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VALIDATION OF SIMULATION MODELS:THE WEAK/MISSING LINK

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ABSTRACT

The validation of the simulation model is generally acknowledged as an integral part of a simulation project. There is, however, no general agreement on how simulation models should be verified and there is often confusion as to the difference between validation and verification. In this paper we first set forth a framework for verification and validation as well as some of the more commonly suggested methods to be used. We then turn to the literature on the application of simulation to see how models are, in practice, verified and validated. To our surprise we found that in the vast majority of the reported applications of simulation there is no mention of verification or validation of the simulation model, and when it is included, typically a single sentence or two is all that is devoted to how the model's credibility was established. We classified reported applications by type of author, organization type and source and found no significant difference in the frequency of the inclusion of verification or validation as part of the reported application.

1.0 Introduction

Since any simulation model developed is only an abstraction of the real system being studied we should always have some doubt about the correspondence between the real system and the model. In this paper we consider the practice of establishing the credibility of simulation models as evidenced by reported applications of simulation. Before presenting our initial findings we will give a brief overview of verification and validation.

1.1 Establishing A Model's Credibility

The terms most often used for the process of establishing that the simulation model is a credible representation of the real system are Model verification and model validation. Fishman and Kiviat [1] are most often credited with first using these two terms and differentiating between the two processes. Verification is the process of determining whether the operational logic of the model (the computer program) corresponds to the "flow chart" logic. In the simplest of terms ,"Are there errors in the program?" . Validation, on the other hand,is the process of determining whether our model, as a conceptualization or an abstraction, is a meaningful and accurate representation of the real system. Other terms that are also used to describe the process of establishing the model's credibility are internal/external validation and logical/technical/operational validation. In this paper we will stay with the more standard terms of verification and validation.

2. The Role of Verification and Validation in Simulation

When building a simulation model of a real system we must pass through several stages or levels of modeling. As shown in Figure 1, starting with the real system we first form a conceptual model of the system which contains the elements of the real system which we believe should be included in our model. From this conceptualization of the system we go on to form a logical model which contains the logical relationships among the elements of the system as well as the exogenous variables that affect the system. This second model is sometimes referred to as a flow chart model. Using this logical model we then develop a computer model which will execute the logic contained in the flow chart model. This computer model may be in written in a general purpose language or in a special purpose simulation language.

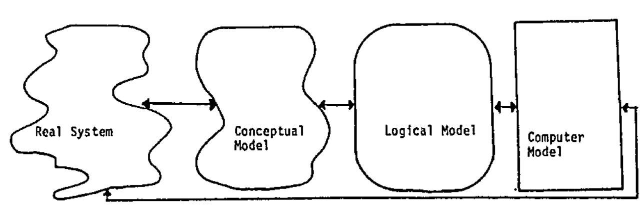

Figure 1

Developing a simulation model is an iterative process with successive refinements at each stage. The basis for iterating between the different models of the real system is the success or failure we have when verifying and validating each of the models. One does not move progressively from the real system to the conceptual model, then to the logical model and finally to the computer model, for in the process of developing and verifying or validating the model at one stage we cannot avoid raising questions about the correctness of the models developed in the prior stages. The interdependence between the adjacent stages of modeling should be apparent but there is also a strong inter-relationship between the conceptual model and the computer model. Although the final stage in modeling is the writing of the code to represent the logical model it is neither realistic nor desirable to have the conceptual model or logical model developed without first looking ahead to the computer model. An experienced simulation analyst will have a repertoire of languages for modeling the real system, with each of these languages having a "world view" which maps well or poorly into the real system. For example, if the real system is a material handling system with products being moved about a factory the world view of GPSS (transactions flowing through the model, vying for entities such as conveyors or workers) may be very useful in the development of the conceptual model. Similarly, if the system is one of concurrent processes sharing a common resource the SIMSCRIPT world view may be advantage in developing the simulation model.

When we validate a model we establish that the model is a credible representation of the real system while verification is the process of determining whether the logic of the model is correctly implemented. Because the objectives of validation and verification are different, the techniques that have proven useful for one task are not always helpful for the other. We will therefore put forth methods for verifying a model's logic and its implementation through a computer program and then take up methods for validating the model.

To verify or validate a simulation model we need to establish a set of criteria to judge whether the model's flow chart and internal logic is correct and whether the conceptual model is a valid representation of the real system. Along with these criteria for evaluating the model we need to specify who will apply the criteria and judge how well it has been met. In the best of circumstances validation and verification is a team effort drawing upon the technical skills of the simulation analyst and the knowledge and insights of the users and managers of the real system. In practice, however, it is not always possible to form such a team and it is often left up to the simulation analyst to verify that the computer model is "working correctly" and then convince the managers and users of the real system that the model is a credible representation of their system.

It is rare to find in the reports of the application of simulation validation or verification of the conceptual model or logical model and for the remainder of the paper we will deal only with verification of the computer model and validation of the simulation model.

2.1 Verification of the Computer Model

Once the logical or flow chart model has been verified the programming of the computer model can begin. The computer model is verified by showing that the computer program is a correct implementation of the logical model. Verifying the computer model is quite different from showing the computer model is a valid representation of the real system and a verified model does not guarantee a valid model.

Some methods of verifying the computer model are unique to simulation while other methods of verification are the same as those used in any software endeavor. The effort required to verify the computer model is heavily dependent upon the programming language used and there is no agreed upon general verification methodology. Verifying the computer model often requires a great deal of imagination and ingenuity on the part of the analyst and is one of the few activities in the simulation project that is best done without the aid of the decision makers or managers.

There are atleast six general approaches to verifying the computer model. These methods are:

1. Structured programming methods
2. Program testing
3. Tracing the simulation
4. Logical relationship checks
5. Comparison to analytic models
6. Graphics

2.2 Validating the Simulation Model

When the computer model has been verified we must next determine if its output is a valid representation of the real system. Unless the simulation model is validated it is at best a correctly executing computer program. Validating the simulation model should be done with the participation of analyst, decision makers and managers of the system. One test for a valid model has been whether the decision makers in the system have enough confidence in the model that they will use the model as part of their decision making process. That is, does the decision maker believe that the model is correctly answering the questions that it was intended to address.

As with verifying the computer model there is no single or predominantly used technique for validating the simulation model, but there are a number of approaches which are frequently used to validate simulation models. The procedures for validating the simulation model depend upon the system being modeled and the modeling enviorment. For example, validating a model of an operating system for a computer which is currently being designed is a very different problem than validating a simulation model of a material handling system which currently exists.

Three methods of validation which are commonly used are:

1. Comparison of the Output of the Model to the Real System
    - Statistical
    - Nonstatistical
2. Face Validity
    - Delphi
    - Turing Test
3. Extreme Behavior

3.0 The practice of Verification and Validation

Although no one would argue that simulation models should not be verified or validated there has been little research into how often and to what extent practitioners of simulation verify and validate their models. In an attempt to get a reading on current practice we turned to the simulation literature. Although our search of the literature was not exhaustive it did cover a broad number of applications reported in a variety of publications. As of this date we have read through 117 reported applications of simulation published over the last 4 years. The sources of these applications are:

Decision Sciences
Industrial Engineering Magazine
IIE Proceedings
Management Science
Management Science Interfaces
Operations Research
SCS Proceedings
Simulation

In these reports of the application of simulation we looked for any evidence that the simulation model was either verified or validated.

In order to summarize the findings from all 117 articles we entered into a database, for each application reviewed, the following information:

1. Title
2. Author
3. Academic Affiliation (yes or no)
4. Source
5. Type of Organization
6. General or Problem Specific Model
7. System Exit Now (yes or no)
8. Application Area
9. Verification Methods Used
10. Validation Methods Used

In general, our findings were not encouraging! Only 36 of the 117 applications reviewed contained ANY reference to verification or validation and in those cases where some mention was made it was typically very brief. One should not immediately conclude that practitioners of simulation do not verify or validate their simulation models but it is clear that verification and validation is not considered to be an important part of reporting a simulation application. The fault may lie as much with the reviewers as the reporting practitioners but the failure to report how models are verified and validated may, in part, explain the lack of progress in establishing accepted procedures for establishing the validity of simulation models. We have not done a similiar analysis for reported application of modeling which did not use a simulation, or for other areas of science. It may be that the practitioners of simulation are no worse than other practitioners who use modeling for problem analysis. This research is still ongoing and during the presentation of the paper we will disclose the latest of our findings.

In line with the definitions of validation and verification, when reviewing a reported application of simulation we often classified "validation efforts" as verification vise versa. It was apparent that practitioners are not universally in agreement on the meanings of these two terms. We were very liberal in citing an application for validation or verification efforts, with credit being given if the topic was brought up in even a single sentence. If there was evidence that the model was verified or validated we attempted to classify the efforts into one of the previously mentioned methods.

We are continuing our search of the literature but our preliminary findings bring into question the extent to which simulation models are verified or validated. In the tables below are the summaries of our findings.

For each classification shown in Tables 1 through 4 a Chi Square Contingency Test was performed and in each case no significant difference was found in the frequency of validation or verification.

4. Conclusions

Based on our research we cannot say with certainty that practitioners of simulation are not verifying or validating their simulation models but it is clear that they do not, as a rule, include these efforts as an important part of any reports or publications. This failure to include validation and verification of simulation models does not add to the credibility of this branch of applied science.

	Verify or Validate (yes,no)				
ACADEMIC	Yes	%	No	%	Total
Yes	19	26	55	74	74
No	17	40	26	60	43
Total	37	31	81	69	117

Table 1. Academic vs NonAcademic

	Verify or Validate (yes,no)				
ORG.TYPE	Yes	%	No	%	Total
Industry	20	42	28	58	48
Govern't	8	26	23	74	31
Military	1	25	3	75	4
Education	1	25	3	75	4
Other	6	29	24	80	30
Total	36	31	81	69	117

Table 2. Organization Type

	Verify or Validate (yes,no)				
SOURCE	Yes	%	No	%	Total
SCS Proc.	22	32	47	68	69
Interfaces	3	27	8	73	11
Simulation	6	60	4	40	10
IIE Proc.	3	33	6	67	9
Dec. Sci.	0	0	8	100	8
Mgt. Sci	1	17	5	83	6
Other	1	25	3	75	4
Total	36	31	81	69	117

Table 3. Source of Reported Application

Method	Number of Times Referenced
Comparison	17
Face Validity	13
Statistical Comparison	5
Other	7
Total	42

Table 4. Methods of Validation

BIBLIOGRAPHY

1. Fishman, G.S. and Kiviat, P. J., "The Statistics of Discrete Event Simulation", Simulation 10 185-195 (1968)