Introduction to Modeling Nonlinear Natural and Human Systems Minitrack

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Numerous natural and human-made systems can be described as nonlinear or complex. Such systems often escape the straight cause-effect and linear modeling patterns which traditional science has successfully used over centuries. Linear approximations of dynamic phenomena rarely deliver satisfactory results. On the other hand, nonlinear modeling techniques became feasible and more popular only with the advent of the digital computer some fifty years ago and have been widely used for little more than a decade and a half. In other words, even though the theoretical foundations were laid out much earlier, practical research and application of nonlinear modeling are still in their infancy compared with linear modeling.

Among the traditional approaches to modeling nonlinear and dynamic systems are techniques such as discrete event simulation or Markov chains. System dynamics (SD), which captures and analyzes the feedback structure of complex dynamic systems, and agent-based modeling (ABM), which focuses on the rule-based emergent behavior of interacting individual agents, are two other prominent modeling techniques. Multi-method approaches, dynamic triangulation, and complementary applications of these modeling techniques in terms of an integrated research design have been proposed before [1-3]. While such integrated designs have not emerged yet, this minitrack acts as a forum for bringing together nonlinear systems modelers of various backgrounds with the ultimate aim of exploring the prospects and benefits of integration through better understanding of each technique's research design potential. The insights from integrated research will certainly be relevant and beneficial not only to academic research but also to managerial practice and decision making.

The first paper in the minitrack's sessions, *Modeling Resource Management for Multi-class Traffic in Mobile Cellular Networks* by Helmut Hlavacs et al., presents a Markov chain-based model of channel allocation for a heterogeneous mix of quality of service and bandwidth demands (so called multi-class traffic) as expected on emerging cellular networks.

The second paper, *Developing a Flexible System-Modeling Environment for Engineers* by David R. Gardner et al., focuses on the modeling of engineering environments in which engineers frequently have to cope with numerous design trade-offs. A modular, mixed-fidelity simulation environment enables engineers to optimize system designs through simulation.

In the third paper, *Simulation Spectrum and Stability Models*, Christopher Landauer discusses what he calls a continuum of modeling styles incorporating interoperable agents, which may encompass both simple and complex agents. He presents a mathematical theory that enables the study and management of system stability.

The fourth paper, *A Dynamic Theory of Collaboration and Decision Making* by Gudergan and Gudergan, presents a system dynamics model-based framework integrating microeconomic and behavioral elements that contribute to the understanding of collaborative decision-making with non-equity partnerships as case in point.

The fifth paper, *Using Fit-Constrained Monte Carlo Trials to Quantify Confidence in Simulation Model Outcomes* by Graham, Choi, and Mullen, argues that standard MC parameter settings in simulations of high-order differential-equations systems may render implausible results, even when taken from plausible ranges of variation. Hence, fit-constrained MC trials may help better quantify confidence in simulation results.

The sixth paper*, Modeling Intergovernmental Collaboration: A System Dynamics Approach* by Anthony Cresswell et al., presents an expert-facilitated group modeling effort by participants in a multi-level, multi-agency governmental project aimed at producing deeper understanding and learning on behalf of project members. The created SD model captures processes of collaborating, trust building, and knowledge sharing as they were perceived to have occurred in the project.

References

[1] S. E. Phelan, "A note on the correspondence between complexity and systems theory," Systemic Practice and Action Research, vol. 12, pp. 237-246, 1999.

[2] H. J. Scholl, "Agent-based versus systems dynamics modeling: A call for cross study and joint research," presented at 34th Haiwaiian International Conference on System Sciences, Maui, HI, 2001.

[3] H. J. Scholl, "Looking Across the Fence: Comparing Findings From SD Modeling Efforts With those of Other Modeling Techniques," presented at 2001 Annual International Conference of the System Dynamics Society, Atlanta, GA, 2001.