INTRODUCTION TO SIMULATION

Dr.K.P.Mohandas,
Professor of Electrical Engineering,
Regional Engineering College, Calicut.

1. INTRODUCTION

To simulate, essentially means to 'mimic' or to try to duplicate a real world process or system over time. Whether done by hand or on a computer, simulation involves the generation of an artificial history of a system. and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system. This means that the more we know about the system, better will be the simulation and more reliable the results from the simulation.. The behavior of a system as it evolves over time is studied by developing a simulation *model* This model is based on a set of assumptions concerning the operation of the system. Just as modeling is an art in getting a re-presentation of a phenomenon or system, simulation is an art of depicting the facts understood from the observations such that more experimentation can yield better understanding of the phenomenon or the system being studied.

In contrast to optimization models, simulation models are "run" rather than solved, even though there may be a few exceptions. Given a set of inputs and model characteristics, the model is run for a set of inputs and the simulated behavior observed. The process of changing inputs and model characteristics results in a set of scenarios that are evaluated. A good solution, either in the analysis of the existing system or in the design of a new system is then recommended for implementation.

2. WHEN IS SIMULATION AN APPROPRIATE TOOL?

The availability of massive computing capabilities at decreasing cost per operation and advances in simulation methodologies have made simulation one of the most widely used and accepted tools in operations research and system analysis. Simulation can be used for the following purposes:

1. Simulation enables the study of , and experimentation with, the internal interactions of a complex system, or a subsystem within a complex system.
2. Informational, organizational and environmental changes can be simulated and the effect of these alterations on the model's behavior can be observed.
3. The knowledge gained in designing a simulation model may be of great value toward suggesting improvement in system under investigation.
4. By changing simulation inputs and observing the resulting outputs, valuable insight may be obtained into which variables are most important and how variables react.
5. Simulation can be used as pedagogical (teaching) device to reinforce analytical solution methodologies.
6. Simulation can used to experiment with new designs or policies prior to implementation so as to prepare for what may happen.
7. Simulation can be used to verify analytical solutions.

3 ADVANTAGES & DISADVANTAGES OF SIMULATION.

Simulation is intuitively appealing to a client because it mimics what happens in real system or what is perceived for a system that is in the design stage. The output data from simulation study should directly correspond to outputs that could be recorded from the real system. Additionally, it is possible to develop a simulation model of a system without dubious assumptions (such as same statistical distribution for every random variable) of mathematically solvable models. For these, and other reasons, simulation is the preferred technique for problem solving in many situations.

Simulation has many advantages and are not completely devoid of disadvantages either. The advantages are :

1. New policies, operating procedures, decision rules, information flows, organizational procedures and so on can be explored without disrupting the ongoing operations of the real system.
2. New hardware designs, physical layouts, transportation systems. etc. can be tested without committing resources for their requisition.
3. Hypotheses about how or why certain phenomena occur can be tested for feasibility.

4. Time can be compressed or expanded allowing for a speed up or slow down of the phenomena under investigation.
5. Insight can be obtained about interaction of variables.
6. Insight can be obtained regarding the significant variables that affect the performance of the system.
7. Bottleneck analysis can be performed indicating where work in process, information, materials, and so on are being excessively delayed.
8. A simulation study can help in understanding how the system operates rather than how individuals think the system operates.
9. "What if" questions can be answered which is useful in the design of systems.

The disadvantages are :

1. Model building requires special training. It is an art that is learned over time and through experience. Furthermore, if two models are constructed by two competent individuals, they may have similarities but it is highly unlikely that they will be the same.
2. Simulation results may be difficult to interpret. Since most simulation outputs are essentially random variables (they are based on random inputs), it may be hard to determine whether an observation is a result of system interrelationships or randomness.
3. Simulation modeling and analysis can be time consuming and expensive . Skimping on resources for modeling and analysis may result in a simulation model or analysis that is not sufficient for the task.
4. Simulation is used in some cases when an analytical solution is possible, or even preferable.. This is particularly true in the simulation of some waiting lines where closed-form queuing models are available.

Some of these disadvantages can be offset as follows:

1. Vendors of simulation software have been actively developing packages that contain models that only need input data for their operation. Such models have the generic tag "simulators" or "templates"
2. Many simulation software vendors have developed output analysis capabilities within their packages for performing very thorough analysis.
3. Simulation can be done faster today due to the advances in the hardware and innovations in simulation methodologies.
4. Closed-form models are not able to analyze many of the complex systems that are encountered in practice…

4. AREAS OF APPLICATION

Some of the major areas of application of simulation can be categorized as given below: (from a recent international Conference on System Simulation & Modelling)

i. Manufacturing Systems

Materials handling system design
Inter-operability for spares inventory planning
Aircraft assembly operations
Agile control of aerospace manufacturing
Distributed model for computer integrated manufacturing
Flexible-routing manufacturing control system. Etc.

ii. Public Systems

Healthcare
Prediction of pharmaceutical costs and outcomes
Cementless hip replacement
Reducing the length of stay in emergency depts.

Military
Issues in operational test and evaluation.
Army officers professional development
Process of military base transition
Combat modeling
Corps battle simulation etc.

Natural Resources
Solid waste management systems and waste remediation system
Operational efficiency at power plants
Environmental restoration activities
Oil spill modeling.

iii. Transportation systems

Cargo transportation and personnel launch
Container port operations
Demand based toll plaza lane staffing

iv. Construction systems

Application of earth-moving systems
Cabled-stayed bridges.
Strengthening the design/construction interface.
Advanced project planning paradigm.

v. Restaurant and Entertainment Systems

Quick service restaurant traffic analysis

Determination of labor requirements
Opportunities in amusement parks.

vi. Business Process Re-engineering

Integrating business process re-engineering with image-based work flow.
Business process modeling and analysis tool

vii. Food Processing

Trawler operations in the fish processing industry
Capacity expansion for processes
Evaluating international competitiveness in broiler production.

viii. Computer System Performance

Heterogeneous networks
Evaluating large scale computer system performance
Client/Server system architecture.

5. CLASSIFICATION OF SIMULATION TECHNIQUES

Broadly, simulation can be classified into two: Analogue and Digital. Analogue simulation can be further divided into direct analogues and indirect analogues.

5.1 ANALOGUE SIMULATION

5.1.1. Direct Analogues.

These are either scale models or an analogues with the elements in the analogue having one to one correspondence with the system being simulated. There are several phenomena in diverse areas following similar characteristics, which can be studied by using a convenient system rather than the original system itself. For example, the behavior of mechanical system as far as vibrations are concerned can be studied by simulating an electrical circuit with resistance, inductance and capacitance, representing the spring constant, friction coefficient and mass or inertia of the mechanical system. It can also be a scale model or prototype, which bears direct relations even in appearance with the original system. Well known examples are Network Analyzers for simulating the power system where each generator is represented by a source, each line by its impedance and each transformer by its equivalent circuit. etc. May be it is convenient to increase the frequency of the supply in simulated system so that the size of the components may be reduced significantly. Another example is a flight simulator, which can simulate the conditions in an aircraft cockpit for training the pilots such that flight conditions are simulated realistically. Electrolytic tanks for simulating flow conditions in a fluid flow system or in electromagnetic circuits is another example of direct analogues.

5.1.2. Indirect Analogues

These are essentially systems or devices which can solve the mathematical equations that describe the system under investigation. Electronic analogue computers are ideal for solving differential equations representing many dynamic systems. The convenience in visualizing the solution (output) on an oscilloscope or an X-y plotter makes it a very useful tool in the research and design of systems. Many standard non-linear phenomena can be simulated and studied using analogue computer.

5.1.3. Merits and demerits of Analogue Simulation.

Merits

A realistic understanding of the system is obtained as there is enough scope for getting 'what if' solutions. Parameter variations can be easily simulated by changing the component values or system configuration itself changed for the purpose of experimentation.

Almost immediate observation of the results of simulation possible since many analogue simulators works in real time.

Demerits

The component tolerances set a limit on the accuracy of the simulations.

Many complex systems cannot be properly described by mathematical equations or represented by realistic components.

Analogue simulation becomes tedious for complex, distributed and time varying systems.

5.2 DIGITAL SIMULATION

Digital simulation can be interpreted as either simulation of systems in a digital (not analogue or continuous) form or simulation on a digital computer or a member of the family. The present discussion uses the second interpretation.

When a problem is to be solved on a digital computer, there are two approaches possible in the present state of affairs in the information technology.

APPROACHES TO DIGITAL SIMULATION

5.2.1 Conventional Program-Oriented Approach.

Here the digital computer is used as a system for solving the equations that describe the system. Differential equations are first digitized to get difference equations with a suitable sampling time and these difference equations are solved by developing a high level language program in FORTRAN PASCAL, C etc. The coded program is compiled and executed for sample sets of data and the accumulated results interpreted in a convenient way as numbers or by using suitable plots. This approach, used from the very beginning of the development of computers has the following features:

1. The analyst should have a good command of the high level language used for programming and the choice of the language also may put some restrictions on the usefulness of the simulation. There are special simulation languages for specific situations and no language can be useful for all the different types of problems.

2. The program can be made very general permitting an extensive study under different conditions ad hence the possibilities are unlimited.

3. By proper programming and by trading off of computation time, better accuracy can be achieved if required.

4. Real time simulation is hardly possible.

5. Observation of the output may require additional software for plotting and visualizations.

6. The success of the simulation depends on the ingenuity of the analyst.

5.2.2. Software package-oriented Approach

Computer markets in these days are flooded with a large number of software packages for tailor-made situations. There are several packages for general purpose commercial applications such as Word processing, Database Management, Spreadsheet calculations, Computer Aided Drafting and so on. Also a large number of simulation packages are also available for a variety of situations. A list of these are given below with the possible applications :

Software Package	Purpose
MATLAB	General purpose matrix computations
Toolboxes	Specific purposes such as Control Systems Signal Processing Artificial Neural Networks Fuzzy Systems Statistics Symbolic Math μ Analysis Wavelet Analysis Nonlinear System Design .etc.
TUTSIM	System Simulation
SIMNON	Non-linear System Simulation
Mathematica	System Simulation
AutoCAD	Drafting
ProEngineer	Solid Modelling
STAD	Structural Analysis
PSpice	Circuit Simulation
Orcad	PCB Design .etc.

Advantages of package-oriented approach

1. The knowledge of the high level language in the conventional approach is to be replaced by the familiarity of the user with the software package. The more familiarity with the package, more effective will be its utilization.

2. The proper choice of the package is essential as each one is tailor-made for a class of problems. Just as word processors cannot do data base manipulations, AutoCAD cannot be used for solving differential equations.

3. Use of software packages does not require any programming skill. They are mostly command oriented and use of the proper commands helps in solving the problem effectively.

Disadvantages

1. Each software is limited in its application and hence its scope is restrictive.
2. Less flexibility as there is no scope for generalization as in programming.

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