Chapter 3
Agent-Based Modeling:
A Historical Perspective and a Review of Validation and Verification Efforts

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ABSTRACT

Models and simulations have been widely used as a means to predict the performance of systems. Agent-based modeling and agent distillations have recently found tremendous success particularly in analyzing ground force employment and doctrine. They have also seen wide use in the social sciences modeling a plethora of real-life scenarios. The use of these models always raises the question of whether the model is correctly encoded (verified) and accurately or faithfully represents the system of interest (validated). The topic of agent-based model verification and validation has received increased interest. This chapter traces the historical roots of agent-based modeling. This review examines the modern influences of systems thinking, cybernetics as well as chaos and complexity on the growth of agent-based modeling. The chapter then examines the philosophical foundations of simulation verification and validation. Simulation verification and validation can be viewed from two quite different perspectives: the simulation philosopher and the simulation practitioner. Personnel from either camp are typically unaware of the other camp's view of simulation verification and validation. This chapter examines both camps while also providing a survey of the literature and efforts pertaining to the verification and validation of agent-based models. The chapter closes with insights pertaining to agent-based modeling, the verification and validation of agent-based models, and potential directions for future research.

INTRODUCTION TO THE CHAPTER

Simulation has long been a favored analytical technique. From early Monte Carlo (sampling) methods, through the powerful discrete-event paradigm, and with the more recent object-oriented and web-based simulation paradigms, simulation has continued to provide analysts a tool that provides valuable insight into many complex, real-world problems. Since many real-world systems feature an influen-

DOI: 10.4018/978-1-60566-774-4.ch003

tial human component, simulationists have often sought to implement simulation representations of that human component into their models, often with little success.

Agent-based modeling has emerged from the object-oriented paradigm with great potential to better model complex, real-world systems including those hard-to-model systems featuring the human component. However, the agent-based modeling paradigm struggles as do all other simulation paradigms with the question of whether the simulation accurately represents the system of interest. This is the simulation validation issue faced by any simulation model developer and user.

This chapter provides a historical perspective on the evolution of agent-based models. Our message is that this new paradigm has a series of historical scientific treads leading to the current state of agent-based modeling. We then delve into the various perspectives associated with verification and validation as a way to make the case for moving away from using "validation" and more towards the concept of model "sanctioning." We close with summary statements and concluding remarks.

INSIGHTS INTO THE EMERGENCE OF AGENT-BASED MODELING

Introduction

Over the years Agent-Based Modeling (ABM) has become a popular tool used to model and understand the many complex, nonlinear systems seen in our world (Ferber, 1999). As a result, many papers geared toward modelers discuss the various aspects and uses of ABM. The topics typically covered include an explanation of ABM, when to use it, how to build it and with what software, how results can be analyzed, research opportunities, and discussions of successful applications of the modeling paradigm. It is also typical to find within these papers brief discussions about the origins of ABM, discussions that tend to emphasize the diverse applications of ABM as well as how some fundamental properties of ABM were discovered. However, these historical discussions often do not go into much depth about the fundamental theories and fields of inquiry that would eventually lead to ABM's emergence. Thus, in this chapter we re-examine some of the scientific developments in computers, complexity, and systems thinking that helped lead to the emergence of ABM, shed new light onto some old theories while connecting them to several key ABM principles of today. This chapter is not a complete account of the field, but does provide a historical perspective into ABM and complexity intended to provide a clearer understanding of the field, show the benefits of understanding the diverse origins of ABM, and hopefully spark further interest into the theories and ideas that laid the foundation for today's ABM paradigm.

The Beginning: Computers

The true origins of ABM can be traced back to when scientists first began discovering and attempting to explain the emergent and complex behavior seen in nonlinear systems. Some of these more familiar discoveries include Adam Smith's Invisible Hand in Economics, Donald Hebb's Cell Assembly, and the Blind Watchmaking in Darwinian Evolution (Axelrod & Cohen, 2000). In each of these theories simple individual entities interact with each other to produce new complex phenomena that seemingly just emerge. In Adam Smith's theory, this emergent phenomena is called the Invisible Hand, which occurs when each individual tries to maximize their own interests and as a result tend to improve the entire community. Similarly, Donald Hebb's Cell Assembly Theory states that individual neurons interacting together form a hierarchy that results in the storage and recall of memories in the human brain. In this case, the emergent phenomena is the memory formed by the relatively simple