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M&S Body of Knowledge: Progress Report and Look Ahead

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M&S Body of Knowledge: Progress Report and Look Ahead

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1 ON CONCEPTUAL AND PHILOSOPHICAL FOUNDATIONS FOR M&S EXPERTS

The *Body of Knowledge* (BoK) is a comprehensive and concise representation of concepts, terms, and activities needed to explain a professional domain by representing the common understanding of relevant professionals and professional associations. Defining the BoK for *Modeling and Simulation* (M&S) is essential for the discipline of M&S.

1.1 Current Dominance of Simulation

In this context it is of interest to identify where the main contributions to M&S of current efforts are derived from since initial efforts as documented by Ören (2005). The predominant role of *Simulation* becomes easily apparent by simply looking at the names of organizations and workshops[†]:

- Spring and Summer *Simulation* Multiconferences of SCS
- Winter *Simulation* Conference of ASA, ACM, IEEE, INFORMS, IIE, NIST, and IEEE
- Principles of Advanced Distributed *Simulation* of ACM, IEEE, and SCS
- Spring, Euro, and Fall *Simulation* Interoperability Workshops of SISO

This list is neither complete nor exclusive and is not meant to be. The list, however, is meant to show that simulation is more emphasized than modeling in M&S. Traditionally, the target audience of these conferences comprises software engineers with a very strong background in developing simulation applications. Current simulation interoperability standards, such as IEEE 1278 and IEEE 1516, focus on interoperability between such computer simulation systems. The discussions on M&S are often dominated by software and implementation challenges of the simulation systems.

However, although such standardization efforts are more than a decade old, many challenges are still unanswered and problems remain unsolved. The author therefore asks: "Did we miss something regarding the conceptual and

[†] American Statistical Association (ASA), Association for Computing Machinery (ACM), Institute of Electrical and Electronics Engineers (IEEE), Institute for Operations Research and the Management Sciences: Simulation Society (INFORMS), Institute of Industrial Engineers (IIE), National Institute of Standards and Technology (NIST), Society for Modeling and Simulation International (SCS).

philosophical foundations for M&S experts?" or "What is special about M&S Engineering that goes beyond Software Engineering?"

1.2 Emphasizing the Modeling in M&S

In the opinion of the author, the reason that we still have so many problems in M&S can be derived from a lack of conceptual and philosophical foundations. In other words: we are too often trying to solve problems where the symptoms show – the simulation – and not where the reasons for the problems are – in the modeling part. This does not mean that current work is without value or wrong. Simulation work is a necessary component of M&S, but it is not sufficient. In the opinion of the author *it is the modeling part that makes M&S unique* from other software engineering influenced disciplines. Consequently, the modeling aspect of M&S, conceptually and philosophically, needs to be emphasized in the M&S BoK. If this is not addressed, M&S gets reduced to only simulation. This reduction leads to the danger of M&S not being perceived as its own discipline, but simply as a tool to support experts in other domains utilizing software engineering-based simulation systems.

Focusing on computer simulation, modeling is understood as the purposeful abstraction and simplification of the perceived reality with the developers intention to support a special task – like training or testing -, or to answer a special research question in analysis and experimentation. At the end of the modeling process, the result shall be a formal specification of the conceptualization including underlying assumptions and constraints. Based on this model, the simulation system is developed and implemented and finally used to simulate.

In order to support new operational tasks or evaluate new operational questions, we federate simulation systems that provide different components of the desired functionality, like composing army and air force simulations to simulate air defense and close air support. To make them work together, we use simulation interoperability standards like IEEE 1278 and IEEE 1516 to translate different simulation internal representations into each other, addressing multi-resolution modeling questions, different formats, and many more challenges on the simulation level.

Conceptually, however, this needs to be further discussed in order to avoid serious resulting mistakes. An example of such mistakes is that we may force, on the simulation level, what was never meant to work together on the modeling level. In the next section, conceptual and philosophical arguments are provided to support this point which is of importance to the M&S expert.

1.3 Conceptual Foundations

The author and colleagues showed in (Tolk et al. 2010) the close relation of real world, models of the real world, and simulation of the model with the *Semiotic Triangle* introduced by Ögden and Richards (1923). They evaluated the question on meaning and why we have problems to understand each other, even when describing the same referent in the real world. Figure 1 shows the triangle annotated with M&S terms.

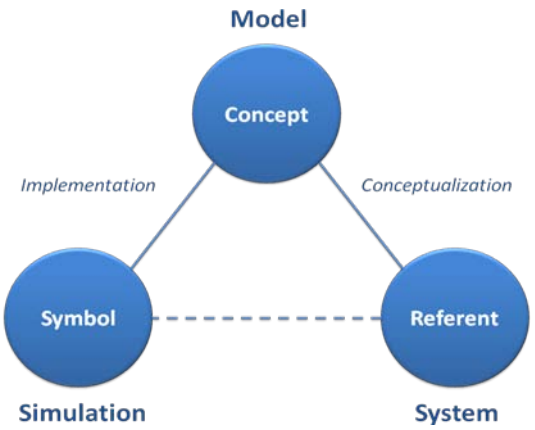

Figure 1: Semiotic Triangle and M&S

The assumption of many system developers is that systems supporting the same domain naturally are using very similar, if not the same, conceptualization. However, the principle documented by Ögden and Richards (1923) semiotic triangle still holds: concepts and symbols explain why communication often fails. Referents are objects in the real world. When communicating about the referents we are really communicating perceptions or interpretations of these referents which are captured in the form of concepts. These concepts reflect the user's viewpoint of the world. However, there is still a limitation in communicating concepts directly. For this, symbols are used to talk about the user's concepts.

Ögden and Richards showed that the symbol refers to the concept, not to the referent, so that alignments of concepts are needed to share a common meaning and increase our understanding. Therefore, the transformation of symbols does not necessarily contribute to such sharing of meaning and understanding. Although the view often is that the simulation stands for the referent, it is so if they agree on the conceptualization.

The importance of this conceptual view increases when it comes to reuse, which includes the selection of a simulation system to support a special task or to answer a special research question. However, as stated earlier, these activities fall into the realm of modeling of the referent.

Figure 2, the extension of the semiotic triangle into a semiotic trapezoid, depicts this challenge: We should align the conceptualizations of the new operation, or special task, with the conceptualization of the existing simulation (and not the simulation itself) to make concepts, assumptions, and constraints explicit. Currently, we bypass the alignment of conceptualizations because they are not available within the simulations, which is a problem.

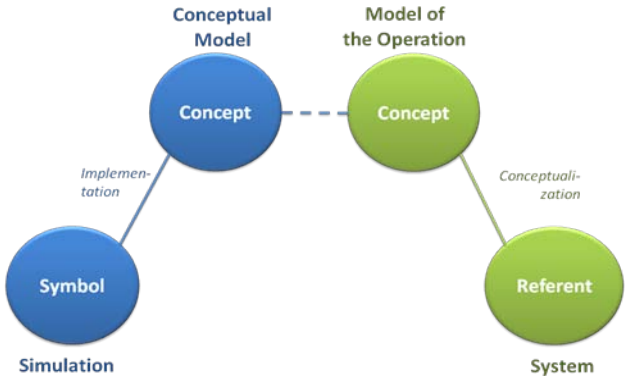

Figure 2: Semiotic Trapezoid for Reuse

The current state of the art for federation development is based on the idea to engineer well-defined interfaces based on simulation interoperability standards between two simulation systems. However, following the results of Ögden and Richards (1923) and generalizing them for M&S, the alignment should happen first on the modeling level, as shown in Figure 3.

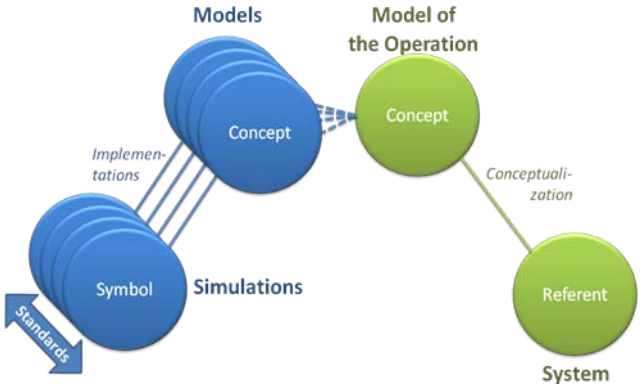

Figure 3: Semiotic Trapezoid for Composition

The federation of simulations should be based on their concepts and how they support the operation to be supported when orchestrated accordingly (Kewley and Tolk 2009). Instead, our current standard focuses on transforming representations within simulations, which is dealing with the symptoms, not the reason for the interoperability challenge.

The author is well aware that this is a simplified view of M&S challenges. However, it was simplified to make the case for conceptualization and modeling in M&S BoK discussions. Recent M&S dissertations contributed to the strong basis for this position (Diallo, 2010, King, 2009).

1.4 Philosophical Foundations

Despite fundamental and overview papers, like the epistemological perspectives of Frank and Troitzsch (2005) and Grune-Yanoff and Weirich (2010), most M&S researchers are not explicitly aware of their philosophical research assumption and the ontological, epistemological, and teleological implications thereof. Ontology is the study of being or the study of what exists, often captured as a system defined by a finite set of systems. Computational representations thereof are only a small subset. Epistemology is the study of how we come to know, or how we define knowledge, represent it, and communicate it with others. Teleology is the study of action and purpose, resulting in methods. Turnitsa, Padilla, and Tolk (2010) relate these to the semiotic triangle and show implications for modeling.

Often without knowing it, M&S experts subscribe with their methods to a positivistic worldview. In short, positivism is rooted in the belief that truth exists on its own, it is independent of the observer and reality is separated from the individual who observes it. The traditional scientific method is rooted in positivism. The alternative viewpoint is interpretivism that holds the belief that truth is a construct of the observer. Reality is relative and cannot be separated from the individual who observes it. Many social and human sciences subscribe to interpretivism. The observation that two scientists can describe the same real world referent system using different categorizations thereof is often used as an example that no knowledge can derived without first building a theory, and therefore a conceptualization. While models are the prototypical representations of conceptualizations and simulations well suited to check for consistency of one or several theories, hence a strong tool for interpretivism, the quest for validations is rooted in the belief that one reality and truth exists, hence being positivistic.

Tying conceptual and philosophical foundations together shows why in particular in the current quest for methodological approaches for human, social, cultural, and behavioral (HSCB, see Numrich and Tolk, 2010) modeling they are pivotal: If the positivistic philosophy is appropriate, all valid models thereof are ‘pruned versions of the tree of knowledge’ and can be mapped into an ever better model of the one reality, as we know it from the world of Newton’s physics, in which higher resolution equals higher fidelity. If

interpretivism is the right approach, we can only assume that each model must be consistent in itself, but several contradictive models of reality can and should exist. The disciplines dealing with HSCB research predominantly are interpretive, nonetheless we hope for valid models to be integrated into the physical models for training and experimentation. M&S experts need to be educated to drive this discussion and contribute to the existential questions of today's research.

In this article on conceptual and philosophical foundations for M&S experts, the author showed the need for conceptual and philosophical foundations to become parts of the M&S BoK. They complete the traditional views as they emerged mainly from software engineering. While the current focus lies in the domain of simulation, adding the modeling component as an equally important domain is needed.

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