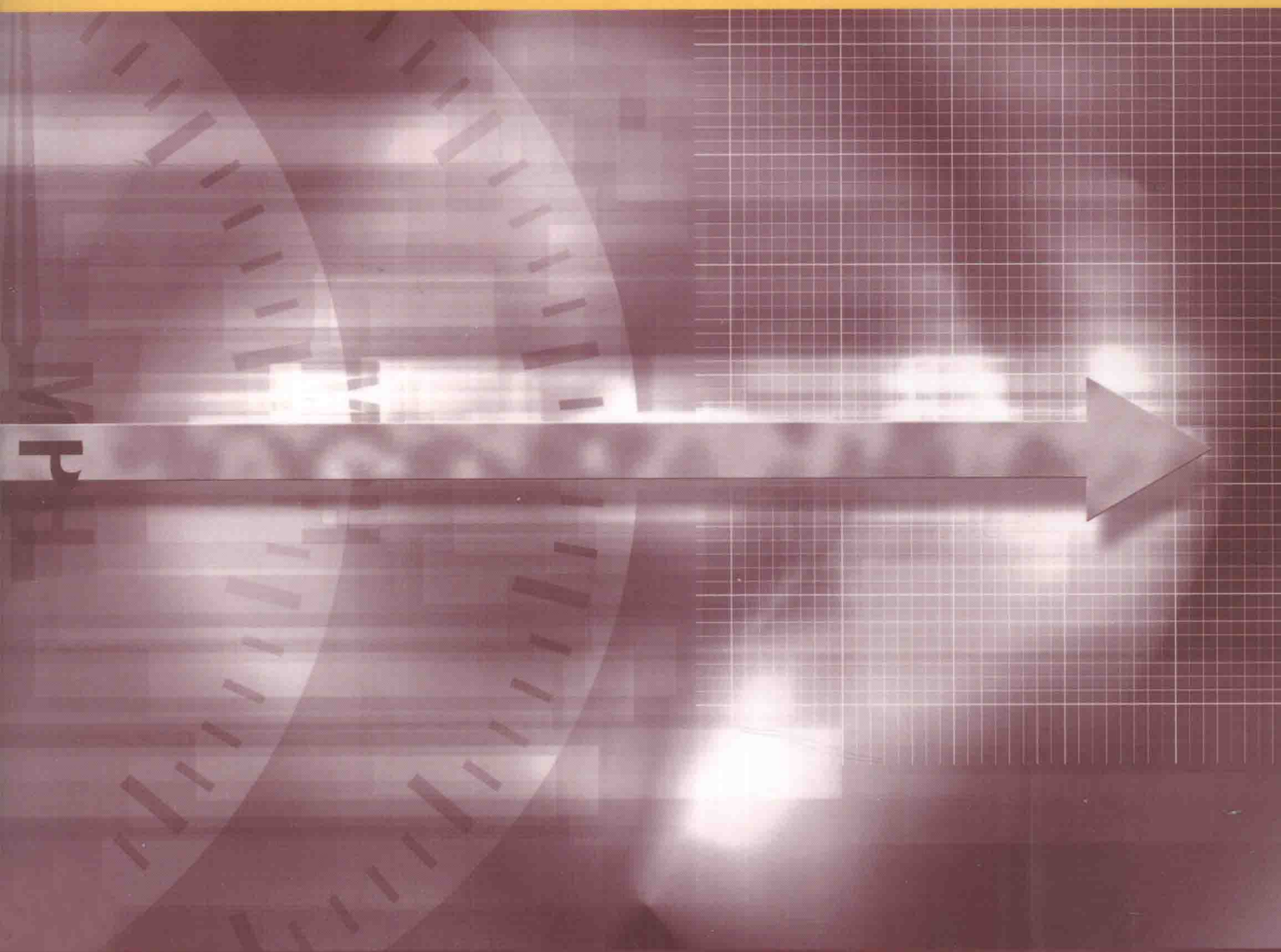
SIMULATION MODELING AND ARENA



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Simulation Modeling and Arena

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Academic Software Installation Instructions

Arena requires Microsoft® Windows 2000 (Service Pack 3 or later), Windows Server 2003, Windows XP (Service Pack 2 or later) or Windows Vista Business Edition; under Windows 2000 and Windows XP you must have Administrator privileges to install the software.

Authorization to Copy Software

This academic software can be installed on any university computer, as well as on students' computers. It is intended for use in conjunction with this book for the purpose of learning simulation and Arena. You have the right to use and make copies of the software for academic use for teaching and research purposes only.

Commercial use of the software is prohibited.

This textbook uses the Arena version available at book release or publishing. It is expected that the Arena examples in this textbook can be compiled and run in the accompanying version as well as future Arena versions. Since new releases of Arena typically outpace updates to textbooks, academic institutions are encouraged to keep their lab and research software up to date and to make copies of their latest install CDs available to students (This is in agreement with EULA specifications), replacing what is included in this book. NOTE: Students should use the same software version as those used in the labs. Arena is forward, but not backward compatible (e.g., an Arena 11.0 model can be loaded into Arena 12.0, but an Arena 12.0 model cannot be loaded into Arena 11.0).

Installing the Arena Software

Follow this sequence to install your Arena software. Please note that you cannot merely accept all the defaults; there are some specific steps you must follow during the installation process:

1. Insert the Arena CD to initiate the autorun program, which displays the Arena installation screen. If it does not run automatically, browse the CD directory to locate autorun.exe and double-click it to start the installation.
2. From the installation dialog, select *Install Arena 12.00.00 (CPR 9)*. When prompted for a serial number, enter STUDENT to activate the academic version. Doing so customizes the install, provides access to the examples referenced in the textbook, and allows you to build larger models.
3. When choosing a location to install Arena on the PC's hard drive, please note that Arena will be placed in the Arena subfolder of the folder you specify.
4. After Arena installs, reboot your computer if requested.
5. If you have further questions, please refer to the User Zone section of our Web site at www.ArenaSimulation.com.

License activation is not supplied with, or required for, the STUDENT version of Arena. If you see an option to install the activation for Arena, this option should be cleared (unchecked). If you are installing the Arena PE Educational Lab Package or for more information on license activation or any other aspect of installation, select *Installation Notes* from the Arena installation screen.

System Requirements

The minimum requirements/recommendations for running the Arena software are:

- Windows Vista Business Edition, Windows XP Professional (SP2 or later), Windows XP Home (SP2 or later), Windows 2000 Professional (SP4 or later), Windows 2000 Server (SP4 or later), Windows Server 2003 (SP1 or later).
- Microsoft Internet Explorer 6.0 (Service Pack 1) or later.
- Adobe Acrobat Reader 7.0 or later to view documentation
- You must have Administrator privileges to install the software; however it is not necessary to have Administrator privileges to run Arena.
- Hard drive with 75-250 MB free disk space (depending on operating system and options installed)
- 256 MB RAM minimum recommendation
- Minimum Pentium processor, 500Mhz or higher
- The running and animation of simulation models can be calculation-intensive, so a faster processor with additional memory may result in significantly improved performance. In addition, a larger monitor and a screen resolution of at least 1024 x 768 is recommended for improved animation viewing.
- **Under Windows 2000 and Windows XP, you must have Administrator privileges to install the software.**

Manuel Rossetti's Supporting Files

Additional chapter files (e.g. Arena and Excel) are provided on the disk. You can access/retrieve them by browsing to the "Manuel Rossetti Supporting Files" folder when the CD is in your computer's optical drive.

Preface

Intended Audience

This is an introductory textbook for a first course in discrete-event simulation modeling and analysis for upper-level undergraduate students as well as entering graduate students. While the text is focused on engineering students (primarily industrial engineering), it could also be used by advanced students in business, computer science, and other disciplines where simulation is practiced. Of course, practitioners interested in learning simulation and Arena could also use this book independently.

What is Simulation Modeling?

Discrete-event simulation is an important tool for the modeling of complex systems. It is used to represent manufacturing, transportation, and service systems in a computer program for the purpose of performing experiments. Representation of the system via a computer program enables the testing of engineering design changes without disruption to the system being modeled. Simulation modeling involves elements of system modeling, computer programming, probability and statistics, and engineering design. Because simulation modeling involves these individually challenging topics, the teaching and learning of simulation modeling can be difficult for both instructors and students. Instructors are faced with the task of presenting computer programming concepts, probability modeling, and statistical analysis, all within the context of demonstrating how to model complex systems such as factories and supply chains. In addition, because of the complexity associated with simulation modeling, specialized computer languages are needed, and thus must be taught to students for

use during the model-building process. This book is intended to help instructors with this daunting task.

Approach, and Use of Arena

Traditionally, there have been two major types of simulation textbooks (1) those that emphasize the theoretical (and mostly statistical) aspects of simulation, and (2) those that emphasize the simulation language or package. The intention of this book is to merge these two aspects of simulation textbooks, while adding and emphasizing the art of model building. Thus, the book contains chapters on modeling and chapters that emphasize the statistical aspects of simulation. However, the coverage of statistical analysis is integrated with the modeling in such a way to emphasize the importance of both topics.

This book uses the Arena Simulation Environment as the primary modeling tool for teaching simulation. Arena is one of the leading simulation modeling packages in the world and has a strong and active user base. While the book uses Arena as the primary modeling tool, the book is not intended to be a user's guide to Arena. Instead, Arena is used as the vehicle for explaining important simulation concepts.

I feel strongly that simulation is best learned by doing. The book is structured to enable and encourage students to get engaged in the material. The overall approach to presenting the material is grounded in a hands-on concept of education. The style of writing is informal, tutorial, and centered around examples that students can implement while reading the chapters. The book assumes a basic knowledge of probability and statistics, and an introductory knowledge of computer programming. Even though these topics are assumed, the book provides integrated material that should help readers review the basics of these topics. Thus, instructors who use this book should not have to formally cover this material, and can be assured that students who read the book will be aware of these concepts within the context of simulation.

Organization of the Book

The first chapter is an introduction to the field of simulation modeling and an introduction to the Arena modeling environment. After Chapter 1, the student should know what simulation is and be able to put different types of simulation into context. Chapter 1 also introduces the important concept of how a discrete-event clock "ticks" and sets the stage for process modeling using activity diagramming. Finally, a simple (but comprehensive) example of Arena is presented so that students will feel comfortable with the tool.

Chapter 2 dives deeper into process-oriented modeling. The statistical aspects of simulation are downplayed within the chapter. The Basic Process template within Arena is thoroughly covered. Important concepts within process-oriented modeling (e.g., entities, attributes, activities, state variables, etc.) are discussed within the context of a number of examples. In addition, a deeper understanding of Arena is developed, including flow of control, input/output, variables, arrays, and debugging. After finishing Chapter 2, the reader should be able to model interesting systems from a process viewpoint using Arena.

Chapter 3 emphasizes the role of randomness in simulation. Specifically, the chapter presents input modeling, random number generation, and random variate generation techniques. After Chapter 3, the student should be able to model the input distributions required for simulation using such tools as EXCEL®, MINITAB™, and ARENA's™ input analyzer. In addition, the student will know why random number generators and their control are essential for simulation modeling. Finally, the primary techniques for generating random variates from

probability distributions are covered (e.g., inversion, acceptance/rejection, convolution, and composition). An appendix is available for Chapter 3 that demonstrates how to perform Monte Carlo simulation within Excel.

Building on the use of stochastic elements in simulation, Chapter 4 discusses the major methods by which simulation output analysis must account for randomness. The various types of statistical quantities (observation based versus time persistent) are defined and then statistical methods are introduced for their analysis. Specifically, the chapter covers the method of replication for finite-horizon simulations, analysis of the initialization-transient period, the replication deletion method, and the batch means method. In addition, the use of simulation to make decisions based on competing alternatives is presented.

Chapter 5 returns to model building by presenting models for important classic modeling situations in queuing and inventory theory. Both analytical and simulation approaches to modeling these systems are covered. For instructors who work in a curriculum that has a separate course on these topics, this chapter presents an opportunity to concentrate on simulating these systems. The analytical material could easily be skipped without loss of continuity; however, often students learn the most about these systems through simulation. In situations where this material is not covered separately, background is presented on these topics to ensure that students can apply the basics of queuing theory and are aware of basic inventory models. The basic models are then extended so that students understand how simulation quickly becomes necessary when modeling more realistic situations.

Chapter 6 presents a thorough treatment of the entity-transfer and material-handling constructs within Arena. Students learn the fundamentals of resource-constrained transfers, free path transporters, conveyors, and fixed path transporters. The animation of models containing these elements is also emphasized.

Chapter 7 pulls together a number of miscellaneous topics that round out the use of Arena. In particular, the chapter covers Arena's activity based costing model and presents advanced aspects of modeling with resources (e.g., schedules and failure modeling). This chapter also presents a few useful modules that were not previously covered (e.g., picking stations, generic stations, and picking up and dropping off entities). An introduction to using Visual Basic and Arena is also presented.

Finally, Chapter 8 presents a detailed case study using Arena. An IIE/Rockwell Software Arena Contest problem is solved in its entirety. This chapter ensures that students will be ready to solve such a problem if assigned the same as a project for the course. The chapter wraps up with some practical advice for performing simulation projects.

Special Features

- *Learning Objectives:* Each chapter begins with specific learning objectives.
- *Output Analysis integrated with Arena:* The statistical aspects of simulation (e.g., output analysis) are integrated with the tool (e.g., Arena). More detailed discussions of the statistical aspects of simulation are presented than are found in many other simulation language–oriented textbooks.
- *Activity-based Learning:* Studies have shown that activity-based learning is critical to student retention of material. The text is organized around model building with the intention that students should be following along at the computer while working through the chapters. Instructors can perform the activities or organize computer laboratory exercises around the development of the models in the text.

- *Emphasis on Computer Programming aspect of Simulation:* The computer programming aspects of simulation receive special emphasis. Students who take a course based on this text will be expected to have had a least one entry-level computer programming course; however, even with this background most students are woefully ill-prepared to use computers to solve problems. The theory-based textbooks do not cover this material and the simulation package textbooks attempt to downplay the programming aspects of their environment so that the modeling environment appears attractive to non–computer-oriented users. This book is intended to enable students to understand the inner workings of the simulation environment and thus demystify the "black box." The language elements of the simulation environment are compared to standard computer language elements so that students can make the appropriate analogies to already studied material.
- *Language-independent Conceptual Modeling Process:* While Arena is the modeling tool, the conceptual modeling process presented in the text is based on language-independent methods, including but not limited to rich picturing, elementary flow charting, activity diagramming, and pseudo-code development. The emphasis is placed on developing a specification for a model that could be implemented in any simulation language environment.
- *Classic Stochastic Models:* Classic stochastic models from operations research are covered. One chapter is dedicated to queuing and inventory models. In many curricula, if the analytical models are presented, they will be taught in a different course. In my opinion, the simulation of classic models along with their analytical treatment can provide for deeper student learning on these topics. In addition, the presentation of these classic models both analytically and through simulation provides simple systems on which to build the teaching of complex, more practical extensions.
- *Examples and Exercises:* Comprehensive examples, exercises, questions, and problem sets were developed from the author's teaching, research, and industrial experiences.
- *Arena Software:* The CD that accompanies the text contains the student version of Arena. In addition, the chapter files (e.g., Arena and Excel) are provided on the disk. You can access/retrieve these files by browsing to the "Manuel Rossetti Supporting Files" folder when the CD is in your computer's optical drive.

Student Resources

The following resources are available on the book website at www.wiley.com/college/rossetti:

- The chapter files (e.g., Arena and Excel).
- Appendix Files as PDF for handy reference.

Instructor Resources

The following resources are available on the instructor section of the book website at www.wiley.com/college/rossetti. Please visit the website to register for a password to access these resources:

- The chapter files (e.g., Arena and Excel) are provided on a disk.
- Lecture Slides: A comprehensive set of Powerpoint slides are for instructors to use within the classroom.

- Sample Syllabus
- Solutions Manual: Detailed or outlined solutions for the exercises in the text are available including the Arena model files where appropriate.
- Image Gallery: All illustrations from the text in electronic format, appropriate for inclusion in lecture slides.

Course Syllabus Suggestion

Early versions of the manuscript for this textbook were used over many semesters in my course at the University of Arkansas. The course that I teach is geared toward junior/senior, undergraduate industrial engineering students. In addition, graduate students who have not yet had a course in simulation enroll in the course. Graduate students are given extra homework assignments and are tested on some of the more theoretical aspects presented in the text (e.g., acceptance/rejection). I am able to cover Chapters 1 through 7 during a typical 16-week semester offering. A typical topic outline follows:

Number of lectures	Topic	Reading
1	Introduction	Chapter 1
4	Basic process modeling	Chapter 2
2	Input modeling	Chapter 3
2	Random number generation	Chapter 3
2	Random variate generation	Chapter 3
2	Finite horizon simulation	Chapter 4
3	Infinite horizon simulation	Chapter 4
2	Comparing alternatives	Chapter 4
4	Queuing and Inventory models	Chapter 5
5	Entity transfer and material handling constructs	Chapter 6
3	Miscellaneous topics in Arena modelling	Chapter 7

I use two exams and a project in the course. Exam 1 covers Chapters 1 to 3 and finite-horizon simulation from Chapter 4. Exam 2 covers the remaining portion of Chapter 4 plus Chapters 5 and 6. I do not formally test the students on the material in Chapter 7 since they will be using all previously learned material and components of Chapter 7 when preparing their final project. Students are assigned homework throughout the semester (about eight assignments). In addition to formal lectures, my course has a computer-based laboratory component that meets 1 day per week. During this time, the students are required to work on computer-based assignments that are based on the examples in the textbook.

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About the Author

Manuel D. Rossetti, Ph.D., P.E., is an associate professor in the Industrial Engineering Department at the University of Arkansas. He received his doctorate in industrial and systems engineering from The Ohio State University. He has published over 70 journal and conference articles in the areas of transportation, manufacturing, health care, and simulation, and he has obtained over $3.1 million in extramural research funding. His research interests include the design, analysis, and optimization of manufacturing, health care, and transportation systems using stochastic modeling, computer simulation, and operations research techniques. He teaches courses in the areas of simulation, transportation and logistics, database systems, and inventory management. He was selected as a Lilly Teaching Fellow in 1997/1998 and has been nominated three times for outstanding teaching awards. He serves as an associate editor for the *International Journal of Modeling and Simulation*, and is active in the Institute of Industrial Engineers, the Institute for Operations Research and Management Science, and the American Society for Engineering Education. He served as co-editor for the 2004 Winter Simulation Conference, and will be co-editor for the 2009 Winter Simulation Conference.

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