The Future of Modeling and Simulation: Beyond Dynamic Complexity and the Current State of Science

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Abstract

After a brief introduction to the state of the art of SD modeling, we discuss recent and foreseeable innovations, and sketch a picture of what the future field of (SD) modeling and simulation could, according to us, look like. The pictures of the current state of the art, of the current state of science, and of the foreseeable state of science, and three illustrations, help us to sketch a functional road map from the current state towards that future. Implementing this road map will require the field to voluntarily reinvent itself. Since we do not know beforehand which new methods, techniques and tools will be most useful, it is clear that the innovators will have to experiment in a methodological sense. Without experimentation and innovation, we could either stay on the aimless plateau or retreat into a safe village. With experimentation and innovation, we may discover several routes into the mountains, enjoy spectacular views, and reach many high peaks.

1 Introduction

Many important issues within, or surpassing, the social sciences and humanities show or may show intricate time evolutionary behavior, mostly on multiple dimensions. Some of these dynamically complex issues are relatively well-know and largely predictable, but have persisted for a long time due to the fact that they are hard to understand or solve. Others –especially potential future issues and grand challenges– are largely unknown and unpredictable.

Most unaided human beings are notoriously bad at dealing with dynamically complex issues. That is, without the help of computational approaches, human beings are unable to assess potential dynamics of such complex issues and the appropriateness of policy options to address them.

Modeling and simulation is a field that develops and applies computational methods to study complex issues and solve problems in management science, social science, environmental science, etc. Over the past half century, multiple modeling methods for simulating such issues and for advising decision-makers facing them have emerged or have been further developed. Examples include System Dynamics modeling and simulation (SD), Discrete Event Simulation (DES), Agent-Based Modeling (ABM), Complex Adaptive Systems modeling (CAS), Multi-Actor Systems modeling (MAS).

All too often, these developments have taken place in distinct fields, such as the SD field or the ABM field, developing into separate 'schools', each ascribing dynamic complexity to the complex underlying mechanisms they first and foremost focus on, such as feedback and accumulation effects in SD or heterogenous actor-specific networks (inter)actions in ABM. The isolated development within separate traditions has limited the potential to learn across fields and advance faster and more effectively towards the shared goal of developing insights about complex systems and supporting decision-makers facing complex issues.

Today however, several initiatives are breaking through the silos opening up new opportunities. Not only are different modeling traditions being used in parallel and are hybrid methods emerging, modeling and simulation fields also started to adopt, or accelerated their adoption of, useful methods and techniques from data science, artificial intelligence, and recent developments in operations research. Some of these innovations are already available while other innovations still require a lot of experimentation. In this paper we will discuss innovations that have recently been developed and are now being demonstrated as well as innovations that are currently being developed and still require a lot of experimentation.

The SD method is used here to illustrate these developments. Starting with a short introduction to the traditional SD method in section 1, some recent innovations are discussed in section 2, followed by some expected evolutions in section 3, resulting in a picture of the longer term future of social simulation in section 4. Confronting the traditional method with the current state of the art and with the expected future states of the art results in a list of recent and necessary future innovations, and, hence, in a functional road map for scientists, software developers, and practitioners in section 5. Finally, conclusions are drawn in section 6.

The remainder of this paper is available upon request.

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