SIMULATION LANGUAGES' VIEW OF THE WORLD

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Introduction

One of the most important problems facing the United States in the decade of the 80s is to develop methods for increasing productivity. Faced with a scarce money supply, it will be necessary to adapt current production plants to meet new demands or to build new facilities with limited expenditures. Thus, we must make wise decisions to obtain an effective use of both our capital and our technical resources in providing goods and services.

A method for helping decision-makers to make wise choices is modeling and simulation. The foundation of this approach involves obtaining an understanding of the problems and concerns related to the decision to be made. This includes a definition of the factors that affect the decision, a listing of the measures by which a good decision will be judged, and the building of a model that forecasts the measures of performance for each decision alternative. Thus, modeling involves a systems approach to problem resolution and consists of four steps. First, a system is decomposed into its significant elements. Second, the elements are analyzed and described. Third, the elements are integrated in a model of the system. Fourth, performance is obtained through the analysis or simulation of the model.

In this paper, information is provided on modeling for decision-making, simulation modeling perspectives, SLAM, dynamic behavior of manufacturing systems, and simulation modeling application areas.

Modeling for Decision-Making

Models are descriptions of systems. In the physical sciences, models are usually developed based on theoretical laws and principles. The models may be scaled physical objects (iconic models), mathematical equations and relations (abstract models) or graphical representations (visual models). The usefulness of models has been demonstrated in describing, designing and analyzing systems. Many students are educated in their discipline by learning how to build and use models, for example, electrical networks and free body diagrams. Model building is a complex process and in most fields, is an art. The modeling of a system is made easier if 1) physical laws are available that pertain to the system; 2) a pictorial or graphical representation can be made of the system; and 3) the variability of system inputs, elements and outputs is manageable.

Industrial engineers, managers and administrators, management scientists and operations researchers deal mainly with the procedural aspects of manufacturing systems. These individuals and their respective fields are attempting to bring order out of chaos with respect to the understanding of the operation of such procedural systems. For our purposes, procedural systems can be thought of in terms of information flow and decision-making with respect to the implementation of stated or implied policy. Emphasis is placed on improving performance through procedural changes or through new designs regarding scheduling, sequencing, distribution, allocation, layout and similar functions (see Figure 1). The modeling of

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Strategic Planning

1. Design of new processes
2. Design of new policies
3. Determination of effect of different priorities
4. Design of new systems
5. Forecast of production levels
6. Determination of required resources
7. Estimation of cost of alternatives

Management Control

8. Determination of how to improve throughput
9. Determination of effect of changes in resource capacities
10. Determination of effect of delays in raw materials
11. Determination of how to relieve bottlenecks
12. Determination of effect of change in demand
13. Determination of effect of equipment failures
14. Determination of system efficiency

Operational Control

15. Determination of capacity
16. Determination of bottlenecks
17. Determination of operational requirements
18. Assessment of in-process inventories
19. Determination of utilizations
20. Determination of critical operational rates
21. Determine best manning configurations

FIGURE 1. *Areas of decision-making for procedural systems.*

procedural systems is often more difficult than the modeling of physical systems for the following reasons: 1) few fundamental laws are available; 2) procedural elements are difficult to describe and represent; 3) policy statements are hard to quantify; 4) random components are significant elements; and 5) human decision-making is an integral part of such systems. In the next section the simulation modeling perspectives that aid in the building of models will be described.

Simulation Modeling Perspectives

In developing a simulation model, it is helpful to select a conceptual framework for describing the system to be modeled. The framework or perspective contains a "world view" within which the system functional relationships are perceived and described. The world view provides a conceptual mechanism for articulating a description of the system.

A system is a collection of items from a circumscribed sector of reality that is the object of study or interest. The scope of every defined system and of every model of that system is determined by its reason for being identified and isolated. The scope of every model is determined by the particular problems the model is designed to solve.

Models of systems can be classified as either discrete change or continuous change. These terms describe the model and not the real system. In most simulation models, time is the major independent variable. Other variables included in the model are functions of time and are dependent variables. The adjectives discrete and continuous when modifying simulation refer to the behavior of the dependent variables. Discrete simulation occurs when the dependent variables change discretely at specified points in simulated time referred to as event times. The number of jobs waiting to be processed is an example of a variable that changes by a discrete amount. In continuous simulation the dependent variables may change continuously over time. The modeling of the concentration of a reactant in a chemical process or the position and velocity of a spacecraft are illustrations of situations where a continuous representation is appropriate. In combined simulation the dependent variables of a model may change discretely, continuously, or continuously with discrete jumps superimposed. For example, when the concentration level of a reactant in a chemical process reaches a prescribed level, the process may be shut down. In the next section, a description of SLAM, Simulation Language for Alternative Modeling, is presented including the mechanisms for building models for discrete, continuous and combined simulations.

Simulation Language for Alternative Modeling, SLAM

SLAM is a simulation language that allows for alternative modeling approaches. It allows systems to be viewed from a process, event, or state variable perspective. These alternate modeling world views are combined in SLAM to provide a unified systems modeling framework. (25)

In SLAM, a discrete change system can be modeled within an event orientation, process orientation, or both. Continuous change systems can be modeled using either differential or difference equations. Combined discrete-continuous change systems can be modeled by combining the event and/or process orientation with the continuous orientation.

The process orientation of SLAM employs a network structure comprised of specialized symbols called nodes and branches. These symbols model elements in a process such as queues, servers, and decision points. The modeling task consists of combining these symbols into a network model which pictorially represents the system of interest. In short, a network is a pictorial representation of a process. The entities in the system (such as people and items) flow through the network model.

In the event orientation of SLAM, the modeler defines the events and the potential changes to the system when an event occurs. The mathematical-logical relationships prescribing the changes associated with each event type are coded by the modeler as FORTRAN subroutines. A set of standard subprograms is provided by SLAM for use by the modeler to perform common discrete event functions such as event scheduling, file manipulations, statistics collection, and random sample generation. The executive control program of SLAM controls the simulation by advancing time and initiating calls to the appropriate event subroutines at the proper points in simulated time. A continuous model is coded in SLAM by specifying the differential or difference equations which describe the dynamic behavior of the state variables. These equations are coded by the modeler in FORTRAN by employing a set of special SLAM defined storage arrays. When differential equations are included in the continuous model, they are automatically integrated by SLAM to calculate the values of the state variables within an accuracy prescribed by the modeler.

An important aspect of SLAM is that alternate world views can be combined within the same simulation model. There are six specific interactions which can take place between the network, discrete event, and continuous world views of SLAM:

1. Entities in the network model can initiate the occurrence of discrete events.
2. Events can alter the flow of entities in the network model.

3. Entities in the network model can cause instantaneous changes to values of the state variables.
4. State variables reaching prescribed threshold values can initiate entities in the network model.
5. Events can cause instantaneous changes to the values of state variables.
6. State variables reaching prescribed threshold values can initiate events.

The ability to construct combined network-event-continuous models with interactions between each orientation greatly enhances the ability to model complex systems.

Modeling Manufacturing Systems (20)

A manufacturing system is a collection of men and machines which operate within an organizational structure to produce a set of products. Production processes are used with the manufacturing system and are affected by financial factors, raw material supplies, union rules, and sales. Surrounding the manufacturing system is an environment that is created by political, social and economic conditions. A need exists for understanding the dynamic behavior of manufacturing systems. This dynamic behavior can be thought of as a plot of system-related variables over a time horizon. For example, plots or tables of interest would be for:

- Profits
- Sales
- Production
- Inventory
- Resource Utilization
- In-Process Inventory
- Equipment and Computer Processing Rates
- Fraction of Jobs Completed On Time
- Scrap Output
- Pollution Emissions

Clearly the list could go on for several pages. The potential variables of interest could reflect the entire business operation associated with the manufacturing system.

In a manufacturing system, there are objects and procedures. The objects are classified as resources or entities where resources represent the elements of the system that are used to produce or affect the entities that are flowing through the system. Both the entities and resources are described by attributes to which values can be given. It is the values of the attributes of resources and entities that constitute the time-varying behavior of the system.

The procedures of system operation cause the attribute values to be changed. Internal to these procedures are decisions that are available to management that can affect system performance.

The objective of a simulation model is to provide a means for describing manufacturing systems and the rules which produce their dynamic behavior. In this way, a method for transforming decisions and procedures into detailed performance measures is made available.

Uses of Simulation Models

Models which portray the time-varying behavior of systems have typically been used in one or more of four modes as: explanatory devices, analysis vehicles, design assessors, or performance predictors. Simulation models are used as explanatory devices to describe in a logical manner the operation of systems. Describing the details of a system's composition and operation is frequently an enlightening experience, even for those familiar with the system.

When a simulation model is used as an analysis vehicle, the effect of a change in system operation is typically being explored. Common questions posed of such models are: What is the bottleneck area? What increase in throughput results from adding new men or equipment? What is the effect of using expeditors, a new dispatching rule, or a new process plan? How will a ten percent increase in orders affect inprocess inventories, resource utilization, and productivity? Analysis with simulation models may be done without making any changes to the real system, often resulting in significant cost savings.

The design of a new system is always an uncertain and risky undertaking because the potential performance of the system is often unknown. Designers aren't certain that the system will function as designed, especially for large systems. However, a simulation model of a new system design allows one to analyze the system to determine to what degree the system will perform as desired. If the design does not perfrom as desired, it can be modified and reevaluated until it meets specified performance criteria. The ability to experiment with a simulation model of a design is similar to having a prototype system or pilot plant.

Simulation models are also used to forecast the future performance of systems as they change and as their environment changes. Such an application can be done on-line or off-line and is a powerful way of controlling the operation of a system.

There are many types of systems which combine to form a complete manufacturing system. Among these are production systems, computer hardware systems, computer software systems, communications systems and procedural systems. A flexible simulation language like SLAM is able to represent each of these types of systems as well as combinations of them. Production systems include the shop floor hardware used to produce the manufacturing products, such as machines and material handling equipment, as well as the personnel required to support the shop floor hardware, such as operators, foremen and expeditors. Computer hardware systems contain such components as storage devices, processing hardware, and data communications equipment. Computer software systems may consist of any type of computer software used in a manufacturing environment including financial and inventory software support programs. Communications systems are any systems which involve the transfer of information between points in the manufacturing environment, while procedural systems are sets of rules and algorithms for accomplishing manufacturing functions. Systems of these types combine to make up entire manufacturing systems. Thus, it is important to be able to represent them individually and in combination.

Simulation Modeling Application Areas

To illustrate the diversity of problem areas in which SLAM and its antecedents GASP IV and Q-GERT have been used, the following list with references is provided:

1. Computer Systems (1, 16, 17, 37)
2. Communications Systems (13, 14)
3. Environmental and Energy Flows (12, 19, 29, 32, 33)
4. Crop Management and Ecological Studies (11, 20, 24, 38)

5. Transportation Systems (2, 8, 23, 39)
6. Policy Analysis (7, 30, 34)
7. Project Planning and Control (3, 4, 5, 10, 22)
8. Materials Handling and Manufacturing (6, 9, 15, 18, 26, 31, 35, 36)
9. Process Design (21, 27, 28)

Concluding Remarks

Management is looking increasingly to scientists and engineers to perform the complex analyses required to improve productivity within existing energy and environmental constraints. Quantitative analysis within the industrial environment is mandatory if we are to obtain the productivity improvements necessary to maintain the United States' world leading productivity levels. The use of computers as the foundation for modeling, analysis, design and planning is a must for the modern scientist and engineer. The opportunities exist and it is up to us to meet our expectations. Models, simulation, and computers will go hand-in-hand in improving the productive capacity of our industrial complex and the quality of life of our citizens.

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