

TOWARDS A SCIENCE OF M&S: THE 5TH EPISTEMOLOGICAL PERSPECTIVES ON SIMULATION CONFERENCE

Anthony H. Dekker

Defence Science and Technology
Organisation (DSTO), Australia

E. Dante Suarez

Business Administration Department
Trinity University, USA

ABSTRACT

The Epistemological Perspectives on Simulation Conference held its fifth biannual conference at Trinity University in San Antonio in October of 2012. The conference series aims to develop general simulation methodologies and explores novel approaches and applications in computer simulation and modeling. The fifth edition of EPOS—the first held outside of Europe—focused on two main areas of discussion: the establishment of a general methodology for modeling and simulation that can be shared among multiple disciplines and the creation of a scientifically solid path forward for the growing area of computational simulation of complex adaptive systems, particularly social ones.

1 INTRODUCTION

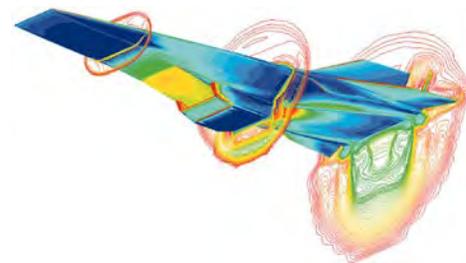
The 5th Epistemological Perspectives on Simulation (EPOS V) conference was held at in San Antonio (Texas) at Trinity University's Holt Conference Center on 10–12 October, 2012. A group of simulation researchers from Australia, Germany, Japan, Mexico, the Netherlands, Taiwan, the UK, and the USA attended. The interdisciplinary group at EPOS V also included philosophers, economists, social scientists, business experts, and epidemiologists. There were keynote addresses, presentations of newly refereed and previously published papers, as well as open discussion sessions. Selected papers will be published in a special issue of the *International Journal of Agent Technologies and Systems*. Papers from two of the four past instances of this conference series can be found at jasss.soc.surrey.ac.uk/8/4/ (2004) and jasss.soc.surrey.ac.uk/13/1/ (2008).



Trinity University, San Antonio, Texas

2 THE PROBLEM

The field of modeling and simulation (M&S) has seen enormous advances in technology. Sophisticated distributed simulations are now almost routine, and physics-based simulations produce results which are so accurate that it is typically unnecessary to confirm them with physical experiments such as wind tunnels. However, for organizational and social simulations, the situation is less rosy. The ontological status of the phenomena being modeled is less clear. Does society “exist,” for example, or is it merely an aggregation of individuals as traditional linear approaches like neoclassical economics claim?



A physics-based simulation: computational fluid dynamic simulation of the NASA X-43 at Mach 7 (NASA image)

The epistemological status of organizational and social simulation results is unclear. Do they provide us **knowledge** of any kind, or merely assistance with problem framing, interesting hypotheses to check, and suggestions to ponder? Certainly, there have been cases where the results of (poorly designed) organizational and social simulations have been deceptive. The conference, then, attempted to establish the aspects of simulation that can be considered knowledge as well as the necessary methodological processes that ensure their validity.

3 QUESTIONS AND TOPICS OF THE EPOS CONFERENCES

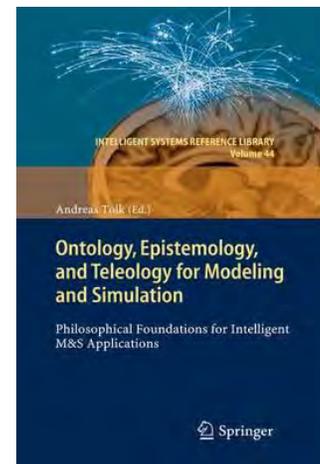
EPOS conferences have been held bi-annually in European sites since 2004. The aim of this series of gatherings is to provide methodological guidelines and interdisciplinary common ground for modeling and simulation of applied phenomena, particularly in the social sciences, but also in the biological and psychological realms. Some examples of questions that this series of workshops has aimed to address include:

- How is simulation different than traditional methodologies in its description of reality? What can we gain from the use of nonlinear modeling and simulation?
- In which ways do computer simulations represent a better methodology and for which real-world phenomena is it best suited to model?
- Through simulation researchers can often model a more detailed representation of physical, natural and social phenomena. What aspects of reality are best understood through simulation? What aspects should be left out?
- How should the methodology of simulation be evaluated and validated? Should increase predictive capacity be the evaluating norm or can we have other ways of evaluating the “goodness” of a model?
- How do different levels of reality interact? How can modeling and simulation address this coexistence and thus allow for the creation of meta-simulations and macro-modeling?
- How can agency be understood in context?
- Can simulation help us develop more precise languages to express social phenomena?

Simulation is a creative and epistemologically-delicate process that has attracted growing attention in the past few decades. The recognition that progress in the science of simulation must go hand in hand with the analysis of its epistemological status has been an important motive for the EPOS workshops since 2004. What appears to be required is an intellectual framework—a **science** of M&S—within which to answer these questions. Such a science of M&S would complement the existing **technology** of M&S and the domain-specific **use** of M&S.



Some delegates at EPOS V



Ontology, Epistemology, and Teleology for Modeling and Simulation, Andreas Tolk (ed), Springer, 2012

These issues have been explored in the four previous EPOS conferences, as well as in the recent book *Ontology, Epistemology, and Teleology for Modeling and Simulation (M&S): Philosophical Foundations for Intelligent M&S Applications* edited by Andreas Tolk, of Old Dominion University. Dr. Tolk gave one of the two keynote speeches of EPOS V, explaining and elaborating on the contents of the book and on the latest advances in the field.

4 SUMMARY OF EPOS V PRESENTATIONS

The presentations, keynote addresses and discussion sessions of EPOS V focused on five main areas:

1. Modeling as one of the levels of human interaction for the production of knowledge,
2. Towards the creation of a new scientific method for modeling and simulation,
3. Applications of the state-of-the-art in computer simulation and nonlinear models of social phenomena,
4. New modeling techniques,
5. New avenues for theory and technological development.

The conference also included four lively and fruitful open discussions where attendees found common ground in which to evaluate their research. The first discussion session, chaired by Yu Zhang of Trinity University and entitled “Multi-Agent Social Simulation: Practices and applications,” allowed for conference participants to express their diverging opinions on the essence of Multi Agent Systems (MAS) and on where the best path forward lies for this growing field. This first discussion panel set the stage for subsequent discussions that continued throughout the meeting days, including the simulation of multiple levels, high-frequency and diverging-frequency interaction among simulated agents. For more of Dr. Zhang’s work, see Zhang and Leezer (2009).

The first discussion session also set the stage for the second one, by introducing the ongoing dilemma of how to model and understand the relationship between structure and agency. Stated simply and as it relates to MAS, simulations that are bottom-up focus on the level of traditional, individually-defined and self-interested agents, while top-down approaches focus on the measuring and understanding of static social structures.

The debate over structure and agency has taken place in the social sciences for centuries (arguably, since the inception of the discipline) and can more recently be found at the center of the research agenda of fields such as Critical Realism (for a summary of this field, see Bhaskar (1998)), but its connection to modeling and simulation has not been fully explored. The second discussion panel, entitled “The Problem of Social Structure: Can social simulation get beyond micro-emergence?” and led by David Byrne of Durham University in the United Kingdom, tackled this connection. While social scientists argue over the ontological reality of social entities, the field of computer simulation has opened a wide door to their study and understanding. M&S must therefore actively participate in this important debate, not only by acknowledging advancements in the social sciences, but also by informing this debate with novel M&S architectures that allow for the joint description of multiple levels of reality (i.e. psychological impulses, consumer behavior, social influences, firm interactions, etc.). For more of Dr. Byrne’s work see Byrne (1998).

The third and fourth discussion panels of the conference built from the theoretical foundations laid out in the first day of the conference to elaborate on the implications of these developments and novel insights for the M&S field. The third panel, entitled “Can We Develop a National Economic Simulation Center?” and led by Joel Jeffrey of Northern Illinois University, connected with Dr. Byrne’s discussion of structure and agency. Both deliberations implicitly advocated for a the reassertion of institutional economics, since its contemporary discussion imbedded in evolutionary approaches resonates well in many

respects with the simulation program. Dr. Jeffrey's reflections on a general mathematical language in which to describe all aspects of social reality produced fertile ground for thought and reflection among the conference participants (for more on this area of study, see Jeffrey (2010)).

The M&S research agenda seems now poised to make significant advances that are and will be more broadly available for policy makers in coming years. The fourth and final discussion panel, entitled "Epistemological Approaches: Which one is best for what?" and led by Anthony Dekker, allowed participants an opportunity to share their ample knowledge and experiences with applied simulations in which the modeler is but one of the many participants of a given research project. This panel explored in particular simulation problems where a verification-and-validation approach was not appropriate, and several participants (such as David Byrne, Jessica Turnley, Alfredo Tirado-Ramos, and Grace Villamor) provided examples of alternative approaches.

All in all, the discussion panels, keynote speeches and paper presentations of this conference seamlessly weaved together all aspects of the reality that research in nonlinear modeling and simulation entail. To give a sense of the methodological and applied issues that researchers in the field must address we offer a short description of works presented at the conference based on the five categories of contributions described above. Because the proceedings of the conference have not been published, we provide reference to published related work of the author for further reference.

4.1 Models as muses of knowledge

Ed McGrady (Center for Naval Analyses) discussed the characteristics of a good wargame, and provided a number of examples of success and failure (Perla and McGrady, 2011). While a wargame may be compromised by serious errors in representing reality, the most important characteristic is often the level of engagement by the human participants (through a form of constructed narrative, in which people are subjects, not objects). The same is often true for simulations, and McGrady's observations were consistent with remarks made by Jessica Turnley in her presentation.

Jessica Turnley (Galisteo Consulting Group) discussed the different roles and goals of the question originator, model funder, model user, disciplinary or theoretical expert, data provider, and model builder. She raised the importance of a solid theoretical base for computational social models, a clear understanding of model purpose, a justified modeling approach, data of sufficient quality, effective cross-disciplinary translation of concepts, and a measure of model "goodness" appropriate to the given goal. This may not involve "validation" in the traditional sense, since the goal of a model may be to generate insights and stimulate creativity, and the achievement of this goal may need to be assessed in other ways. See Turnley et al. (2012).

Shingo Takahashi (Waseda University, Japan) discussed a validation case study involving a Japanese theme park where the researchers were constrained by not being allowed to contact customers. The park allowed for a real-life simulation of crowd control. Previous work in Terano (2003).

Michael Agar (Ethknoworks) outlined a perspective on agent-based social modeling based on narrative. "Narrative" is also paired with what could be referred to as interpretive human social research, and is discussed in many guises—as a form of data, as a methodology, as a major subtype of the general category, and as a reporting style that better represents the nonlinear dynamic nature of the research process. See Agar (1996).

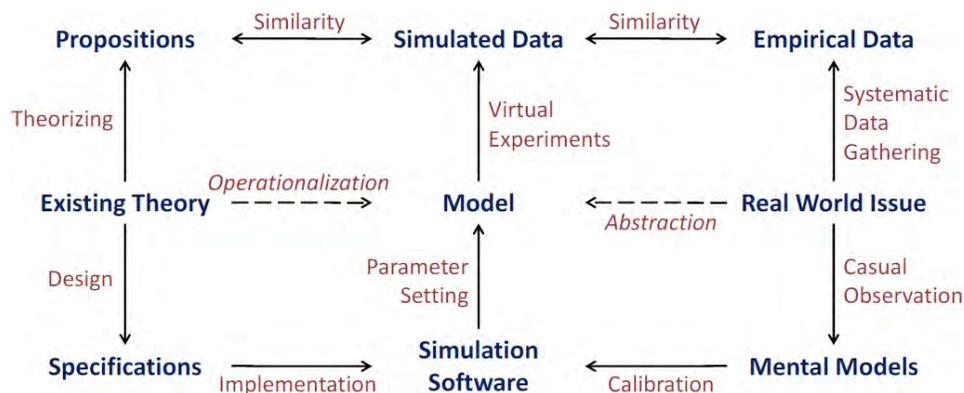
4.2 Towards a new methodology for modeling and simulation

Grace Villamor (University of Bonn) discussed the empirical validation of agent-based land use models, proposing an analytical framework and discussing alternatives to classical validation – such as companion modeling, the Open COllaboration for POLicy MOdelling (OCOPOMO). This presentation focused on the need for reliable decision-making models for land-change science with direct relevance to modeling hu-

man-environmental systems through the empirical validation approaches. This includes the recognition of the caveats and pitfalls in the empirical modeling process of human decision making that go beyond extrapolation of historic trends. The presentation described a typology of empirical validation for the agent decision-making models, and outlined an analytical framework to address the human-biophysical causal relationship in land-use models. For more on this project see Akiefnawati et al. (2010).

Anthony Dekker (DSTO) discussed a formal framework for classical verification-and-validation of social and organizational simulation, exploring the necessary processes, and giving a number of simple examples, including a validation of the Kuramoto model as a model of organizational synchronization, and some experiments with the Long House Valley model of Axtell *et al.* (see, for a summary of this approach, Dean, Gumerman, Epstein, Axtell, Swedlund, Parker, & McCarroll, S. (2000)). However, for many social and organizational simulations, a classical verification-and-validation approach may not be appropriate, and some of the approaches outlined by other speakers are necessary. For earlier work, see Dekker (2007).

Martin Ihrig (University of Pennsylvania) explored epistemological issues in the context of the diagram below (a number of similar diagrams were presented during the conference). Several aspects of simulation can be understood through this diagram. For example, the first two rows relate to validation, and the third row to verification. This presentation was well-received, but in discussion, it was suggested that this diagram could be improved. In particular, it does not adequately handle more exploratory studies which do not have a single “correct” theory, and also does not fully distinguish between “conceptual” models and “implemented” models. See background work in Ihrig and Abrahams (2007).

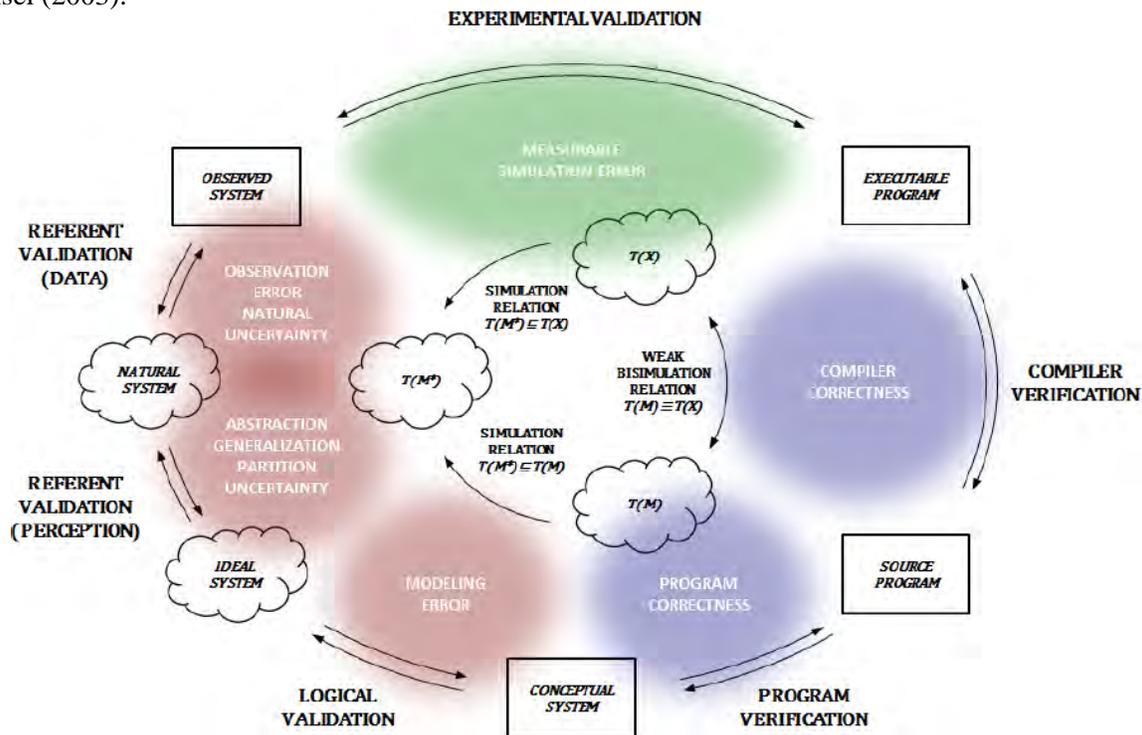


From Martin Ihrig’s presentation

Ipek Bozkurt (University of Houston-Clear Lake) explored issues also discussed in Tolk’s keynote, giving an excellent summary of epistemological, ontological, teleological and methodological considerations of modeling and simulation – that is, issues of “what do we know?,” “what exists?,” “what is our goal?,” and “how do we do it?” These issues were placed in the context of the **semiotic triangle** of object (referent), conceptualization (model), and symbol (simulation). Related work can be found in Sousa-Poza et al. (2008).

Eric Weisel (General Dynamics IT) presented a more mathematically formalized framework, summarized in the diagram below. This diagram divides the gap between an observed system and an executable simulation into a five separate stages, and thus provides theoretical guidance to the verification and validation process. There were some contradictions with the framework presented by Dekker, however, which appeared to reflect differences between high-fidelity models (the main focus of Weisel’s work) and low-fidelity models (the main focus of Dekker’s work). An adequate mathematically formalized frame-

work covering both kinds of model has yet to be developed. For more on the author's work see Petty and Weisel (2003).



From Eric Weisel's presentation

4.3 Case studies and summaries of the state-of-the-art in M&S

A number of interesting case studies provided further illumination of the concepts discussed at the conference. The following description presents the essence of these works.

Shu-Heng Chen (National Chengchi University, Taiwan) presented a keynote address exploring issues in the field of economic modeling. The keynote address was entitled: "On the Market Origin of Agent-Based Simulation in Economics: KISS, yes! But, where?" and directly and indirectly dealt with the issue of how much detail our models should have. In particular, Professor Chen presented a thorough overview of the development over the years of nonlinear models of market interactions. Chen and Yeh (2001).

Mario Gonzalez-Fuentes (Trinity University) discussed social simulation issues related to marketing. The field of marketing involves issues that can only be understood with a nonlinear approach that incorporates multiple levels of social, cultural, psychological and economic reality. This field has nonetheless lagged behind other in incorporating developments in M&S, thus representing fertile area for future applications. For more on the author's approach see Gómez Torres and González Fuentes (2011).

Alfredo Tirado-Ramos (Emory University) discussed the important public health issue of simulating HIV infection propagation networks. This is an area where network-enabled agent-based models are effective. The case study that Dr. Tirado-Ramos is working on is not only very important for our society (and in particular for the community in the state of Georgia that he is analyzing), but also clearly reflects many of the issues that simulations often encounter. For this reason, the case study allowed the conference participants a fertile opportunity for grounded discussion. Related work can be found in Tirado-Ramos et al. (2012) and Richardson et al. (2012).

4.4 New modeling techniques

A number of other presentations explored relevant and newly developed modeling techniques.

Ruben Mancha (Trinity University) discussed the use of system dynamics to model affective phenomena in agents, combining Soft-System Methodology, System Dynamics, and the Cognitive Affective Personality System model, to facilitate the design and development of simulated agents (e.g., agent based models) with interacting affective and cognitive units. Find previous related work in Mancha et al. (2009).

Gennaro Di Tosto (Utrecht University, the Netherlands) also explored affective phenomena, incorporating drives in agents in order to study compliance with government policies (specifically, smoking bans). See related work in Giardini et al. (2008).

Manuel Castañón-Puga (Autonomous University of Baja California, Mexico) discussed the use of fuzzy inference to model the competitiveness of IT firms in Tijuana. He and his collaborators are developing fuzzy-logic extensions to NetLogo which appear very promising for social and organizational modeling. See Castañón-Puga et al. (2008).

4.5 Avenues for future research

Dante Suarez (Trinity University) discussed distributed agency, addressing the important issue of levels of simulation. This prompted a fruitful discussion regarding the goals, beliefs, etc. of groups, organizations, and societies—and whether such attributes are meaningful. In a multi-level simulation, such as an agent-based economic simulation, the micro (individual), macro (social/national), and meso (group) levels interact in ways that are not fully understood. Find background work in Suarez et al. (2008).

Andreas Tolk (Old Dominion University) presented in his keynote address a broad summary of the state-of-the-art in M&S methodological advances, highlighting the importance of ontology, teleology, and methodology as well as epistemology (O/T/M/E); clarifying the difference between M&S Engineering, M&S Science, and M&S Applications; and exploring the semiotic triangle of system/model/simulation. In discussion, it became clear that “emergence” is not a useful concept, since the results of a simulation are implicit in the algorithm and the data (although the simulation acts as an “intellectual prosthesis” to help see this), and “emergence” thus takes place in the observer’s head rather than in the simulation. The importance of extending “systems thinking” to “model thinking” was also discussed.

5 THE WAY FORWARD

It was clear from discussion that a sufficiently general and sufficiently formal framework for the epistemology of simulation has yet to be developed, although the recent book *Ontology, Epistemology, and Teleology for Modeling and Simulation: Philosophical Foundations for Intelligent M&S Applications* edited by Andreas Tolk includes several elements of such a framework (Tolk, 2012). The need for interdisciplinary modeling teams, especially when dealing with social phenomena, was also recognized.

The importance of *narrative*, of *engagement*, and of *trust* also emerged as threads throughout the conference, but the relation of these to the various formal models remains unclear, and the various formal models have as yet not been unified. An extension of “systems thinking” to “model thinking” also appears necessary. Finally, although several important techniques were discussed, the community as yet lacks a taxonomy that indicates when a particular technique is appropriate. Further work in this area should provide useful common frameworks in years to come.

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AUTHOR BIOGRAPHIES

ANTHONY H. DEKKER obtained his PhD from the University of Tasmania in 1991. Following a number of years teaching computer science at universities in Australia and Singapore, he joined the Australian Defence Science and Technology Organisation (DSTO), where his interests include organizational structures, agent-based simulation, and network theory. His email address is dekker@acm.org

E. DANTE SUAREZ is Associate Chair of the Department of Business Administration at Trinity University. He obtained a PhD in Economics from Arizona State University in 2001. His research of complex adaptive systems explores the way in which agents interact with each other in multidimensional environments to create the rich dynamics of innovation, evolution and adaptation we see in society. Dr. Suarez collaborates with computer scientists to create multi-leveled computer simulations of societies, political ideologies, trading economies and urban landscapes. His email address is esuarez@trinity.edu