Preface

The Chinese Proverb cites that "I hear and I forget. I see and I remember. I do and I understand", in this context, Simulation is the next best thing after the "I do" part, as it is the nearest thing to giving real life picture to images in the mind. Mirrors reflect real life into no existing picture, whereas simulation embodies our notions and ideas into a picture that cannot only be seen, but played and experimented with as well. Simulation environments exist on a number of dimensions in the market.

The desirable features in Discrete Event Simulation environments are taxonomiesed as modeling features, simulation systems features, and implementation features. While the modeling features include modularity, reuse and the hierarchical structure of the model, the simulation systems features include the scalability, portability, and interoperability of the simulation system, and the implementations features include distribution execution, execution over the internet, and ease of use. In order to accomplish the aforementioned desirable features, many components must be examined, while taking into account the market supply and demand factors. Actually, the race to accomplish such desirable features is as old as simulation itself. The components to be examined in this book are: Methodologies, Simulation language, Tutorials, Statistical analysis packages, Modeling, Animation, Interface, interoperability standards, Uses and Applications, Stochastic / Deterministic, Time handling, and History.

In **Handbook of Research on Discrete Event Simulation Environments: Technologies and Applications**, simulation is discussed from within the different features of theory and application. The goal of this book is not to look at simulation from traditional perspectives, but to illustrate the benefits and issues that arise from the application of simulation within other disciplines. This book focuses on major breakthroughs within the technological arena, with particular concentration on the accelerating principles, concepts and applications.

The book caters to the needs of scholars, PhD candidates, researchers, as well as, graduate level students of computer science, operations research, and economics disciplines. The target audience for this book also includes academic libraries throughout the world that are interested in cutting edge research. Another important segment of readers are students of Master of Business Administration (MBA) and Master of Public Affairs (MPA) programs, which include information systems components as part of their curriculum. To make the book accessible to all, a companion website was developed, which can be reached through the link (http://www.computercrossroad.org/).

This book is organized in 22 chapters. On the whole, the chapters of this book fall into five categories, while crossing paths with different disciplines, of which the first, *Simulation Prelude*, concentrates on simulation theory, while the second concentrates on *Petri Nets*, whereas the third section concentrates on *Monte Carlo*, besides the fourth section that sheds light on *visualization and real-time simulation*, likewise, the fifth section, *living simulation*, gives color to the black and white picture. The fifth section

discusses simulation applications in neural networks, data mining, networks, banks, construction, thereby aiming to enrich this book with others knowledge, experience, thought and insight.

Chapter 1, *Simulation: Body of Knowledge*, attempts to define the knowledge body of simulation and describes the underlying principles of simulation education. It argues that any programs in Modelling and Simulation should recognize the multi-and interdisciplinary character of the field and realize the program in wide co-operation. The chapter starts with the clarification of the major objectives and principles of the Modelling and Simulation Program and the related degrees, based on a broad business and real world perspective. After reviewing students' background, especially the communication, interpersonal, and team skills, the analytical and critical thinking skills, furthermore some of the additional skills leading to a career, the employer's view and possible career paths are examined. Finally, the core knowledge body, the curriculum design and program related issues are discussed. The author hopes to contribute to the recent discussions about modelling and simulation education and the profession.

Chapter 2, *Simulation Environments as Vocational and Training Tools,* investigates over 50 simulation packages and simulators used in vocational and course training in many fields. Accordingly, the 50 simulation packages were categorized in the following fields: Pilot Training, Chemistry, Physics, Mathematics, Environment and ecological systems, Cosmology and astrophysics, Medicine and Surgery training, Cosmetic surgery, Engineering – Civil engineering, architecture, interior design, Computer and communication networks, Stock Market Analysis, Financial Models and Marketing, Military Training and Virtual Reality. The incentive for using simulation environments as vocational and training tools is to save live, money and effort.

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

Chapter 4, *Verification and Validation of Simulation Models*, discusses validation and verification of simulation models. The different approaches to deciding model validity are presented; how model validation and verification relate to the model development process are discussed; various validation techniques are defined; conceptual model validity, model verification, operational validity, and data validity; superior verification and validation technique for simulation models relied on a multistage approach are described; ways to document results are given; and a recommended procedure is presented.

Chapter 5, *DEVS-Based Simulation Interoperability*, introduces the usage of DEVS for the purpose of implementing interoperability across heterogeneous simulation models. It shows that the DEVS framework provides a simple, yet effective conceptual basis for handling simulation interoperability. It discusses the various useful properties of the DEVS framework, describes the Shared Abstract Model (SAM) approach for interoperating simulation models, and compares it to other approaches. The DEVS approach enables formal model specification with component models implemented in multiple programming languages. The simplicity of the integration of component models designed in the DEVS, DTSS, and DESS simulation formalisms and implemented in the programming languages Java and C++ is demonstrated by a basic educational example and by a real world forest carbon accounting model. The

authors hope, that readers will appreciate the combination of generalness and simplicity and that readers will consider using the DEVS approach for simulation interoperability in their own projects.

The second section concentrates on, *Monte Carlo Simulation* where it is covered in chapter 6 and 7 as follows:

Chapter 6, *Experimental Error Measurement in Monte Carlo Simulation*, describes the set up step series, developed by the Genoa Research Group on Production System Simulation at the beginning of the '80s, as a sequence, through which it is possible at first statistically validate the simulator, then estimate the variables which effectively affect the different target functions, then obtain, through the regression meta-models, the relations linking the independent variables to the dependent ones (target functions) and, finally, proceed to the detection of the optimal functioning conditions. The authors pay great attention to the treatment, the evaluation and control of the Experimental Error, under the form of Mean Square Pure Error (MS_{PE}), a measurement which is always culpably neglected in the traditional experimentation on the simulation models but, that potentially can consistently invalidate with its magnitude the value of the results obtained from the model.

Chapter 7, *Efficient Discrete Simulation of Coded Wireless Communication Systems*, presents a simulation method, named Accelerated Simulation Method (ASM), that provides a high degree of efficiency and accuracy, namely for lower BER, where the application of methods like the Monte Carlo simulation method (MCSM) is prohibitive, due to high computational and time requirements. The present work generalizes the application of the ASM to a Wireless Communication System's (WCS) modelled as a stochastic discrete channel model, considering a real channel, where there are several random effects that result in random energy fluctuations of the received symbols. The performance of the coded WCS is assessed efficiently, with soft-decision (SD) and hard-decision (HD) decoding. The authors show that this new method already achieves a time efficiency of two or three orders of magnitude for SD and HD, considering a BER = 1×10^{-4} when compared to MCSM. The presented performance results are compared with the MCSM, to check its accuracy.

The third part of the book concentrates on *Petri Nets*. The chapters 8 through 10 cover this part as follows:

Chapter 8, *Teaching Principles of Petri Nets in Hardware Courses and Student's Projects*, presents the principles of using Petri Net formalism in hardware design courses, especially in the course "Architecture of peripheral devices". Several models and results obtained by student individual or group projects are mentioned. First the using of formalism as a modeling tool is presented consecutively from Place/Transition nets to Coloured Petri nets. Then the possible Petri Nets using as a hardware specification for direct hardware implementation (synthesized VHDL for FPGA) is described. Implementation and simulation results of three directly implemented models are presented

Chapter 9, *An Introduction to Reflective Petri Nets*, introduces Reflective Petri nets, a formal model for dynamic discrete-event systems. Based on a typical reflective architecture, in which functional aspects are cleanly separated from evolutionary ones, that model preserves the description effectiveness and the analysis capabilities of Petri nets. On the short-time perspective of implementing a discrete-event simulation engine, Reflective Petri nets are provided with timed state-transition semantics.

Chapter 10, *Trying out Reflective Petri Nets on a Dynamic Workflow Case*, proposes a recent Petri net-based reflective layout, called Reflective Petri nets, as a formal model for dynamic workflows. A localized open problem is considered: how to determine what tasks should be redone and which ones do not when transferring a workflow instance from an old to a new template. The problem is efficiently but rather empirically addressed in a workflow management system. The proposed approach is formal,

may be generalized, and is based on the preservation of classical Petri nets structural properties, which permit an efficient characterization of workflow's soundness.

The fourth section of the book concentrates on visualization and real-time simulation. The chapters 11 through 14 cover this part as follows:

Chapter 11, *Applications of Visual Algorithm Simulation*, represent a novel idea to promote the interaction between the user and the algorithm visualization system called visual algorithm simulation. As a proof of concept, the chapter represents an application framework called Matrix that encapsulates the idea of visual algorithm simulation. The framework is applied by the TRAKLA2 learning environment in which algorithm simulation is employed to produce algorithm simulation exercises. Moreover, the benefits of such exercises and applications of visual algorithm simulation in general are discussed.

Chapter 12, *Virtual Reality: A New Era of Simulation And Modelling*, represent a novel idea to promote the interaction between the user and the algorithm visualization system called visual algorithm simulation. As a proof of concept, the chapter represents an application framework called Matrix that encapsulates the idea of visual algorithm simulation. The framework is applied by the TRAKLA2 learning environment in which algorithm simulation is employed to produce algorithm simulation exercises. Moreover, the benefits of such exercises and applications of visual algorithm simulation in general are discussed.

Chapter 13, *Implementation of a DES Environment*, describes a program system that implements a Discrete Event Simulation (DES) development environment. The simulation environment was created using the LabVIEW graphical programming system; a National Instruments software product. In this programming environment the user can connect different procedures and data structures with "graphical wires" to implement a simulation model, thereby creating an executable simulation program. The connected individual objects simulate a discrete event problem. The chapter describes all simulation model objects, their attributes and methods. Another important element of the discrete event simulator is the task list, which has also been created using task type objects. The simulation system uses the "next event simulation" technique and refreshes the actual state (attribute values of all model objects) at every event. The state changes are determined by the entity objects, their input, current content, and output. Every model object can access (read) all and modify (write) a selected number of object attribute values. This property of the simulation system provides the possibility to build a complex discrete event system using predefined discrete event model objects.

Chapter 14, *Using Simulation Systems for Decision Support*, describes the use of simulation systems for decision support in support of real operations, which is the most challenging application domain in the discipline of modeling and simulation. To this end, the systems must be integrated as services into the operational infrastructure. To support discovery, selection, and composition of services, they need to be annotated regarding technical, syntactic, semantic, pragmatic, dynamic, and conceptual categories. The systems themselves must be complete and validated. The data must be obtainable, preferably via common protocols shared with the operational infrastructure. Agents and automated forces must produce situation adequate behavior. If these requirements for simulation systems and their annotations are fulfilled, decision support simulation can contribute significantly to the situational awareness up to cognitive levels of the decision maker.

The final part of the book, *living simulation*, The chapters 15 through 22 cover this part as follows:

Chapter 15, *The Simulation of Spiking Neural Networks*, is an overview of the simulation of spiking neural networks that relates discrete event simulation to other approaches. To illustrate the issues surrounding this work, the second half of this chapter presents a case study of the SpikeStream neural

simulator that covers the architecture, performance and typical applications of this software along with some recent experiments.

Chapter 16, *An Integrated Data Mining and Simulation Solution*, we will propose an intelligent DSS framework based on data mining and simulation integration. The main output of this framework is the increase of knowledge. Two case studies are presented, the first one on car market demand simulation. The simulation model was built using neural networks to get the first set of prediction results. Data mining methodology used named ANFIS (Adaptive Neuro-Fuzzy Inference System). The second case study demonstrates how applying data mining and simulation in assuring quality in higher education

Chapter 17, *Modeling and Simulation of IEEE 802.11g using OMNeT++*, aims to provide a tutorial on OMNeT++ focusing on modeling and performance study of the IEEE 802.11g wireless network. Due to the complex nature of computer and telecommunication networks, it is often difficult to predict the impact of different parameters on system performance especially when deploying wireless networks. Computer simulation has become a popular methodology for performance study of computer and telecommunication networks. This popularity results from the availability of various sophisticated and powerful simulation software packages, and also because of the flexibility in model construction and validation offered by simulation. While various network simulators exist for building a variety of network models, choosing a good network simulator is very important in modeling and performance analysis of wireless networks. A good simulator is one that is easy to use; more flexible in model development, modification and validation; and incorporates appropriate analysis of simulation output data, pseudo-random number generators, and statistical accuracy of the simulation results. OMNeT++ is becoming one of the most popular network simulators because it has all the features of a good simulator.

Chapter 18, *Performance Modeling of IEEE 802.11 WLAN using OPNET: A Tutorial*, aims to provide a tutorial on OPNET focusing on the simulation and performance modeling of IEEE 802.11 wireless local area networks (WLANs). Results obtained show that OPNET provides credible simulation results close to a real system.

Chapter 19, *On the Use of Discrete-Event Simulation in Computer Networks Analysis and Design,* describes a newly developed research-level computer network simulator, which can be used to evaluate the performance of a number of flooding algorithms in ideal and realistic mobile ad hoc network (MANET) environments. It is referred to as MANSim.

Chapter 20, *Queuing Theory and Discrete Events Simulation for Health Care: From Basic Processes to Complex Systems with Interdependencies*, objective is twofold: (i) to illustrate practical limitations of queuing analytic (QA) compared to Discrete-event simulation (DES) by applying both of them to analyze the same problems, and (ii) to demonstrate practical application of DES models starting from simple examples and proceeding to rather advanced models.

Chapter 21, *Modelling a Small Firm in Jordan Using System Dynamics*, objective of this chapter is to introduce new performance measures using systems thinking paradigm that can be used by the Jordanian banks to assess the credit worthiness of firms applying for credit. A simulator based on system dynamics methodology which is the thinking tool presented in this chapter. The system dynamics methodology allows the bank to test "What If" scenarios based on a model which captures the behavior of the real system over time.

Chapter 22, *The State of Computer Simulation Applications in Construction*, presents an overview of computer simulation efforts that have been performed in the area of construction engineering and management. Also, it presents two computer simulation applications in construction; earthmoving and construction of bridges' decks. Comprehensive case studies are worked out to illustrate the practicality

of using computer simulation in scheduling construction projects, taking into account the associated uncertainties inherited in construction operations.

In conclusion, it is worth reaffirming that this book is not meant to look at simulation from within the different features of theory and application, nor is the goal of this book to look at simulation from traditional perspectives, in fact this book points toward illustrating the benefits and issues that arise from the application of simulation within other disciplines. As such, this book is organized in 22 chapters, sorted into five categories, while crossing paths with different disciplines, of which the first, *Simulation Prelude*, concentrated on simulation theory, while the second concentrated on *Petri Nets*, whereas the third section concentrated on *Monte Carlo*, besides the fourth section that shed light on *visualization and real-time simulation*, concluding in the fifth section, *living simulation*, which gave color to the black and white picture, as it discussed simulation applications in neural networks, data mining, networks, banks, construction.