification vs. Validation

- *Verification*
  - Computational model should be consistent with specification model
  - Did we build the <u>model right</u>?
- *Validation*
  - Computational model should be consistent with the system being analyzed
  - Did we build the <u>right model</u>?
  - Can an expert distinguish simulation output from system output?
- Interactive graphics can prove valuable

Steps in Simulation Study