A SURVEY ON MODEL VV&A OF SYSTEM SIMULATION

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ABSTRACT

Model verification, validation and accreditation (VV&A) of system simulation are detailedly discussed in this paper. The necessity of VV&A is explained by analyzing the factors on which the model and the reality are discrepant. The VV&A technology is expounded in detail not only in the conceptual aspect but also in the methodological aspect. Some principles, difficulties and problems that should be paid attention to are discussed concretely and reasonedly. The paper is expected to be instructional and helpful to the VV&A study.

1 INTRODUCTION

System simulation is also called models and simulations (M&S), which is brought and developed gradually with the development of computer technology in 1940's. M&S means the study process of experimentation on real system through modeling. With the fast development of every aspect such as good-performance computer, communication, and network, the method and instrumentality of system simulation technology update constantly, which has applied to many fields such as scientific research, engineering design, assistant decision, run optimization, campaign modeling, transportation and ecosystem, especially in some complicated systems which are either expensive, long, dangerous, or hard to realize through real system.

We depend more on system simulation as it develops and is applied widely and deep to other fields. Model Verification, Validation and Accreditation, VV&A for short, are just developing fast with it. The simulation result is impossible to be exactly the same as the real one, because simulation is based on model but not on the real event. So establishing a right, credible and valid model is the sticking point and premises of ensuring the simulation result has high confidence level. Only the simulation result is made certain to be right and confident, can it has the practicality meaning. Therefore, people of simulation field inland or overseas pay more and more attentions on the theories and methods of modeling and validating as time goes on. Adopting VV&A technology is an important method and effectual approach of enhancing the confidence of simulation.

2 THE SIGNIFICANCE OF VV&A STUDY

When we are modeling or simulating, there are a lot of factors that make the model and the real object discrepant, which makes the VV&A work seems to be very necessary. These factors include:

(1) The principium or method is wrong. Or although they are right, the hypothesis, parameters' selecting, or simplification of model may not be correct;

(2) Some secondary factors may be overlooked in the course of modeling. Some factors that contribute less to the system or seem to be irrelevant are ignored, which in some degrees is potentially dangerous. For the studied object may changes in the course of modification, which makes some ignored factors' effect increase and can not be ignored any more; There is not an obvious criterion to estimate whether a factor should be ignored or not by now; Some factors may be not considered because of the solving method's limitation (such as the limitation of restriction's number or no solution); Some factors that caused by people.

(3) Time of simulation test is short. So enough samples can not be obtained, which brings lots of errors to the last analysis. The precision of running result is influenced.

(4) There are errors when selecting the model's initial data. Data or at least distribution of model must be the same as initial one. The deviation may cause great "fluctuation" of the simulation result. Reasonable data may also shorten the "warm-up" time of simulation.

(5) There are errors when determining the distribution of random variable or selecting parameters. The devia-

tion or lack of initial data because of difficulty of their collection must cause errors in the determining of the distribution of random variable or selecting parameters, which influences the validity of the model.

(6) Statistical error of simulation's output. The simulation's variables' statistical results that are recorded before the system is steady may be wrong; A statistical method may not be adopted by all models; The seeming consistency of the simulation and the real system shouldn't become the main criterion of the model's estimation.

(7) When computerizing, solving and testing, the model's validity may be influenced by byte's length of computer, coding errors, algorithmic errors and so on.

It is obvious that simulation model has unavoidable "connatural inexactitude" because of above reasons. Therefore it is very important to estimate model's credibility through VV&A.

3 CONCEPTS AND CONTENT OF VV&A

Correct concepts are the basis of VV&A. These years, common understandings are compassed on the conceptual study of simulation model as the validity's study and application more widely and deeper:

Verification: It is the course of determining whether the model and simulation represent developer's conceptual description and technological need. What it concerns is "whether establishing model correctly?" It reflects the correctness level;

Validation: It is the course of determining whether the model and simulation represent the real event in the aspect of expected usage. What it concerns is "whether establishing a valid model?" It reflects the validity level that the simulation result represents the real event;

Accreditation: It is the course of determining whether authority can accept the model and simulation in the aspect of expected usage. What it concerns is "whether trusting the simulation model and result?" It reflects the confidence level of people's on the simulation model and result.

We can see from figure 1 that the relationship of verification, validation and accreditation is consanguineous, including "intersection" and "inclusion" among them. Verification work provides gist for affirming every function of the system; Validation work provides gist for validity estimation of the system; While the core question of VV&A work is credibility estimation, namely the sponsor and the user's confidence on the issue's solution using simulation system.

The whole course of VV&A includes validation of conceptual model and simulation result; Verification of structural design and software. Verification and validation will improve the correctness of the system simulation; While accreditation will determine the confidence level of the system simulation.

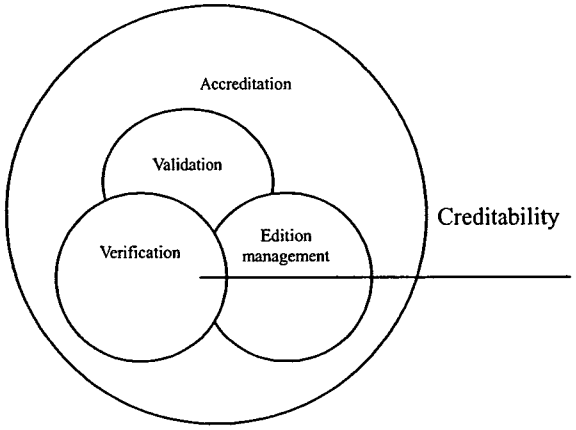

Figure1 VV&A concepts of simulation

4 THE PRINCIPLES OF VV&A

In order to enhance the understanding of VV&A concepts of simulation system, it is necessary to discuss the principle of VV&A, which has instructional meaning on studying the theory and practice of VV&A.

The VV&A Propositional Instructional Criterion published by DOD of U.S. sums up 12 pieces of principles of generally applicability. It is used to instruct the management of VV&A and operate activities of VV&A. Osman Balci has put forward 15 pieces of principles of verification, verification and testing (VV&T) on the basis of summing up relevant data, which can be the important reference of VV&A. Synthesizing the above data, VV&A work should follow these main principles:

(1) Relative correctness principle: the correctness of simulation system is relative to its application purpose. There is not absolute correct simulation system. The correctness of same simulation may be completely different for different simulation purpose.

(2) Whole life period principle: VV&A should be carried through the whole life period of simulation instead of being done after having completed the simulation. Proper VV&A work should be arranged in every phase according to its study content and influence to practical application objective to find the existent problems and influences. Otherwise it is difficult to realize the real function of VV&A.

(3) Limited objective principle: the objective of VV&A should be closed to the application objective and functional demand of simulation system. For those items that are irrespective to application objective, in order to decrease the expenses, the VV&A may not be done.

(4) Necessary but not sufficient principle: estimation of simulation system can not ensure the correctness and acceptability of system application's result, namely VV&A is necessary but not sufficient. Three errors should be avoided: □the simulation system is correct while being rejected; □the simulation system is wrong while being adopted; □ solving a wrong question wrongly.

(5) Integrality principle: the verification and validation of every part can not ensure the integral correctness of whole system. The correctness of whole system must be verified and validated from the whole system.

(6) Degree principle: what we got from the estimation is not the simple logical result of adoption or rejection, but the degree of acceptance relative to the application objective of simulation.

(7) Creativity principle: VV&A is not only a science but also an art. Simulation itself is a technology of creativity. So ample creativity is more needed to estimate simulation. And the estimators should have ample creativity and insight.

(8) Well planning and recording principle: well planning should select the most helpful activities to enhancing the correctness of simulation system and the credibility of simulation result. Optimizing the implementary course to find problems furthest and improve the quality of the simulation. Recording all results of every work to provide necessary information for next step of work, check and accept.

(9) Analytical principle: not only the data obtained by testing system should be fully made use of, but also the knowledge and experience of system analysts should be fully made use of so as to analyze the problems that can not be estimated by testing.

(10) Relative independent principle: in order to avoid developers' influence on VV&A, VV&A should ensure the estimation's independence from the developers. But VV&A should cooperate with developers to enhance the understanding of system so as to do VV&A work well.

(11) Right data principle: the data/database that VV&A needs must be verified, validated and accredited in order to testify their correctness and sufficiency.

5 SUMMARIZATION OF METHODOLOGICAL STUDY OF VV&A

The methodological study of VV&A mainly answers two questions: (1) how to express and measure the credibility of simulation? (2) what method should be adopted to do VV&A work of simulation?

Verification analyzes the correctness and precision of simulation system. There are many methods of validation, in which the method of comparing the simulation result and the theoretical analyzed result or the real test result under the same input condition is a valid approach, which has attracted people's attention. Accreditation is based on running the simulation system and the showing all kinks of documents.

By now, many theories and methods of VV&A have been brought forward. But the primary work fastens on the model validation. While the study of model verification is very limited, and its primary work fastens on the verifica-

Table 1 summarization of model validation

Dynamic relevancy analysis	Testing statistical hypothesis			Time series & spectrum analysis	Others
	Parameter estimation	Parameter hypothesis test	Non-parameter hypothesis test		
TIC analysis	Point estimation	t-test	Denotation test	Time series analysis	Graphic test
Grey correlation analysis	Region estimation	F-test	Sum of orders test	Classical spectrum estimation	Expert's experience
Regression analysis	Least squares estimation	χ^2-test	Process test	Modern spectrum estimation	Sensitivity analysis
.....	Maximum likelihood estimation	Bayes	Order test	Wavelet analysis	Indetermination method
	Bayes	.....	.....	.....	.....
	.....				

tion of programs. The existing validation methods are shown on table 1.

The pertinency of every validation method is different. For example regression analysis, region estimation, hypothesis test and sensitivity analysis are based on the result of simulation, while time series analysis and spectrum analysis are based on time series and spectrum. Validation methods can also be divided into qualitative analysis and quantitative analysis. The former checks the consistency of simulation output and real output by computing a performance index (such as TIC viz. Theil Inequality Coefficient, grey correlation coefficient etc.). Qualitative conclusion is obtained from this method. The later can give the quantitative analysis result of the consistency of simulation output and real output. Every method has it's own applicability and limitation. Although quantitative method usually has strict theory basis, its result may not be more credible than qualitative method's.

In principle, all methods of software field can be applied to simulation program verification expect that different method has different practicality value. Balci summarized all kinds of methods and their classification of model verification. They are symbol analysis, static analysis, dynamic analysis, restriction analysis and theory proving etc.. Although the effects of symbol analysis, restriction analysis and theory proving are good, their implements are difficult, even imposable for some complicated systems. Moreover the standardization level, the consuming and significance of manpower resource and computer resource of every method are different too.

6 DIFFICULTIES AND PROBLEMS OF VV&A

Model verification and validation are not simple courses. The difficulties in practice are shown as follows:

(1) Model validation is a course of practice-theory-practice. Sometimes repetitiousness is needed to accomplish the work.

(2) Model validation is indeterminate. The comparability of model and studied object has some indetermination. This is mainly because that the understanding level of the studied object and the methods and techniques adopted are different.

(3) Model validation is affected by many factors, including interior and exterior causes. Interior cause indicates the model itself, namely those structures and parameters that respectively represent the model's commonness and individuality. Their correctness or not should take more attention. Exterior cause is the running environment of model. The most essence is the comparability of simulation's input and the real system's input to create the condition of validity analysis.

(4) Usually there are lots of complicated statistics analysis and computation in the validation of big complicated systems, and the cost is high. This makes it impossible to validating the model thoroughly in practice.

(5) Under some circumstances, credible output of real system is hard or even impossible to get, which brings great difficulties to the validation. For example we can not experimentalize on the real systems of society, economy, ecosystem and environment; In the missile&weaponry system, though some eigendata that represent real system's performance can be got though target practice test, these referenced data are very limited and deficient.

(6) Each kind of credibility estimation is considered on different aspect. The final confidence is the integration of all confidences. But how to integrate them is just one of the greatest difficulties.

Besides, these problems should be noticed in model validation:

(1) Commonness: there are commonness among all systems from VV&A to the experiment and management of simulation because they use the same simulation technology. Therefore the ideas and methods of VV&A can be generalized from one system to other homogeneous systems or applied to other inhomogeneous systems selectively.

(2) Particularity: a criterion or method that applied to all model validations can not be found because of the great difference of real systems. The adopted criterion or method should be different if the study purpose or emphasis point is different even for one system. Therefore when validation, not only the commonness but also the particularity should be seen. Grasping where the shoe pinches to solve problems.

(3) Purpose: the purpose of simulation determines the complication and hiberarchy of it. This is a pivotal factor that affects the selection of validation and criterion.

(4) Discrepancy: it indicates the discrepancy of time-region-model and frequency-region-model. Time-region response particularity indicates the response of all kinds of typical input signals of the system. The relevant system parameters are difficult to work out. Therefore great errors may be produced. Frequency-region response particularity indicates the steady state response of different given sine-input-signal of the system. It checks the system in the concerned frequency region. Therefore the model parameters' influence on the system particularity can be roundly discovered thus the precision is high. But the expression of frequency region is difficult for multi-input and multi-output systems.

(5) Incomplete attainability: the simulation is simply the similar disposal of real system, and they can not be completely equivalent or isomorphic indeed. This is because: the input aggregation of simulation can not be completely equal to that of the real system; There must are all kinds of modeling errors when dealing with multi-similitude of real system under many limitations and hypothesizes; The system has the "grey" part and "black" part all along. Therefore the model is considered to be a valid model only when it has met the confidence level, implemented the simulation purpose and met the demands of studied issue.

Knowing the technical difficulties and relevant problems of VV&A will be helpful to the estimation of credibility.

7 CONCLUSION

VV&A technology has caught people's eyes overseas while it is still in the ascendant interiorly. The difficulty and demand of VV&A are improving as the enlargement of simulation's scale and the increase of its complexity. So the study of large complicated system especially of the high-speed dynamic simulation system (such as missile system and coordination of fuse and warhead system) should be enhanced. In order to increase the efficiency of estimation and validity, the research work of automatization, intelligentizing, integration and standardization of VV&A should be developed. In practice the arrangement management and the integration study should be enhanced too. And the visibility of VV&A should be realized by the integration of the visibility technology and VV&A technology. These problems are all expected to be solved.

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