System Simulation
Chapter 1: Introduction to Simulation

Fatih Cavdur
fatih@psu.edu

March 29, 2014

Introduction

- A simulation is the imitation of the operation of a real-world process or system over time.
- The behavior of a system as it evolves over time is studied by developing a simulation *model*.
- The model usually takes the form of a set of assumptions concerning the operation of the system that are expressed in mathematical, logical and symbolic relationships between the *entities* of the system.
- Once developed and validated, a model can be used to investigate a wide variety of "what-if" questions about the real-world system.

Introduction - cont.

- Simulation can also be used to study systems in the design state, before such systems are built.
- Thus, simulation modeling can be used both as an analysis tool for predicting the effect of changes to existing systems, and a design tool to predict the performance of new systems under varying sets of circumstances.
- In some instances, a model can be developed which is simple enough to be "solved" analytically using some mathematical methods, such as differential calculus, probability theory etc.

Introduction - cont.

- The solution usually consists of one or more numerical parameters, which are called measures of performance (performance measures) of the system.
- However, many real-world systems are so complex that models of theses systems are virtually impossible to solve analytically.
- In these instances, numerical, computer-based simulation can be used to imitate the behavior of the system over time.

When Simulation is the Appropriate Tool

- Simulation enables the study of, and experimentation with, the internal interactions of a complex system / sub-system.
- Informational, organizational etc. changes can be simulated, and the effect of these alterations can be observed.
- The knowledge gained during the designing of a simulation model could be of great value toward suggesting improvement in the system under investigation.
- Changing simulation inputs and observing outputs can produce valuable insights into which variables are important and how they interact.
- Simulation can be used as a pedagogical device to reinforce analytic solution methodologies.

Chapter 1 - Introduction to Simulation

When Simulation is the Appropriate Tool - cont.

- Simulation enables the study of, and experimentation with, the internal interactions of a complex system / sub-system.
- Informational, organizational etc. changes can be simulated, and the effect of these alterations can be observed.
- The knowledge gained during the designing of a simulation model could be of great value toward suggesting improvement in the system under investigation.
- Changing simulation inputs and observing outputs can produce valuable insights into which variables are important and how they interact.
- Simulation can be used as a pedagogical device to reinforce analytic solution methodologies.

When Simulation is the Appropriate Tool - cont.

- Simulation can be used to experiment with new designs and policies before implementation.
- Simulation can be used to verify analystic solutions.
- Simulating different capabilities for a machine etc. can help determine the requirements on it.
- Simulation models designed for training make learning possible without the cost and disruption.
- Animation shows a system in simulation operation so that the plan can be visualized.
- Modern systems are so complex that their interactions can be treated only through simulation

When Simulation is not the Appropriate Tool

- When the problem can be solved by common sense.
- If the problem can be solved analytically.
- If it is easier to perform direct experiments.
- If the costs exceed the savings.
- If the resources or time are not available.
- If no data is available.
- If it is not possible to verify and validate the model.
- If unreasonable expectations exist.
- If the systems behavior is too complex or cannot be defined.

Advantages

- New policies, operating procedures etc. can be explored without any disruption on the real system.
- New designs can be tested without investing.
- Hypotheses about how or why certain phenomena occur can be tested.
- Time can be compressed or expanded.

Advantages - cont.

- Insights can be obtained about the interaction of variables.
- Insights can be obtained about the importance of variables to the performance of the system.
- Bottleneck analysis can be performed.
- Can help in understanding how the system operates.
- “what-if” questions can be answered.

Disadvantages. But...

- Model building requires special training. But we have easy-to-use simulation packages.
- Simulation result can be difficult to interpret. But we have simulation packages with output-analysis capabilities.
- Simulation modeling and analysis can be time consuming and expensive. But it is getting faster and easier due to the advances in hardware / software.
- Simulation is used in some cases where an analytical solution is possible, such as some queue models etc. But analytic models are not able to analyze most of the complex systems in practice.

Areas of Application

- Manufacturing
- Semiconductor Manufacturing
- Construction Engineering and Project Management
- Military Applications
- Logistics, Supply Chain and Distribution
- Transportation and Traffic
- Business Process Simulation
- Health Care

Systems and System Environments

- A *system* is defined as a group of objects that are joined together in some regular interaction or interdependence toward the accomplishment of some purpose.
- A system is often affected by changes occurring outside the system. Such changes are said to occur in the *system environment*.
- In modeling systems, it is necessary to decide on the *boundary* between the system and its environment. This decision may depend on the purpose of the study.

Components of a System

- An *entity* is an object of interest in the system.
- An *attribute* is a property of an entity.
- An *activity* represents a time period of specified length.
- The *state* of a system is defined as the collection of variables necessary to describe the system at any time.
- An *event* is defined as an instantaneous occurrence that might change the state of the system.
- We use the term *endogenous* and *exogenous* to describe activities and events occurring withing a system and in the environment that affect the system, respectively.

Components of a System - Examples

Table : Examples of Systems and Components

System	Entities	Attributes	Activities	Events	State Variables
banking	customers	account balance	depositing	arrival	number of busy tellers
production	machines	speed	welding	breakdown	status of machines
communication	messages	destination	transmitting	arrival	number of waiting
...	...	...	...	...	...

Discrete and Continuous Systems

- Few systems in practice are wholly discrete or continuous.
- A *discrete system* is one in which the state variables change only at a discrete set of points in time. Ex: Bank.
- A *continuous system* is one in which the state variables change continuously over time. Ex: Head of water behind a dam.

Model of a System

- Experiment with the system, or with the model.
- A *model* is defined as a representation of a system for the purpose of studying that system.
- For most studies, it is only necessary to consider those aspects of the system that affect the problem under investigation.
- Different models of the same system could be required as the purpose of investigation changes.

Types of Models

- Mathematical or Physical
- Static (Monte Carlo Simulation) or Dynamic
- Deterministic or Stochastic
- Discrete or Continuous

Discrete-Event System Simulation

- We will focus on discrete-event system simulation in this class.
- It is the modeling of systems in which the state variables change only at a discrete set of points in time.
- Simulation models are analyzed numerical methods rather than by analytical methods.
- They are "run" rather than "solved".
- Most of the time, we use computers for simulation since real-world simulation models are rather large, and the amount of data we deal is vast.

Steps in a Simulation Study

Phase I: Discovery and Orientation

1. Problem formulation.
2. Setting the objectives and overall project plan.

Steps in a Simulation Study - cont.

Phase II: Model Building and Data Collection

3. Model conceptualization.
4. Data collection.
5. Model translation.
6. Verified? Is the (computer) model correct?
7. Validated? Does the model represent the real-system?

Steps in a Simulation Study - cont.

Phase III: Running of the Model

8. Experimental design.
9. Production runs and analysis.
10. More runs?

Steps in a Simulation Study - cont.

Phase IV: Implementation

11. Documentation and reporting.
12. Implementation.

Homework

- Reading HW: Chapter 1.
- Chapter 1 Exercises: 1, 2, 3.