APPLYING A DOCUMENTATION GUIDELINE FOR VERIFICATION AND VALIDATION OF SIMULATION MODELS AND APPLICATIONS: AN INDUSTRIAL CASE STUDY

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ABSTRACT

Documentation in a structured and well-defined way becomes an urgent requirement not only for developing simulation models and applications (M&S), but also for conducting their verification and validation (V&V). Since meaningful model documentation is always associated with more effort than usual, a reasonable balance between quality and efficiency should be achieved in all practical applications. This work presents an industrial case study of applying a documentation guideline to a small simulation development project. The main objectives of this case study were firstly to estimate the effort involved in the documentation of M&S work products and their V&V in this project context, and in addition, to investigate the feedback for improving the proposed documentation guideline. Based on the gathered findings, a further case study for a more complex simulation project is planned.

INTRODUCTION

That the documentation of modelling and simulation (M&S) applications is an essential issue for a successful simulation project is hardly controversial. However, under pressure, time and cost constraints, model documentation in practical applications is often sacrificed first (Balci 1997), or conducted only in an arbitrary and informal manner (Gass 1984, Kleijnen 1995). Suchlike problems of documentation lead not only to loss of operational efficiency, continued use and further development of simulation models (or their components), but also to increasing risks of using improper results in terms of credibility assessment.

Faced with this practical challenge, the Institute for Technology of Intelligent Systems (ITIS) has developed a model documentation guideline (Lehmann et al. 2005), which enables structured and well-defined documentation for developing M&S applications as well as conducting their verification and validation (V&V). Furthermore, a tailoring concept is also proposed, by means of which project-specific model documentation can be determined with respect to actual cost, time and application constraints. For the purpose of concept refinement, empirical investigations are necessary to learn more about the transformation and application of this guideline in practice. Hence a series of case studies were planned, which enable the estimation of this guideline in different project contexts, on the one hand, and the close cooperation of ITIS with a selected simulation provider, namely the company szenaris GmbH which was the simulation and training division of Ray Sono AG at the time when the studies were planned and partially conducted, to gather empirical findings and exchange their knowledge, on the other hand.

This paper presents the first effort of the planned investigations, in which the proposed documentation guideline was applied to a relatively small and manageable simulation development project, the so-called KoCUA FSB (Ray Sono AG 2008). However, due to some unexpected limitations related to the project execution, the complete documentation of the simulation model and its V&V was no more possible in this regard, and some kind of adaptation had to be arranged. Thus, the purposes of this case study were modified as follows: (1) estimating the effort expended in the documentation activities for a rough cost-benefit analysis; and (2) investigating the feedback for further development of the proposed guideline.

The remainder of this paper is structured as follows: a brief overview of the applied documentation guideline is introduced in the following section. Then the simu-

lation project selected for this case study is described. After that, the execution and some relevant results of this case study are presented. Based on these results, lessons learned are discussed, and the last section concludes with thoughts on further work.

The APPLIED DOCUMENTATION GUIDELINE

The proposed model documentation guideline defines detailed requirements, useful and applicable templates for documenting an M&S project and its associated V&V efforts throughout the entire model development life cycle, including the following essential components (as shown in Figure 1):

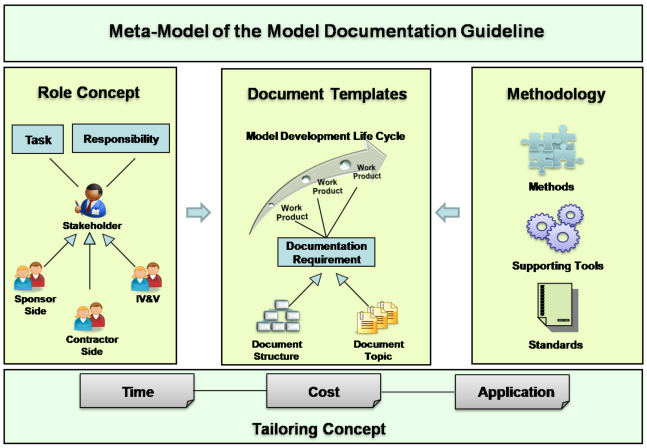

Figure 1: Overview of the Applied Guideline for Model Documentation

- **Meta models.** The fundamental structuring of the guideline is illustrated in the form of meta models, which serve as a common basis to describe the introduced core elements, such as the role concept, the documentation templates, the methodological supporting and the tailoring concept, and relationships between these elements as well as their semantic. In addition, all meta models are specified and organized in different degrees of abstraction to meet the specific needs of each user group of this guideline.

- **Roles.** With the intention of defining functional tasks and competencies for persons, who will participate in the model development and documentation activities, a well-structured role concept is introduced. During the process of project planning, roles are assigned to concrete persons or organizational units with certain responsibilities, e.g. contributory or responsible. While several roles may support in the creation of a product, only one responsible role can be assigned to each work product. Since an M&S project should normally involve three kinds of parties (Wang and Lehmann 2007), namely participants from the sponsor side, the contractor side, and the independent V&V (Arthur and Nance 2000), this role concept has been developed in a manner which offers organization-independent orientation for project management.

- **Document templates.** To facilitate the model documentation activities, concrete structure and contents requirements for each work product created during the M&S life cycle are specified in the form of document templates. As the reference process, a structured process for developing M&S applications and conducting their V&V (Brade 2000) is employed. With respect to the compatibility with current M&S (quasi) standards (Balci and Saadi 2002, Sargent 2003), this process has been mapped to several selected international M&S V&V processes (Brade et al. 2005). All of the proposed templates can be directly applied to an M&S project or adapted as required before use.

- **Methodological supporting.** With the aid of some selected practical methods, supporting tools, and standardized processes (The V-Modell XT 2005) specified in this guideline, it is possible for each potential user to find a more efficient way of preparing model documentation and keeping consistent information across all created documents.

- **Tailoring.** Because of different characteristics of organization structures and project environments, this model documentation guideline needs some kind of adaptation or tailoring prior to application. For this purpose, a multistage tailoring concept is established, which enables the project-specific selection of essential products, documents, and activities for developing M&S applications and conducting their V&V according to specified cost, time and application constraints. By applying this tailoring mechanism, only relevant M&S products are taken into account during model development process. This implies a reduction of project complexity.

CASE STUDY CONTEXT

In order to gain first experiences in practical application, this guideline was used to document the simulation model being developed by the company szenaris in the context of the project KoCUA FSB (Ray Sono AG 2008). As Figure 2 shows, the project considered in this case study was intended to build a training simulator for cooperative training in teams (KoCUA) of an Improved Ribbon Bridge (FSB), which was to be used in training of military personnel for the exercise scenarios like transporting, launching, and retrieving interior and ramp bays of a float bridge, moving and connecting

bridge bays on the water etc. As an extended system component, the developed simulator had to be then integrated into an existing computer aided training system environment, and cooperate with other components.

Figure 2: Team Training with the Simulator

The case study of using the documentation guideline was defined as a separate project in addition to the main development project, and had to be conducted cooperatively by the company szenaris and the research institute ITIS. While szenaris had to implement the proposed guideline and prepare model documents for each work product created during the development of the training simulator, ITIS provided support of coaching when required and evaluated the quality of completed model documents in form and content.
Unfortunately, the planning of this case study was behind schedule with the simulator development project. Starting already in November 2007, the development of the training simulator was planned to be exactly one year. The kickoff meeting of the case study project, however, was held only in March 2008. This meant that the completely continuous model documentation in parallel with each phase of the M&S life cycle was no more possible. Since the model development was under a company specific modelling process already in the programming phase at that time, and the documentation so far was only performed fractionally in an informal way, some kind of "post-documentation" had to be arranged and conducted. Additionally, due to the somewhat short duration of the case study project, only a continuous subset of the developed simulation model was selected from the sponsor needs, the M&S requirements specification, the conceptual model to the executable model, and then consistently documented. Thus, the main purposes of this case study were limited to:

- on the part of szenaris
  - using the proposed tailoring concept to select a subset of the model being developed for documentation
  - preparing model documents for each M&S development phase according to the guideline
  - preliminary cost-benefit analysis for application of the guideline
- on the part of ITIS
  - supporting the model documentation as well as the tailoring activities
  - if possible, checking correctness and consistency of the subset of the model based on the prepared model documents (mainly for estimation of V&V effort)
  - gathering feedback for the purpose of further development

EXECUTION AND RESULTS OF THE CASE STUDY

After selecting a subset of the sponsor needs with respect to the actual project conditions supported by ITIS, the team members from szenaris began backwards to prepare the associated model documents of each already performed M&S phase for the selected requirements, and regularly sent their finished versions as email attachments. The received documents were then inspected by the personnel from ITIS. The inspection focused on (1) whether the prepared model documents met the requirements of the proposed guideline formally; and (2) whether they were correct and consistent with respect to the selected subset of the M&S requirements. The objective of the inspection was not to conduct V&V of the overall simulation model being developed officially, but rather to acquire a preliminary effort estimation of applying this documentation guideline.
To facilitate communication between the two working teams from the different locations (Bremen and Munich, Germany), the solution of video conferencing was applied. Depending on requirements, open questions and different opinions were exchanged through video conferencing weekly or biweekly. Additionally, four workshops were arranged for the purpose of face-to-face discussion, and distributed evenly over the project period from March to November 2008.

Table 1: Model Documents Prepared in the Case Study

Predefined work products	**Versions**
Structured Problem Definition (SPD)	5
Conceptual Model (CM)	7
Formal Model (FM)	2
Executable Model (EM)	7
Simulation Result (SR)	1

Following the instructions of the applied guideline, model documentation in this case study was conducted

in an iterative manner. Hence, as shown in Table 1, there exist different but consecutive model documents for each developed M&S phase. Compared to seven document versions of CM, only two documents of FM were prepared. This was due to the fact that the simulation environment "Virtools" (Virtools 2008) was applied to the development of the training simulator. Since the physically correct behaviors and interactions of all the objects considered in the simulation study were realized by means of the "Havocs Physics Engine" which is integrated in the simulation environment of Virtools, and its associated mechanisms, however just like a black box, are not available to the users, an explicit description of the formal model developed in this way was extremely difficult, and therefore was not considered as a part of model documentation in this case study. In the present two documents of FM, the reasons for this tailoring decision were documented. The single document of SR included the operation protocols and results of different test scenarios.

Table 2: Estimated Effort on the part of szenaris

Work expended	**Pers. days**
1. Guideline introduction	16.5
2. Preparing the model documents	58.5
3. Quality assurance	10
4. Workshops and meetings	15
Total	**100**

Table 3: Estimated Effort on the part of ITIS

Work expended	**Pers. days**
1. Coaching	8
2. Inspection of the model documents	20
3. Workshops	5
Total	**33**

Table 2 and 3 show the respective estimates of the expended effort directly related to the model documentation activities of szenaris and ITIS. Other expenditure such as project management, business trips, or preparation of the final report is not taken into account in this context. Since only a fractional part of the developed simulation model was considered in the case study and the calculation made in Table 2 was just based on the selected subset, the real expenditure required for a complete model documentation on the part of szenaris could be incurred approximately five times higher.

LESSONS LEARNED

Based on the findings achieved in this case study, some relevant lessons learned are summarized, which could serve as expertise for both theoretical concept refinement and practice applications. They are largely independent of the current project constellation and as such can be applied to other M&S projects as well.

- **The applied guideline was perceived as beneficial by the team members of szenaris.** For instance, in the course of the model development, it became apparent that the original interaction concept, which had been developed in the context of an early simulation project and was applied as a finished component to the conceptual model (CM) in this project, was in some respects incomplete and thus caused confusing ambiguity and misunderstanding within the model development team. In this regard, the precisely conducted model documentation according to this guideline was an appropriate remedy.
- **Standardized formalization methods are indispensable for model documentation.** Conducting a simulation project always requires multifaceted knowledge in diverse disciplines. A development team alone includes different project roles with individual expertise. Hence, using standardized formalization methods enables a common platform for understanding and exchange of opinions not only within a model development team, but also between the three participating parties of sponsors, contractors and IV&V.
- **Adaptability is one of the key criteria for application of a model documentation guideline.** Since there exist no two organizations with the same structural properties, and furthermore, every simulation project differs in terms of objectives, scale, scope and technical challenges, a model documentation guideline could be never well suited for all possible circumstances. Therefore, the potential of an M&S documentation guideline to be adapted to different project environments is a crucial issue for its acceptance in practice.
- **Know-how protection is still an essential topic concerning model documentation and (independent) model V&V.** From the V&V's point of view, precise and detailed model description significantly facilitates V&V efforts. On the other side, however, a simulation provider usually expresses great concerns about the possible loss of his estimable know-how, when all key parts of models have to be available to an independent third party by reason of V&V. Therefore, additional investigations should be carried out for the purpose of conducting model V&V more effectively and keeping company's know-how safe contractually and legally.
- **The expenditure of model documentation and model V&V should be regarded as early**

as tendering of an M&S project. In order to prevent that model documentation and V&V become an easy prey because of time and cost pressures occurred during project execution, sponsors should require the separate calculation of planned documentation and V&V costs in request for proposal, and all potential contractors must give a realistic cost estimate in their project offers.

CONCLUSION AND FUTURE WORK

This paper presents an empirical investigation of applying a documentation guideline to a practical M&S project. Due to some inevitable limitations, however, the documentation of the complete simulation model being developed and its associated V&V activities could not be conducted in this case study. Hence, a consistent subset of the model was determined by means of the proposed tailoring concept according to the actual project conditions. Additionally some kind of "post-documentation" had to be partially conducted. According to the selected modelling aspects, the model documents were prepared in an iterative manner for each development phase of the M&S life cycle.

The applied documentation guideline, especially due to its well-defined structure and adaptability for different project constellations, was appreciated as understandable and profitable by the development team of szenaris. The experiences gained from this case study can be used to improve the model development process of szenaris as well as to refine the proposed documentation guideline. Additionally, several lessons learned provide insights into general issues concerning model documentation and model V&V.

Since the calculation of the effort expanded in this investigation was based on the partially implemented model documentation, the impact of introduction and application of this guideline on the overall project costs could only be estimated roughly on a large scale. Thus, in the context of this case study, a reasonable cost-benefit analysis is infeasible. Our future work is intended to conduct a further industrial case study, in which this documentation guideline will be applied to a more complex simulation project, and model documentation will be conducted completely and continuously with model development. Additionally, the effort required for a systematic model V&V will be also investigated.

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