City University

Dept. of Computer Science and Engineering
SE 401 Computer Simulation and Modeling
Fahim Shahriar, Lecturer, Dept. of CSE

Class Lecture Notes (SE401)

Class Lecture Notes 1 (SE401)

Definition

Simulation: Simulation of a system is the operation of a model in terms of time or space, which helps analyze the performance of an existing or a proposed system. In other words, simulation is the process of using a model to study the performance of a system. It is an act of using a model for simulation.

Modelling: Modelling is the process of representing a model which includes its construction and working. This model is similar to a real system, which helps the analyst predict the effect of changes to the system. In other words, modelling is creating a model which represents a system including their properties. It is an act of building a model.

History of Simulation: The historical perspective of simulation is as enumerated in a chronological order.

- 1940 − A method named 'Monte Carlo' was developed by researchers (John von Neumann, Stanislaw Ulan, Edward Teller, Herman Kahn) and physicists working on a Manhattan project to study neutron scattering.
- 1960 − The first special-purpose simulation languages were developed, such as SIMSCRIPT by Harry Markowitz at the RAND Corporation.
- 1970 − During this period, research was initiated on mathematical foundations of simulation.
- 1980 − During this period, PC-based simulation software, graphical user interfaces and object-oriented programming were developed.
- 1990 − During this period, web-based simulation, fancy animated graphics, simulation-based optimization, Markov-chain Monte Carlo methods were developed.

Concept of Simulation

- Simulation is the representation of a real life system by another system, which depicts the important characteristics of the real system and allows experimentation on it.
- In another word simulation is an imitation of the reality.
- Simulation has long been used by the researchers, analysts, designers and other professionals in the physical and non-physical experimentations and investigations.

System: The term system is derived from the Greek word "systema", which means an organized relationship among functioning units or components. A system is a collection of components where individual components are constrained by connecting interrelationships such that the system as a whole fulfills some specific functions in response to varying demands. In short, a system is an orderly grouping of interdependent components linked together according to a plan to achieve a specific objective. It is designed to achieve one or more objectives. Example: transportation system, telephone system, accounting system, production system, and computer system etc.

The study of the systems concepts has three basic implications:

1. A system must be designed to achieve a predetermined objective
2. Interrelationships and interdependence must exist among the components
3. The objectives of the organization as a whole have a higher priority than the objectives of its subsystems.

Types of systems:

Discrete: State variables change instantaneously at separated points in time. For example, Bank model: State changes occur only when a customer arrives or departs.

Continuous: State variables change continuously as a function of time. For example, Airplane flight: State variables like position, velocity change continuously.

Components: Three basic components are: Entity, Attributes, Activities
Simulation models consist of the following components: system entities, input variables, performance measures, and functional relationships.
The components of the system are as given below:
Entities: An entity is an object of interest in the system. In other words, any person or a thing which is given more priority in a system. For example, in system of communication the most preferable thing is message.
Attribute: An attribute is a property of entity.
Activity: An activity represents time period of specified length.
Event: An event can be defined as an instantaneous occurrence that might change the state of system.
State variables: A state variables is one of set of variables.

Entities: An entity represents an object whose value can be static or dynamic, depending upon the process with other entities.

Attributes: Attributes are the local values used by the entity.

Activities:

States:
The system state variables are a set of data, required to define the internal process within the system at a given point of time.
In a discrete-event model, the system state variables remain constant over intervals of time and the values change at defined points called event times.
In continuous-event model, the system state variables are defined by differential equation results whose value changes continuously over time.

Model:
A model is a simplified representation of a system at some particular point in time or space intended to promote understanding of the real system.

Types of Simulation:

1. Static and Dynamic
2. Discrete and Continuous
3. Stochastic and Deterministic

Static simulation: Static simulation represents a system, which does not change with time or represents the system at a particular point in time. Static simulation include models which are not affected with time.
Dynamic simulation: Dynamic simulation represent systems as they change over time. Dynamic Simulation include models which are affected with time.

Discrete simulation: Systems in which the state changes at discrete points in time called discrete systems. Example: Changes in the factory occur discontinuously so factory system is a discrete system.
Continuous simulation: System in which the state of the system changes continuously with time are called continuous systems. *Example*: The movement of the aircraft occurs smoothly so aircraft system is a continuous system.

Deterministic simulation: In deterministic models, the output of the model is fully determined by the parameter values and the initial conditions. Deterministic simulation models have a known set of inputs, which result into unique set of outputs. Deterministic systems are not affected by randomness and their output is not a random variable. *Example*: AND, OR, NOT operations.
Stochastic simulation: In stochastic model, there are one or more random input variables, which lead to random outputs. The same set of parameter values and initial conditions will lead to an ensemble of different outputs. Stochastic systems are affected by randomness and their output is a random variable. *Example*: Throwing a dice or tossing a coin.

Why simulation:

- It may be too difficult, hazardous, or expensive to observe a real, operational system
- Parts of the system may not be observable (e.g., internals of a silicon chip or biological system)

- In many situations experimenting with actual system may not be possible at all. For example, it is not possible to conduct experiment, to study the behavior of a man on the surface of moon. In some other situations, even if experimentation is possible, it may be too costly and risky.

Uses of simulation:

- Analyze systems before they are built
- Reduce number of design mistakes
- Optimize design
- Analyze operational systems
- Create virtual environments for training, entertainment

When to use simulation:

1. Simulation is very useful for experiments with the internal interactions of a complex system, or of a subsystem within a complex system.
2. Simulation can be employed to experiment with new designs and policies, before implementing
3. Simulation can be used to verify the results obtained by analytical methods and reinforce the analytical techniques.
4. Simulation is very useful in determining the influence of changes in input variables on the output of the system.
5. Simulation helps in suggesting modifications in the system under investigation for its optimal performance.

Advantages of simulation and modeling:

- **Easy to understand** - Simulation helps to learn about real system, without having the system at all or without working on real-time systems. Simulation is a very good tool of training and has advantageously been used for training in the operation of complex system. Space engineers simulate space flights in laboratories to train the future astronauts for working in weightless environment. Airline pilots are given extensive training on flight simulators, before they are allowed to handle real planes.
- **Easy to test** - Allows to make changes into the system and their effect on the output without working on real-time systems. In the real system, the changes we want to study may take place too slowly or too fast to be observed conveniently. Computer simulation can compress the performance of a system over years into a few minutes of computer running time.
- **Easy to upgrade** - Allows to determine the system requirements by applying different configurations. Simulation Models are comparatively flexible and can be modified to accommodate the changing environment to the real situation.
- **Easy to identifying constraints** - Allows to foresee the difficulties and perform bottleneck analysis which may come up due to the introduction of new machines, equipment's and processes. It thus eliminates the need of costly trial and error method of trying out the new concepts. And reduce delay in the work process, information, etc. in real system.
- **Easy to diagnose problems** - Certain systems are so complex that it is not easy to understand their interaction at a time. However, Modelling & Simulation allows to understand all the interactions and analyze their effect. Additionally, new policies, operations, and procedures can be explored without affecting the real system.

Disadvantages of simulation and modeling:

- Designing a model is an art that is learned over time and through experience and which requires domain knowledge and training. Furthermore, if two models are constructed by two competent individuals, they may have similarities, but it is highly unlike that they will be the same.
- Operations are performed on the system using random number, hence difficult to predict the result.
- Simulation results are difficult to interpret. Since most simulation outputs are essentially random variables, it may be hard to determine whether an observation is a result of system interrelations or randomness. So it requires experts to understand.
- Simulation is used in some cases when an analytical solution is possible, or even preferable.

- Simulation requires manpower and the analysis process can be time consuming and expensive.

Pitfalls in Simulation:

Typical reasons why simulation projects fail include the following:

- Failure to state clear objectives at the outset.
- Failure to involve individuals affected by outcome.
- Overrunning budget and time constraints.
- Failure to document and get a consensus on input data.
- Including more detail than is needed.
- Including variables that have little or no impact on system behavior.
- Failure to verify and validate the model.
- Basing decisions on a single run observation.
- Basing decisions on average statistics when the output is actually.
- Being too technical and detailed in presenting the results to management.

Phases in simulation:

Phase 1: ***Problem Formulation:*** This includes *problem formulation* step.

Phase 2: ***Model Building:*** This includes *model construction*, *data collection*, *model programming*, and *validation of model*.

Phase 3: ***Running the Model:*** This includes *experimental design*, *simulation runs and analysis of results.*

Phase 4: ***Implementation:*** This includes *documentation* and *implementation*.

Steps of simulation:

1. **Problem formation:** Identify the problem with an existing system or set requirements of a proposed system. Prepare a problem statement.
2. **Model construction:** Design the problem while taking care of the existing system factors and limitations.
3. **Data Collection:** Collect and start processing the system data. Choose input variables and create entities for the simulation process.
4. **Model programming:** Develop the model using network diagrams and verify it using various verifications techniques.
5. **Validation:** Validate the model by comparing its performance under various conditions with the real system.
6. **Design of experiment:** Select an appropriate experimental design as per requirement.
7. **Simulation run and analysis:** Choose an appropriate simulation software to run the model. Perform an experiment on the model by changing the variable values to find the best solution. Induce experimental conditions on the model and observe the performance and result.
8. **Documentation:** Create a document of the model for future use, which includes objectives, assumptions, input variables and performance in detail.
9. **Implementation:** Finally, apply these results into the real-time system.

Application areas of simulation and modeling:

Modelling & Simulation can be applied to the following areas:

, training & support, designing semiconductors, telecommunications, civil engineering designs & presentations, and E-business models.

Additionally, it is used to study the internal structure of a complex system such as the biological system. It is used while optimizing the system design such as routing algorithm, assembly line, etc. It is used to test new designs and policies. It is used to verify analytic solutions.

Manufacturing: Design analysis and optimization of production system, materials management, capacity planning, layout planning, and performance evaluation, evaluation of process quality.

Business: Market analysis, prediction of consumer behavior, and optimization of marketing strategy and logistics, comparative evaluation of marketing campaigns.

Military: Testing of alternative combat strategies, air operations, sea operations, simulated war exercises, practicing ordinance effectiveness, inventory management.
Healthcare applications: such as planning of health services, expected patient density, facilities requirement, hospital staffing, estimating the effectiveness of a health care program.
Communication Applications: Such as network design, and optimization, evaluating network reliability, manpower planning, sizing of message buffers.
Computer Applications: Such as designing hardware configurations and operating system protocols, sharing networking.
Economic applications: such as portfolio management, forecasting impact of Govt. Policies and international market fluctuations on the economy. Budgeting and forecasting market fluctuations.
Transportation applications: Design and testing of alternative transportation policies, transportation networks-roads, railways, airways etc. Evaluation of timetables, traffic planning.
Environment application: Solid waste management, performance evaluation of environmental programs, evaluation of pollution control systems.
Biological applications: Such as population genetics and spread of epidemics.

Discrete Event Simulation:
Components of a Discrete Event Simulation:
System state: the collection of variables to describe the system at a particular time.
Simulation clock: a variable giving the current value of simulated time.
Event list: a list containing the next time when each type of event will occur.
Statistical counters: variables used for storing statistical information about system performance.

- Classification of Simulation Models: Static, Dynamic, Discrete, Continuous, Stochastic, Deterministic
- Time Advanced Mechanisms, Components and Organization of a Discrete Event Simulation Model

EXAMPLES
SYSTEMENTITIESATTRIBUTESACTIVITIESEVENTSSTATE VARIABLES
Banking Customers Checking-account balance Making deposits Arrival – departure Number of busy tellers and number of customer waiting Production Machines Speed, capacity, breakdown rates Welding, stamping Breakdown Status of machines (busy, idle or down) Grocery store Shoppers Length of grocery list Checking out Arrival at checkout counters, Departure from checkout counters Number of shoppers in line, Number of checkout lanes in operations2/9/2017ISL432 Simulation in Operations Management17

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Discrete Event Simulation: Modeling of a system as it evolves over time by a representation where the state variables change instantaneously at separated points in time. More precisely, state can change at only a countable number of points in time. These points in time are when EVENTS occur.

Event: Instantaneous occurrence that may change the state of the system.

Entities: They are objects that compose a simulation model. For example, customers and servers. Entities are characterized by data values called attributes. For each entity in the model there's a record.

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System state: the collection of variables to describe the system at a particular time.

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