# QUALITY ASSESSMENT OF SIMULATION MODELLING

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Abstract: In simulation modelling quality assessment is not common practice. The classical quality aspects (correctness, reliability, usability, etc.) are relevant to simulation modelling, but model validation is a more favored simulation feature, although it will not necessarily render satisfaction to other quality aspects. In this paper an integrated approach is proposed, using a Simulation Maturity Model (SMM) to improve overall quality. The simulation modelling process (SMP) is decomposed into a complex series of actions each with its product(s), which are evaluated in a series of tests. The approach will be implemented into QUASIMODEM, a model of the SMP.

Keywords: Quality assessment, simulation maturity model (SMM), simulation modelling process (SMP), defining SMP, testing, model validation

## 1. INTRODUCTION

Quality management has much in common with sex (Crosby, 1979): everyone is for it, everyone feels they understand it, everyone thinks execution is only a matter of following one's natural inclinations. There are many reasons to adopt quality assessment as an integral part of all simulation studies. Quality is not the result of 'following natural inclinations'.

Determination of quality is part of everyday life. By tasting food one can evaluate its taste, its freshness, its tenderness, its smell. Judges in ice dancing translate things like complexity, artistic values and harmony of a performance into a simple report mark. All of these quality factors are subjective and even in case quality is measured using some kind of metrics it is only rarely objective. Arbitrary and subjective elements can not be excluded. The main topic in this paper is not how to evaluate quality but how to improve quality.

Opposite to software development, quality assurance for simulation models is not common practice. If scientists build those

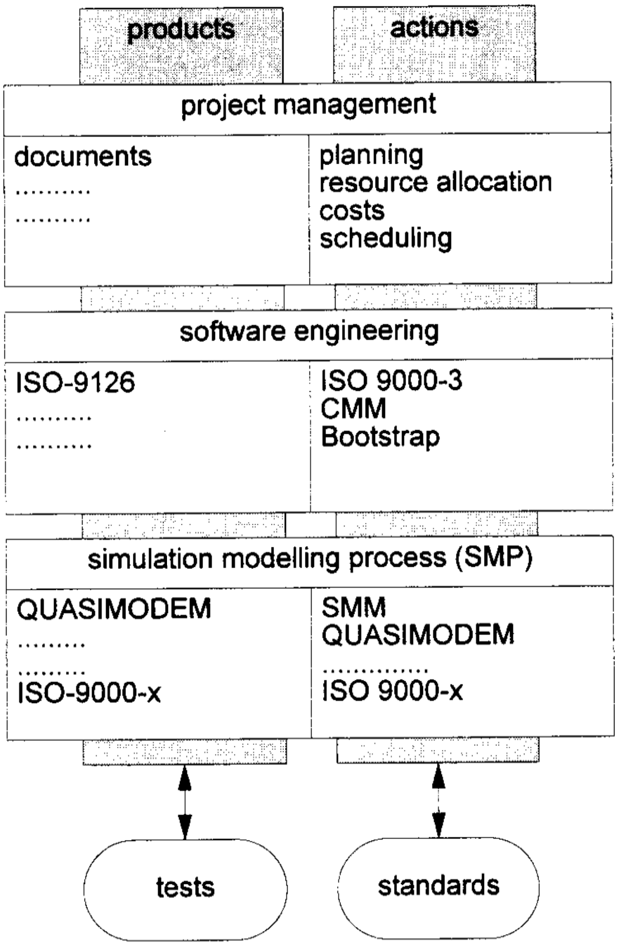


Fig. 1. The simulation modelling in its context.

models, they consider a model as a research tool and hardly as a product, which can be used for decision making. At least they don't develop a model which is designed for other applications. In more technical domains there is a tendency to improve and evaluate model quality. In domains with less hard, 'grey' models, which are based on incomplete, not accepted theories and hypotheses, quality assessment is not a modeler's every day routine.

In this paper quality aspects like correctness, reliability, usability will be discussed in regard to the overall simulation modelling process (SMP). Quality assessment in simulation is very complex and includes different items like software quality assurance, project management and several model validation items (Fig. 1). Here model quality improvement is attacked with two main approaches. At first, a Simulation Maturity Model (SMM) is used to control the SMP. At second, a series of tests will be proposed to evaluate some products of the modelling process. Both approaches will be integrated in the design of a simulation modelling quality tool: QUASIMODEM.

## 2. QUALITY ASPECTS

Classical aspects of quality, such as those defined by McCall *et al.* (1977) for software, are also relevant to simulation modelling. These are:

- *correctness* extent to which a model satisfies its specifications
- *reliability* extent to which a model can be expected to perform its intended function with required precision
- *efficiency* amount of computing resources and code required by a model to perform its function
- *integrity* extent to which access to model with data by unauthorized persons can be controlled
- *usability* effort required to learn, operate, prepare input, and interpret output of a model
- *maintainability* effort required to locate and fix an error in a model
- *testability* effort required to test a model to ensure it performs its intended function
- *flexibility* effort required to modify an operational model
- *portability* effort required to transfer a model from one hardware and/or software system environment to another
- *reusability* extent to which a model or parts of a model can be reused in other applications related to the packaging and scope of the functions that the model performs
- *interoperability* effort required to couple one model to another

Besides these aspects, borrowed from software engineering, validation is the main quality aspect in simulation modelling. Model validation is discussed extensively in literature, but most authors offer merely a terminology instead of a method (Sargent, 1982; Sargent 1984a; Sargent, 1984b; Knepell & Aragno, 1993; Sheng *et al.*, 1993). Furthermore it has to be concluded that many models are invalid to some extent. This is especially true for models based on a weak theoretical base. Validation will not improve model quality. Validated models reproduce system behavior correctly, but this does not imply that other quality requirements are satisfied. The computer instance of that model may be hard to use or not flexible to change.

In this paper those quality aspects will be discussed which have a meaning in simulation modelling beyond those relevant for software quality only.

## 3. THE SIMULATION MODELLING PROCESS

Many authors proposed schemes for the simulation modelling process (SMP), but Sargent's (1982, 1984a, 1984b) is the most popular in regard to model validation. He distinguishes a problem, a conceptual model and a computer model. The step from problem to conceptual model is called problem analysis and modelling, the step from concept to computer model is called programming and implementation. Finally the link between computer model back to the real world is called experimentation. Each of these three steps is evaluated respectively in conceptual model validation, model verification and operational validation. Additionally, the validity of the model will also be evaluated with respect to data (observations of the real system).

By decomposition of the SMP into actions, each with one or more products, a more detailed scheme is generated (Scholten, 1994; Scholten and Udink ten Cate, 1995). This detailed scheme allows a better quality assessment as is discussed in this paper.

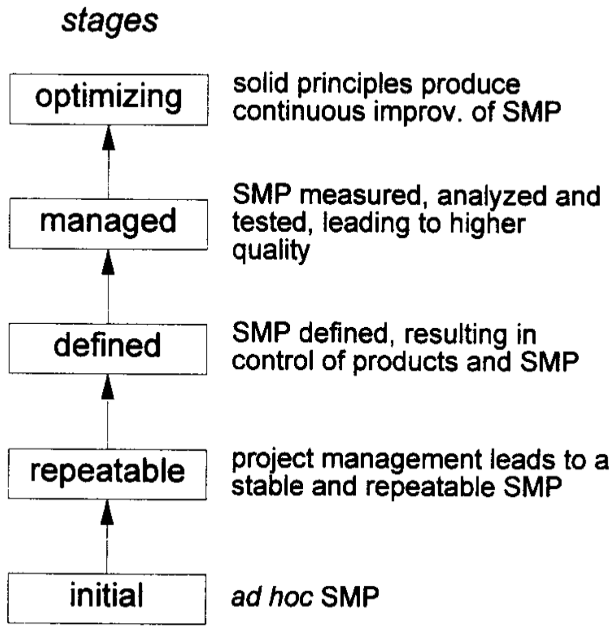


Fig. 2. Stages in the Simulation Maturity Model.

Humphrey (1989) uses a Capability Maturity Model (CMM) which classifies software producing organizations based on their operational practice belonging to one of the following stages: *ad hoc*, repeatable, defined, managed and optimized (Fig. 2). According to Humphrey's model, Scholten and Udink ten Cate (1995) proposed a Simulation Maturity Model with corresponding stages.

Major improvements in simulation modelling quality may be achieved in the defining and managing stage. Based on the detailed scheme of the SMP a tool will be developed, which aims to define the process accurately and which enables measuring, analysis and testing of the resulting products.

In addition to this approach, simulation modelling has to be embedded into a project organization. This will facilitate a satisfactory progress of the project.

## 4. QUASIMODEM

A tool will be build to define the SMP. QUASIMODEM (QUAlity of SImulation MODElling Model) is a model of the SMP. It represents the structure of the original model and the behavior of the modelling process (Scholten, 1994; Scholten and Udink ten Cate, 1995). It consists of a structure of linked frames, which can be adapted by the user. There are frames for actions and for products. Each action produces a product, uses one or more products or consists (at a more detailed level) of a substructure of actions and products. Decision actions do not merely generate a product, but point back to one or more previous actions. An action frame includes answers to many questions, such as *what* (what has been done and what kind of methods are used), *who*, *how*, *purpose*, *prerequisites*, *required products*, *resulting products*, *documentation*, etc.. A product frame includes descriptions of *parent and child actions*, *prerequisites*, *purpose*, *tests* and *test results*, *where recorded*, *documentation*.

A scheme of the main stages of the SMP and its most relevant actions and products is given in Fig. 3.

The different roles of people involved in the modelling process, deserve some more detailed attention at this point. The following actors may be distinguished:

- *customer* is the client determines requirements and acceptance of products
- *modeler/developer* engineer translates scientific/technical domain knowledge into a model; develops and analyzes the model
- *domain expert* scientists who's knowledge is incorporated into the model; judges model validity
- *project manager* coordinates tasks and manages project, negotiates with the customer on requirements specifications, how specifications are met, and final product acceptance
- *user* will use model for predictions, scenario studies, and risk analyses to support decision and policy making
- *policy/decision maker* uses the work of model users
- *tester* performs tests on the modelling process and resulting products, but is member of the project team
- *auditor/reviewer* external model evaluator

All of these simulation modelling roles can be played by one or more persons and one person may play more than one role. Each action has a client (the actor who uses/requires the execution of the action) and a server (the actor who executes the tasks of the action). With this approach all responsibilities are made explicit, which promotes overall quality of the process, its actions and its products.

QUASIMODEM uses internally a formal model description language which will facilitate portability of models. The formal description of a model will be translated by modelling environment dependent interface to enable the use of different modelling environments.

QUASIMODEM is not a set of prescriptions, but it records every modelling action and product. Thus it promotes repeatability of the modelling process and it defines the SMP in terms of the SMM (stage 3). In addition to other methods, which only force the modeler into a straitjacket of rules and guidelines, QUASIMODEM stimulates a systematic modelling process, of which all subjective and objective choices and decisions are made explicit. It incorporates checks on the simulation quality aspects of section 2.

The methodical approach encourages the incorporation of software quality assurance procedures and the embedding of the modelling process in a project organization. Both latter aspects are not discussed here. The relation between software engineering, project management, the simulation modelling process in relation to quality assurance is shown in Figure 1.

The use of QUASIMODEM assists in testing simulation modelling. A limited number of tests and evaluations will simplify managing the process.

## 5. TESTING

Several tests have been designed to evaluate the modelling process, its actions and products.

- *process*: QUASIMODEM implicitly generates a check list and records all modelling activities and all resulting products, which will simplifies auditing, project management and process control
- *quality aspect check*: QUASIMODEM simplifies accounting for the simulation quality aspects of section 2; some are incorporated, while others are evaluated in a checklist approach
- *complexity*: in early stages this complexity evaluation method will assist in cost estimates and human resources needed for the project
- *conceptual model validation*: using face validation, consistent incorporation of theory and hypotheses can be checked, including a correct representation of the system and its behavior, proper levels of detail and aggregation, based on system observations; statistical and other tests may assist experts in this test; the development of a conceptual model will be supported by specification matrices and a formal model description language
- *dimensional correctness*: a dimensional correctness tool will check for corresponding dimensions and units in all processes within the implemented simulation model
- *mass balance bookkeeping*: bookkeeping of material flows may detect errors of many models in the domains physics, chemics, (agro-)ecology, environmental science
- *quantitative validation*: historical data validation using statistical techniques or the approach proposed by Mankin et al. (1975) and implemented by Scholten and Van der Tol (1994)
- *operational validation*: checks if the model is conform its intended goals
- *software project requirements*: software reviews, software audits, userinterface conventions, design standards, acceptance tests, coding standards

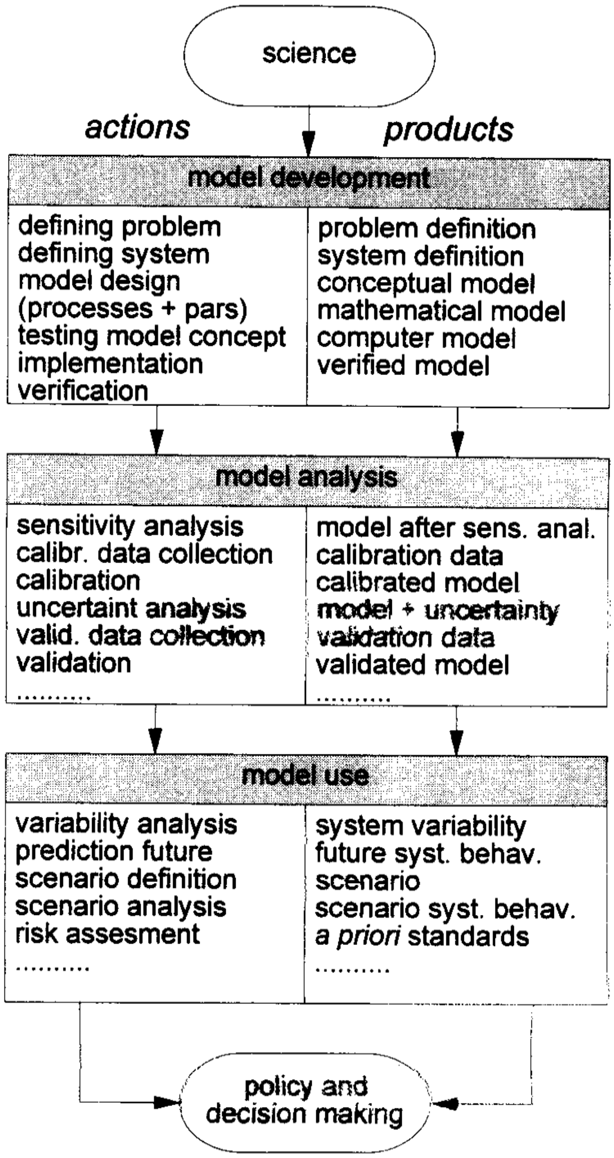


Fig. 3. Actions and processes of the SMP.

## 6. CONCLUSIONS

Using a complex tool like QUASIMODEM will promotes simulation modelling quality. The simulation modelling process (SMP) will be made explicit, repeatable, and thus controllable (auditing). This approach will not eliminate all subjective elements, but makes the modelling process explicit and limits the series of commonly made errors. In this way, modelling will not be an art, but an engineering task. The resulting product, a model, will be more appropriate for its intended use.

## 7. LITERATURE


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