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VALIDATION ASPECTS IN SIMULATION MODELLING

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ABSTRACT

We discuss the relationships between simulation and validation of simulation output. Discussion draws on salient aspects of both simulation and validation activities. We discuss verification techniques and conclude the paper with specific guidelines on how simulation models should be validated.

KEY WORDS: Simulation, validation, verification, model.

1. INTRODUCTION

Simulation is a technique used to generate data, which, in turn are utilised to provide insight about the operation of a system or a process of interest. According to Webster's dictionary, simulation is the act of imitation.

To simulate, in a general sense, means to pretend or to assume the appearance of something without being the real thing. Simulation is a technique for evaluating and observing the behaviour of a model (simulation itself is not a model). Simulation is not using the real process; it is using a copy of a real model. Simulation is very useful, because is quicker and easier to experiment on a copy of the system on the computer, than on the real system.

The overall objective of a simulation model *validation* activity is to provide assurance that model behaviour corresponds to real-world system or process behaviour.

The relationship between validation and performance evaluation is apparent when the complete validation activity is considered. Validation contributes to the better understanding of the system or process involved and in addition enhances knowledge about relationships between model components.

2. PROCESS OF SIMULATION

Simulation involves the implementation of distinguishable steps, namely:

- *problem definition* – must provide sufficient detail to permit a full understanding of the scope of the work to be carried out;

- *model building* – once there is a clear problem statement, the system will have to de defined. This will involve descriptions of the elements or entities themselves and descriptions about the way these elements interact within the system;
- *data collection* – once the system elements for study have been modelled it is necessary to actually quantify probability distributions of interest;
- *program code* – the language which will be used has to be selected;
- *verification* – once the computer program is complete it is necessary to ensure that the code is actually doing what is expected;
- *experimental design* – this step has to be well planned and statistically valid;
- *implementation* – this step involves running the model according to the experimental design;
- *documentation* – is the final step and consists of documenting the entire simulation study which hopefully meets the requirements of the problem definition.

Normally, the term model is associated with scale replica, usually in three dimensions. In a more general sense we define a "model as a representation of some object of inquiry based on abstracting from reality those aspects pertinent to the inquiry, to the extent appropriate for the inquiry, for the purpose of description, understanding, prediction, or manipulation" [1, p.5-2].

The concept of using a model 'was born' as a means to conserve resources in testing, evaluating, and considering alternatives.

The steps in designing a model are:

- define the question you want to answer - the question defines what the result should look like;
- define the measurement (s) by which to judge the system behaviour;
- sketch the model layout;
- gather necessary data;
- build the model in stages;
- test each stage;
- analyse the results; and,
- make changes as necessary.

3. VALIDATION

After the steps in designing a model are completed, the model has to be validated. Validation means to compare the model's output to a result known to be correct. Usually it is a real system. Once it matches satisfactorily, the changes to the model can de done, to see the changes in the real system. If you model systems that don't exist yet, you have to validate portions of the model

A problem is defined by identifying the variables and parameters to be included in the model. Figure 1 describes the computer simulation methodology. Two classes of variables are normally present:

- variables controllable by the decision maker (ex. 'which customer will be served next?');
- uncontrolled variables associated with the environment (ex. 'how many customers will arrive?').

Parameters are properties of the system being studied that remain constant during the study period (ex. the distribution of the customer population).

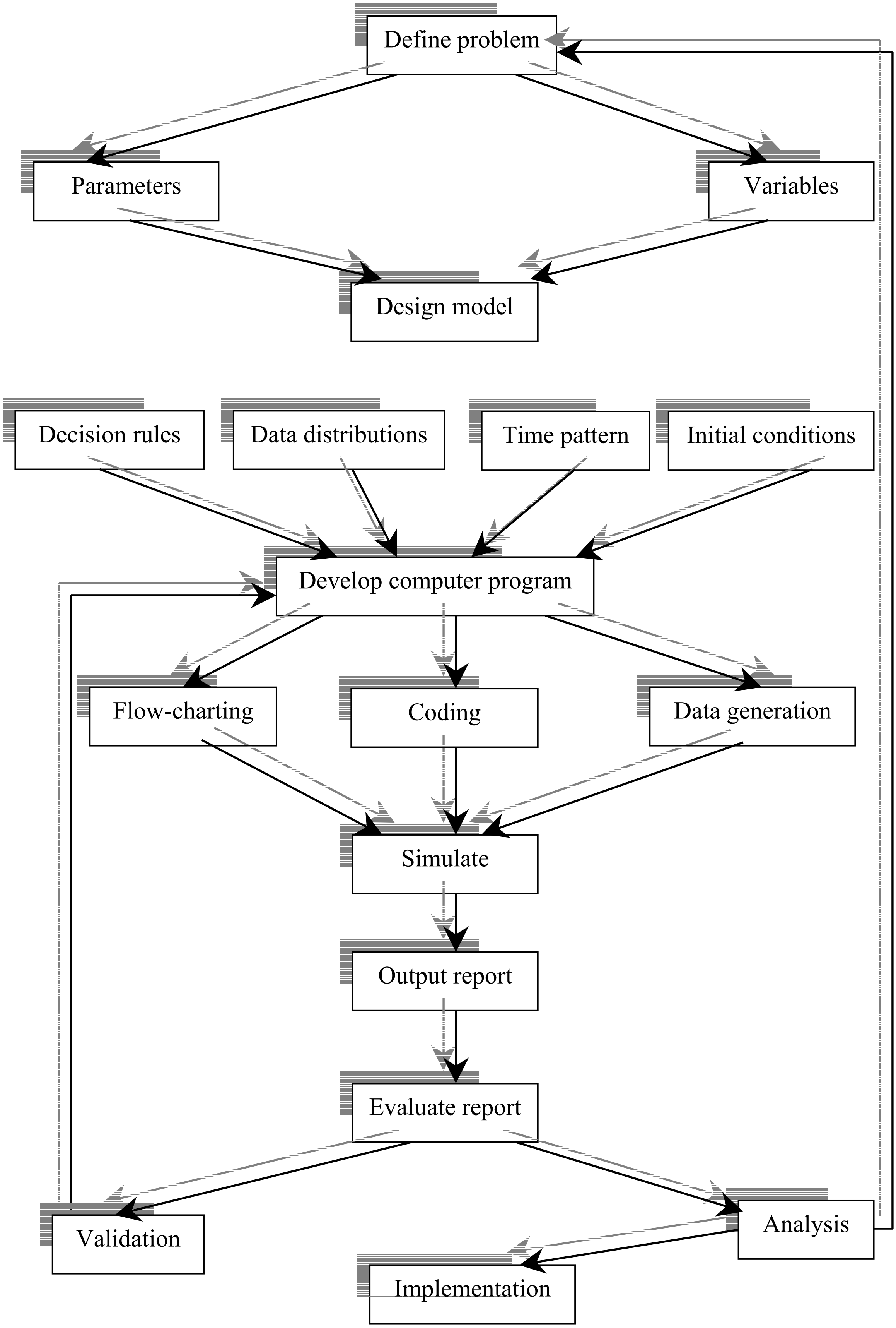

Figure 1. Computer simulation methodology

A simulation model is constructed by setting the starting conditions for the study, specifying the time increments (fixed or variable) at which the system will be observed, determining the decision rules that affect the behaviour of the system, and specifying the probability distributions for variables.

A computer program is developed by flowcharting the problem to display how the system dynamically responds to the conditions of interest, translating the flowchart into computer language, and obtaining a random number generator.

The output of a simulation exercise will depend on the program governing to run. The role of the output is to represents adequately actual conditions. Errors appear from mistakes in flowchart logic and coding. On the other hand, errors can appear from basic data and assumption, too. Prediction errors may result from following:

- the model is structurally incorrect; and,
- parameters are incorrectly estimated.

A simulation model can be incorrect for any of three reasons:

- structural error;
- parameter error; and,
- simulation error.

Real validation depends on how closely the simulation conditions resemble actual performance after the modelled system is implemented.

To assess performance time and cost are often deployed as criteria. Time is the criterion for utilisation, and cost is used for investment comparisons.

4. VERIFICATION OF SIMULATION MODELS

To verify the simulation model different techniques can be used [2, p. 334]. Because the simulation model is a computer program, some of these techniques can be used for debugging any computer program, while others are unique for simulation modeling.

One of the techniques is to write the computer program in modules or subprograms instead of writing a big program. If the computer program is writing in this way, it is simpler to compile and to find the mistakes which can appear.

Another technique, which is used when is developing a large simulation models, is to have more than one person to read the computer program, because the person who writes a particular subprogram may get into a mental rut and can not evaluate correct the work which is done.

One of the most powerful techniques that can be used to debug a discrete-event simulation model is a trace. In a trace, the state of the simulated system is printed out just after each event occurs in order to see whether the program is operating as intended. In performing a trace it is desirable to evaluate each possible program path and also the program's ability to deal with 'extreme' conditions.

Another technique is to display the simulation output on a graphics terminal as the simulation progresses.

The last technique about which we discuss is to run the simulation model under simplifying assumptions for which the model's true characteristics are known or can be easily verified.

Figure 2 summarizes the verification techniques discussed in this section.

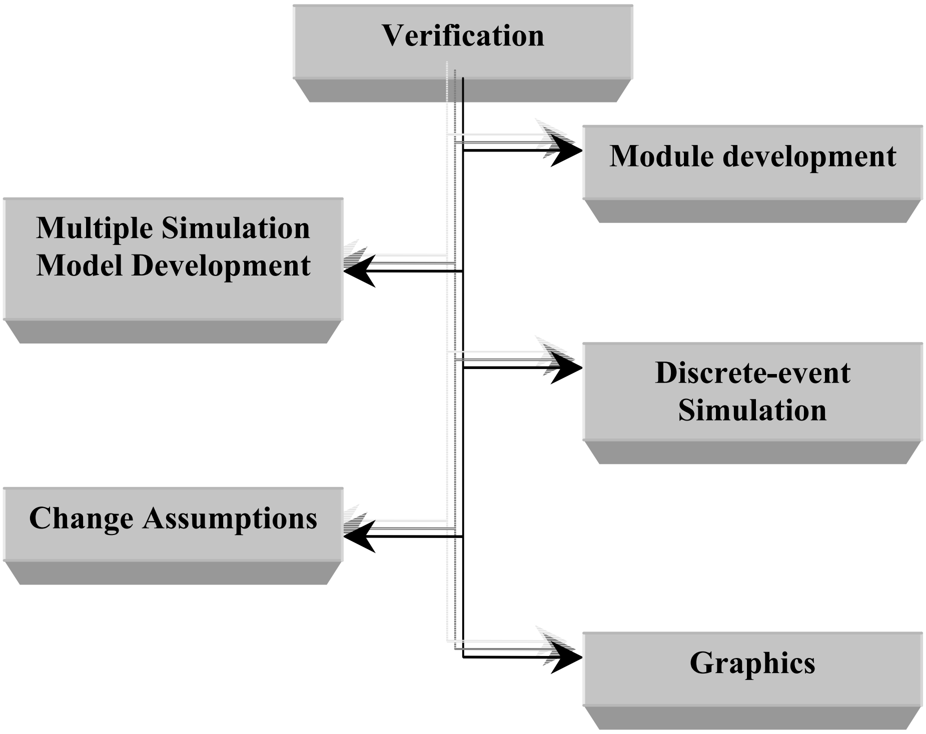

Figure 2. Techniques used to verify the simulation model

5. CONCLUSIONS

Usually, a system is simulated to help a manager to make a decision or to obtain more particular data about the real system.

There is no reason to simulate a system without having a particular purpose, because a model valid for one purpose may not be valid for another and also because the output from a simulation run is distributed, and a single run cannot provide a statistically valid estimator. This is the opposite of the analytical methods which can provide exact solutions.

But, on the other hand, the simulation can be used to estimate the performance of existing systems when some conditions are changed or when some complex systems cannot be easy described with a mathematical model that allows for an analytical solution.

So, because of all this reasons, it is very important that the validation of the simulation model to be done correctly. To this end, one should keep in mind that the characteristics of effective simulation modelling are *reliability* and *relevance*. Reliability refers to the expected level of confidence regarding the success of the attempted simulation effort, and relevance refers to the relationship between the real-world system or process being simulated and the simulation effort itself.

The degree of reliability required of any given simulation depends on its criticality in terms of needs and cost. There are two underlying factors which contribute to simulation reliability in any given situation. These are consistency of logic supporting model development and the validity of premises upon which this logic is based. When involved in simulation one should keep in mind that objectives should be clearly defined at all levels involved: strategic, tactical, operational and performance assessment. Desired results should be clearly spelled out in a way that can be readily translated in simulation modelling and analysis.

Simulation modelling and analysis is like the highways. They are very expensive to build and there is no sense in building them until you know exactly where they are going to wind up.

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