Levent Yilmaz and Tuncer Ören

Agent-Directed Simulation and Systems Engineering

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Levent Yilmaz and Tuncer Ören

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To Funda
Levent Yilmaz

To Füsun
Tuncer Ören

Foreword

What makes agent software different from ordinary software? What can modeling and simulation contribute to agent systems? Conversely, is there a role for agents in modeling and simulation? This book is the first extended work to provide in-depth answers to these questions and others like them. Indeed, the term “agent” has become a ubiquitous “buzzword” used in an enormous variety of contexts to refer to a wide range of software attributes. So it is very timely to bring together a group of experts to offer their unique insights into various aspects of agent software as they relate primarily to modeling and simulation and to systems engineering. However, this book is more than a collection of essays on agents in their diverse applications. The editors, Tuncer Ören and Levent Yilmaz, combining depth of experience with bleeding-edge enthusiasm, provide a degree of coherence well beyond that usually seen in edited collections. In addition to writing some of the key chapters, the editors contribute new concepts and organizing principles that illuminate the current state of the art and reveal intriguing possibilities for theory and applications going forward.

The looseness of terminology in information technology is something we have grown to live with as the field has developed. Terms such as “agent” that have broad connotations are useful for such socially important activities as building communities of interest, organizing conferences, and successfully communicating with the nontechnical layperson. However, there comes a point where imprecise terminologies need to be given greater definitiveness so that critical concepts can be delineated and clarified, thereby allowing the field to move forward on a sounder foundation. To address this need, the book opens with a chapter that provides an integrative and comprehensive view of modeling and simulation, laying the basis for the rest of the book. Interspersed in the sequel are chapters that provide similarly foundational discussions of agent concepts, systems engineering, and the application of each one of these areas to the other. Whether you are a software developer, simulation practitioner, or systems engineer, you will find some eye-opening material in this presentation.

The central thesis of the book is that, while simulation in application to agents is fairly well established, the converse application of agents to the enterprise of modeling and simulation is much less appreciated and, as the editors assert, no less important. Indeed, Ören’s taxonomy in the opening chapter alone is worth the

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price of admission. His framework enables one to consider the mutual synergies among modeling and simulation, system theories, systems engineering, software agents, and artificial intelligence. I can envision research professors and graduate students being stimulated to explore branches of this tree toward new research directions in proposals or dissertations.

As a contributor of a chapter to the book, I can attest that its title, "Agent-Directed Simulation and Systems Engineering", challenged me to address its novel theme in the context of my own and fellow authors' work. Interoperability has become a critical feature in modern systems of systems engineering. Testing for interoperability (the ability of independent systems to effectively communicate) has likewise become a necessary part of the overall system development process. Our work in this context employs foundational modeling and simulation concepts in novel ways. We use models derived from system requirements to execute in real time as agents deployed across a network to observe net-enabled collaboration of participants. In this way, agent, modeling and simulation, and systems engineering, concepts, and technologies are brought together to provide a testing solution that would be difficult to synthesize otherwise.

We used the term "agent-implemented" in our title (Chapter 13) to suggest the particular flavor of support provided by agents in this context. By all means, let the reader be challenged to find new species of agent-directed, enabled, oriented, or driven simulation to further the goals of model-based systems engineering. And conversely!

December 2008 *Bernard P. Zeigler*

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Preface

Simulation is the enabling technology for hundreds of very important application areas requiring any type of decision support (such as prediction, evaluation, testing, planning, acquisition, and proof of concept), understanding, and education, as well as training to develop and/or enhance motor skills to gain proficiency in the use of equipment, decision making and communication skills, and operational skills by getting real-life-like experience in controlled environments.

The maturity of simulation is (1) *facilitated* by the advances of computer hardware, software engineering, artificial intelligence, software agents, and system theories; (2) *due* to the dedicated contributions of several simulationists, the requirements of advanced users, and the support of influential people who realize its importance; and (3) *achieved* through developments, improvements, and especially through several paradigm shifts. As presented by Thomas Kuhn in his seminal book *The Structure of Scientific Revolutions*, three stages are necessary for a paradigm shift to occur. In the first stage, a paradigm becomes dominant. In the second stage, limitations or problems with the dominant paradigm are observed or better anticipated. In the third stage, a new paradigm that would surpass these limitations and problems is proposed and after some delay becomes the new dominant paradigm.

This book emphasizes the benefits of a double synergy: first, the synergy of modeling and simulation with software engineering, which leads to agent-directed simulation; and then the synergy of agent-directed simulation with systems engineering.

The use of agents in computational modeling has now become pervasive. The power of agents comes partly from their ability to conceptualize problems and devise solutions in terms of interacting entities that communicate, collaborate, coordinate, and intentionally deliberate their actions and reactions. The significant benefit gained by an event-based interactive computing perspective over algorithmic computation is due to our new understanding of complex systems and the universal principles, as well as patterns underlying their mechanisms. This coherent theme about the significance of interaction spans complex systems from cellular mechanisms in systems biology, physiology, brain dynamics, organizational dynamics, ecosystems, as well as patterns of human behavior and culture that define the dynamics of sociotechnical, cognitive, and cultural systems. The call for decentralized problem solving, adaptation, and flexibility in systems engineering

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is also resulting in increased use of agent technologies to engineer robustness and resilience into complex artificial systems, while increasing our ability to explore and understand information processes underlying natural systems.

The motivation behind this book, however, goes beyond recognition of these observations. Since its adoption by the simulation modeling and systems engineering communities, the use of agents, unfortunately, has been limited to development of models that use agents as design metaphors. Yet this limited treatment of agents in simulation and systems engineering misses opportunities where agent and simulation technologies are together a central theme. Thus this book aims to fill a gap in the agent, modeling and simulation, and systems engineering communities. By expanding our horizons on the use of agents in modeling and simulation to build, explore, and understand both artificial and natural systems, the book presents a comprehensive framework, called agent-directed simulation, that consists of three distinct, yet related, areas that can be grouped under two categories as follows.

1. Simulation for sgents (agent simulation): simulation of agent systems in engineering, human and social dynamics, military applications, etc.
2. Agents for simulation: agent-supported simulation deals with the use of agents as a support facility to enable computer assistance in problem solving, experimentation, or enhancing cognitive capabilities; agent-based simulation focuses on the use of agents for the generation of model behavior in a simulation study.

While agent-based modeling is widely appreciated and used in model-based science and engineering, the potential use of agents in developing next-generation intelligent and adaptive simulators and their inclusion in the simulation frontend or backend interfaces are not yet as widely acknowledged. Furthermore, the growth of new advanced distributed computing standards along with the rapid rise of service orientation is providing a new context that acts as a critical driver for the development of next-generation systems. These standards revolve around pervasive computing, Web services, grid, autonomic computing, ambient intelligence, etc. The supporting role that intelligent agents can play in the design and development of such systems is becoming pervasive, and simulation plays a critical role in the analysis and design of such systems. The synergy between systems engineering, simulation modeling, and agent technologies is examined in this book to facilitate mutual advancement of each area.

To explore interrelations between systems engineering, simulation modeling, and agent technologies, the book is comprised of three parts. First, we start with a background section that includes a comprehensive overview of modeling and simulation, agent paradigm, systems engineering, and quality assurance. In the second part, we examine the use of systems engineering principles, formal methods, tools, toolkits, and environments for developing agent-directed simulation systems. The final section focuses on the role that agent-directed simulation can play in various systems engineering problems such as testing and evaluation, process performance analysis, decision support, and organization and work system engineering.

Writing this book would not have been possible without the support of many people. The efforts of the referees were instrumental in shaping the contents. Esther Dörring, Anja Tschörtner, and other staff members at Wiley were also very helpful in facilitating the process as well as in supporting the production and final camera-ready copy. Special thanks to authors, since without their intellectual work and creative contributions this book could not exist.

We hope that the introduction of agent-directed simulation and systems engineering as a comprehensive framework that expands our horizons on the mutual contributions of modeling and simulation, software agents, and systems engineering will achieve a broader impact of the associated theories, methodologies, and applications and that challenging and complex problems can be tackled more appropriately. We both wish everyone a pleasant and fruitful time reading and using this book.

December 2008 *Levent Yilmaz and Tuncer Ören*

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