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Guest Editorial

Enhancing simulation composability and interoperability using conceptual/semantic/ontological models

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Two emerging trends in modelling and simulation (M&S) are beginning to dovetail in a potentially highly productive manner, namely conceptual modelling and semantic modelling. Conceptual modelling has existed for several decades, but its importance has risen to the forefront in the last decade (Taylor and Robinson, 2006; Robinson, 2007). Also, during the last decade, progress on the Semantic Web has begun to influence M&S, with the development of general modelling ontologies (Miller *et al*, 2004), as well as ontologies for modelling particular domains (Durak *et al*, 2006). An ontology, which is a formal specification of a conceptualization (Gruber, 1993), can be used to rigorously define a domain of discourse in terms of classes/concepts, properties/relationships and instances/individuals. For the Semantic Web, ontologies are typically specified using the Web Ontology Language (OWL). Although, conceptual modelling is broader than just semantics (it includes additional issues such as pragmatics (Tolk *et al*, 2008)), progress in the Semantic Web and ontologies is certainly beneficial to conceptual modelling. Benefits are accrued in many ways including the large knowledge bases being placed on the Web in numerous fields in which simulation studies are conducted and the powerful reasoning algorithms based on description logic being developed that allow the consistency of large specifications to be checked.

Conceptual and semantic models are useful for developing executable simulations in general, but are particularly helpful in supporting composability and interoperability. Interoperability of simulation systems is concerned with the correctness of interactions among components in the simulation environment and builds on the composability of their underlying models. In order to fully utilize and share the underlying models, the interactions have to be made explicit, which requires well-documented conceptual models as well as their implementations.

Several best practices and even standardized methods exist supporting integration of two or more simulations in order to provide a broader basis for M&S-based research, as envisioned in the 1996 National Science Foundation (NSF) Report on 'Simulation-based Engineering Science' showing the potential of using simulation technology and methods to revolutionize engineering science. In addition, it is recognized by several experts in the field, during panel discussions conducted during recent conferences, that the focus of effort needs to shift from the implementation aspects to the conceptual aspects of modelling and simulation as well. In all these discussions, the value and necessity of simulation integration efforts was recognized as a necessary part of interoperability and composability, but it was also recognized that these efforts are not sufficient.

While the community agrees on the necessity of unambiguous and machine readable documentation of the conceptual component of M&S in principle, the details of different approaches are currently not well aligned (Balci *et al*, 2010). However, one discussion topic is most often observed when it comes to conceptual modelling: the increased use of ontological means supporting precisely defined formal models that capture semantics, yet afford more flexibility in syntax. In particular, the experts of several related panels expressed their conviction that ontologies offer a means for enhancing composability and interoperability among models and simulations developed independently. The rationale for supporting this belief that emerges from these discussions is that an ontology is a formal specification of a conceptualization, which fulfills the requirements for a conceptual model:

- It is a conceptual representation of systems and their underlying models.
- It is a specification, which enables the application of scientific evaluation methods.
- It is formal, which allows machines to process and to a degree understand the specification.

During recent years, the number of applications of semantic/ontological models in support of composability and interoperability has increased. In order to highlight the depth and breadth of this emerging approach to enhancing interoperability in modelling and simulation, *the Journal of Simulation* has dedicated a special issue to this topic. The special issue consists of eight papers highlighting various aspects of this topic. The first paper by Hofman establishes a context for this special issue by providing philosophical and historical background on ontologies, as well as, an assessment of their long-run utility for M&S. The second paper by Ezzell *et al* provides additional background on how developments in the Semantic Web can be useful for

M&S and in particular discusses how ontologies can be used in an interactive visual process to create dynamic models. Taking a different tact, the third paper by Balci and Arthur discusses a general framework for how conceptual models can be used to improve reusability and composability. The fourth paper by Benjamin *et al* then ties this back to the main theme of the special issues by making the case for the important role that ontologies can play in creating integrated simulation models. McGinnis *et al* in the fifth paper take a practical, software engineering tact on the problem of creating simulations by developing conceptual/semantic models using the Systems Modelling Language (SysML), an extended Unified Modelling Language (UML). Although OWL and UML are different, they share much in common and there have been several efforts to use UML-like languages for creating ontologies (Brockmans *et al*, 2004). In the sixth paper, Kerzher *et al* observe the frequent similarity between descriptive/structural models and their corresponding analysis/simulation models. They develop a technique for exploiting this similarity that involves generating analysis/simulation models in Modelica from descriptive/structural models in SysML. The seventh paper by Durak *et al* provides an overview of the TSONT OWL-based ontology and how it enhances support for reuse, interoperability and composability of simulation models. The TSONT ontology is used for simulations involving munitions/projectiles. The eighth and final paper by Ford *et al* uses OWL ontologies and the Semantic Web Rule Language to establish and maintain interoperability between the multitude of software components used in military training and live-event simulations.

The collection of papers in this special issue provides the reader with a snapshot of the progress being made in semantic modelling and the use of ontologies to aid in developing and using simulations. Particular focus is given to their application to conceptual modelling and how they can enhance reusability, composability and interoperability. Although this new area of research within M&S has gained a foothold, many issues still need to be resolved and much further development is needed. Some issues for future work include: (i) how to achieve a critical mass of ontological knowledge (with upper ontologies, domain ontologies and modelling ontologies as well as the need to align them), (ii) the development and certification of agreed-upon ontologies to serve as a foundation for everyone to use (like the OBO Foundry (Smith *et al*, 2007) used by the biological sciences), (iii) how this work will effect existing standards for interoperability such as IEEE1278: Distributed Interactive Simulation and IEEE1516: High Level Architecture and (iv) yet deeper issues related to the philosophy of modelling as well as the need for additional formalisms for both the Semantic Web and Conceptual Modelling.

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