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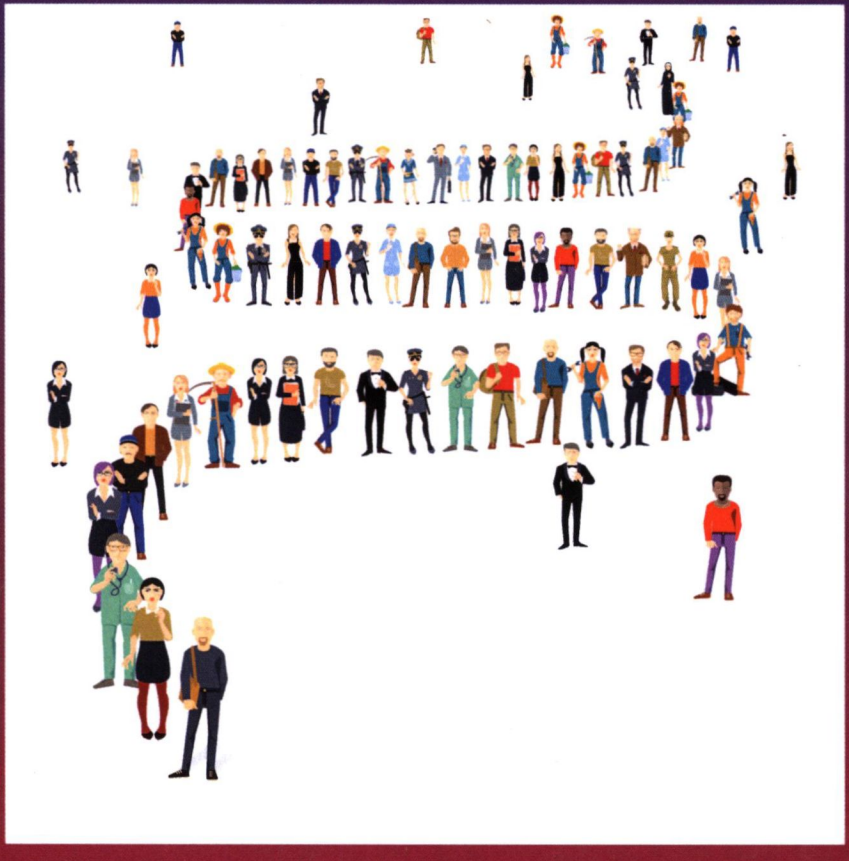
Computer Simulation

A Foundational Approach Using Python



Yahya E. Osais

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Computer simulation is an effective and popular universal tool that can be applied to almost all disciplines. Requiring only basic knowledge of programming, mathematics, and probability theory, **Computer Simulation: A Foundational Approach Using Python** offers a straightforward perspective of programming to introduce the fundamentals of computer simulation.

Typically, simulation involves two key steps: modeling and implementation. In this book, these processes are divided to minimize confusion and help introductory students grasp the transition to stochastic simulation. Modeling is covered in the first half of each chapter and is presented with event graphs and design of experiments. Then, as a tool of choice for scientists and engineers, Python programs are used throughout the book to help students implement their knowledge. The chapters are aided by a heavy use of illustrations, and many examples are provided to re-enforce the concepts presented. The book also features a full chapter of case studies, as well as real working code, encouraging students to compare results obtained from simulation with those obtained using analytical methods. Additionally, most of the necessary mathematics is abstracted by procedures that show how the mathematical techniques can be implemented in the real world. This helps make the shift from models to programs straightforward.

Some other features of this book are:

- Simulation programs are divided into two distinct components: simulator and model
- Both simulation without an event list and with an event list are covered
- The single-queue single-server queuing system is used as a running example throughout the book
- A complete chapter on the Monte Carlo method and variance-reduction techniques are included

The main target of the book is computer science and engineering students who are interested mainly in directly applying the techniques to their research problems. The book will be of great interest to senior undergraduate and starting graduate students in the fields of computer science and engineering and industrial engineering.

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6000 Broken Sound Parkway, NW
Suite 300, Boca Raton, FL 33487
711 Third Avenue
New York, NY 10017
2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN, UK

K25849
ISBN: 978-1-4987-2682-5
90000
9 781498 726825
www.crcpress.com

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

A CHAPMAN & HALL BOOK

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

International Standard Book Number-13: 978-1-498-72682-5 (Hardback)

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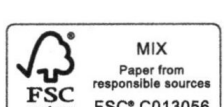

Printed and bound in Great Britain by
TJ International Ltd, Padstow, Cornwall

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To my wife, Asmahan,
and my daughters, Renad, Retal, and Remas.

Foreword

Computer simulation is an effective and popular universal tool. It can be applied to almost all disciplines. Typically, simulation involves two key steps: modeling and implementation, which are highlighted in this book. Modeling can performed using event graphs, which are revived by this book. As for implementation, complete Python programs are given, which is considered a new effort. This is an interesting combination as the translation process from models to programs is straightforward.

The book also dedicates a complete chapter on the popular Monte Carlo simulation method. This chapter covers several variance-reduction techniques along with their implementation in Python. Three interesting case studies are discussed in detail. The book features good examples and exercises for readers and students.

This book is highly recommended for a graduate course in modeling and simulation. It is also recommended for an introductory course in modeling and simulation for a senior undergraduate course. In addition, it can be a good reference for researchers and working engineers and scientists who work on modeling and simulation and optimization. This book is a good addition to the field of modeling and simulation. I hope you will enjoy the book as much as I have enjoyed reviewing it.

Mohammad S. Obaidat, Fellow of IEEE and Fellow of SCS
Past President of the Society for Modeling and Simulation International, SCS
Founding Editor in Chief, Security and Privacy Journal, Wiley
Editor-in-Chief, International Journal of Communication Systems
June 2017

Preface

This book is not just another book on discrete-event simulation. It emphasizes modeling and programming without sacrificing mathematical rigor. The book will be of great interest to senior undergraduate and starting graduate students in the fields of computer science and engineering and industrial engineering. The book is designed for a one-semester graduate course on computer simulation. Each chapter can be covered in about one week. The instructor is also encouraged to dedicate one week for learning the Python programming language. Appendix A can be used for this purpose. A basic knowledge of programming, mathematics, statistics, and probability theory is required to understand this book.

The book has the following features. First, a simulation program is clearly divided into two parts: simulator and model. In this way, implementation details based on a specific programming language will not coexist with the modeling techniques in the same chapter. As a result, student confusion is minimized. The second feature of the book is the use of the Python programming language. Python is becoming the tool of choice for scientists and engineers due to its short learning curve and many open-source libraries. In addition, Python has a REPL[1] which makes experimentation much faster. The third feature is the use of event graphs for building simulation models. This formalism will aid students in mastering the important skill of simulation modeling. A complete chapter is dedicated to it. The book also features a complete chapter on the Monte Carlo method and variance-reduction techniques. Several examples are given along with complete programs.

The book is divided into four parts. The first part represents a complete course on the fundamentals of discrete-event simulation. It is comprised of chapters 1 to 6. This first part is appropriate for an undergraduate course on discrete-event simulation. Materials from other chapters can be added to this course. For example, chapter 10 and 11 should be covered in full if time permits. For an advanced course on computer simulation, the second and third part should be fully covered. The case studies in the fourth part can be covered if time permits. In such a course, the emphasis should be on model building and programming.

[1] REPL = Read-Evaluate-Print Loop

To the Reader

While writing this book, I had assumed that nothing is obvious. Hence, all the necessary details that you may need are included in the book. However, you can always skip ahead and return to what you skip if something is not clear. Also, note that throughout this book, "he" is used to to refer to both genders. I find the use of "he or she" disruptive and awkward. Finally, the source code is deliberately inefficient and serves only as an illustration of the mathematical calculation. Use it at your own risk.

Website

The author maintains a website for the book. The address is `http://faculty.kfupm.edu.sa/coe/yosais/simbook`. Presentations, programs, and other materials can be downloaded from this website. A code repository is also available on Github at `https://github.com/yosais/Computer-Simulation-Book`.

Acknowledgments

I would like to thank all the graduate students who took the course with me while developing the material of the book between 2012 and 2017. Their understanding and enthusiasm were very helpful.

I would also like to thank King Fahd University of Petroleum and Minerals (KFUPM) for financially supporting the writing of this book through project number **BW151001**.

Last but not least, I would like to thank my wife for her understanding and extra patience.

Yahya Osais
Dhahran, Saudi Arabia
2017

About the Author

Yahya E. Osais is a faculty member in the department of computer engineering at King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. He earned his B.Sc. and M.Sc. from the same department in 2000 and 2003, respectively. In 2010, he obtained his Ph.D. from the department of systems and computer engineering at Carleton University, Ontario, Canada.

Dr. Osais regularly teaches a graduate course in computer simulation for students in the college of computer science and engineering at KFUPM. He also teaches courses on computer engineering design and web technologies. His current research interest includes stochastic modeling and simulation, cyber-physical systems, and the Internet of things.