What is Simulation?

- A *simulation* is the imitation of the operation of a real-world process or system over time.
  - Could be done by hand or on a computer.
  - Involves generation of data & artificial history of a system, observation of the data and history, and inferences concerning the system's characteristics.
- To study a system, we often have to make *assumptions* about the operation of the system.
- Assumptions constitute a *model*, used to understand the behavior of a system.

What is Simulation?

- Analytical solutions: if the model relationships are simple enough to use mathematical methods to obtain *exact* information on system
- Simulation: Develop a simulation model and evaluate the model usually with a computer to *estimate* the desired characteristics of the model.

Simulation Model

- A simplified representation of a sys. (or process or theory), not sys. Itself.
- Models can’t have all attributes; they are simplified, controlled, generalized, or idealized.
- For a model to be useful, all its relevant behaviors must be determined in a practical way, given a reasonably limited set of descriptions.
- A model must be validated.
- After validation, a model can be used to investigate and predicate system behaviors, or answer “what-if” questions to enhance understanding, training, prediction, and evaluation of alternatives.

When Simulation is Appropriate?

- Study the internal interactions of a complex (sub)-system.
- Observe model’s behavior and resulting outputs due to changes on external environment or internal variables.
- Improve system through model building.
- Experiment new designs and policies prior to implementation.
- Understand & verify analytic solutions.
- Identify & determine requirements.
- Allow training & learning at a lower cost.
- Visualize operations through animation.
- It’s difficult, time-consuming, expensive, hazardous, or impossible to solve the problem by conventional analytic or numeric methods.

When Simulation is Not Appropriate?

- When the problem can be solved using common sense.
- When the problem can be solved analytically.
- When it is easier to perform direct experiments.
- When the costs exceed the savings.
- When resources or time are not available.
- When no data is available.
- When verification & validation cannot be performed.
- When the power is overestimated.
- When the system is too complex or can’t be defined.

Areas of Applications

- Computer systems, e.g. scheduling, memory management
- Computer networks and communications
- Manufacturing
- Semiconductor manufacturing
- Construction engineering
- Military applications
- Transportation
- Business process
- …..

Systems and system environment

- To model a system, we first need to know what a system is.
- A system: objects and their relationships and interactions.
- System environment: changes happen outside the system, but affect the system
- Boundary

Components of a System

- Entity: system object
- Attribute: property of an entity
- Activity: operation is a specific time period
- State: collection of variables needed to describe the system at any time.
- Event: an instantaneous occurrence that may change the state of the system.
- Table 1.1 on page 11.

Discrete and Continuous Systems

- Discrete system: state variable(s) change only at a discrete set of points in time.
  - Example: number of customers waiting in line

- Continuous system: state variable(s) change continuously or smoothly over time.
  - Example: chemical level in a tank, electric current

Types of Models

- Models:
  - Physical: model home, model of a bridge, wax model of a person
  - Mathematical (symbolic): $\alpha(\varphi!\sigma\kappa\phi)(\nu\varpi o\varepsilon) = \mu\varepsilon 3!$
    - Simulation model
      - **Static** (at some point in time) vs. **Dynamic** (change over time)
      - **Deterministic** (known inputs) vs. **Stochastic** (random variables, inputs/outputs)
      - **Discrete** vs. **Continuous**

- Focus of this course:
  Discrete, dynamic, and stochastic

Discrete-Event System Simulation

- Modeling of systems in which the state variable changes at a discrete set of points in time.
- Methods: numerical instead of analytical
  - Analytical: deductive reasoning of math; accurate
  - Numerical: computational procedures; approximate
- Simulation models are “run” rather than solved.
  - Observation of the real system, entities, interactions
  - Assumptions of the model
  - Collection of data
  - Analysis and estimation of system performance

Steps in a Simulation Study

Figure 1.3 on page 16:

- Problem formulation
- Setting of objectives and project plan
- Model conceptualization
- Data collection
- Model translation
- Verification
- Validation
- Experimental design
- Production runs and analysis
- More runs
- Documentation and reporting
- Implementation

Verification and Validation

- The most important step in the process: **validation**
- Validation should not be an isolated task that follows model development, but rather an *integral* part of model development.
- Verification: “Are we building the model right?”
  - Is the model programmed correctly (input parameters and logical structure)?
- Validation: “Are we building the right model?”
  - Is the model an accurate representation of the real system?
  - Iterative process of comparing the model to actual system behavior and refine the model

Model Building

Iterative process consisting of three main steps:

- Observe the real system & the interactions of components and collect data
  - Domain specific knowledge
  - Stakeholders: operators, technicians, engineers, …
- Construct a conceptual model
  - Assumptions or hypotheses on components and parameter values
  - Structure of the system
- Translate the operational model to computer recognizable form