Devendra K. Chaturvedi

Modeling and Simulation of Systems Using MATLAB® and Simulink®

CRC Press
Taylor & Francis Group

Modeling and Simulation of Systems Using MATLAB® and Simulink®

Devendra K. Chaturvedi

CRC Press
Taylor & Francis Group
Boca Raton London New York

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

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

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number: 978-1-4398-0672-2 (Hardback)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

Modeling and Simulation of Systems Using MATLAB® and Simulink®

Dedicated to

The cherished memories of my guru and guide

Most Revered Dr. Makund Behari Lal Sahab

DSc (Lucknow), DSc (Edinburgh)

(1907–2002)

August Founder of Dayalbagh Educational Institute

Preface

Systems engineering has great potential for solving problems related to physical, conceptual, and esoteric systems. The power of systems engineering lies in the three R's of science, namely, reductionism, repeatability, and refutation. Reductionism recognizes the fact that any system can be decomposed into a set of components that follow the fundamental laws of physics. The diversity of the real world can be reduced into laboratory experiments, which can be validated by their repeatability, and one can make intellectual progress by the refutation of hypotheses. Due to advancements in systems engineering for handling complex systems, modeling and simulation have, of late, become popular.

Modeling and simulation are very important tools of systems engineering that have now become a central activity in all disciplines of engineering and science. Not only do they help us gain a better understanding of the functioning of the real world, they are also important for the design of new systems as they enable us to predict the system behavior before the system is actually built. Modeling and simulation also allow us to analyze systems accurately under varying operating conditions.

This book aims to provide a comprehensive, state-of-the-art coverage of all important aspects of modeling and simulation of physical as well as conceptual systems. It strives to motivate beginners in this area through the modeling of real-life examples and their simulation to gain better insights into real-world systems. The extensive references and related literature at the end of every chapter can also be referred to for further studies in the area of modeling and simulation.

This book aims to

- Provide a basic understanding of systems and their modeling and simulation
- Explain the step-by-step procedure for modeling using top-down, bottom-up, and middle-out approaches
- Develop models for complex systems and reduce their order so as to use them effectively for online applications
- Present the simulation code in MATLAB®/Simulink® for gaining quick and useful insights into real-world systems
- Apply soft computing techniques for modeling nonlinear, ill-defined, and complex systems

The book will serve as a primary text for a variety of courses. It can be used as a first course in modeling and simulation at the junior, the senior, or the graduate levels in engineering, manufacturing, business, or computer science (Chapters 1 through 3, 5, and 8), providing a broad idea about modeling and simulation. At the end of such a course, the student would be prepared to carry out complete and effective simulation studies, and to take advanced modeling and simulation courses.

This book will also serve as a second course for more advanced studies in modeling and simulation for graduate students (Chapters 6 through 11) in any of the above disciplines. After completing this course, the student should be able to comprehend and conduct simulation research.

Finally, this book will serve as an introduction to simulation as part of a general course in operations research or management science (Chapters 1 through 3 and 6 through 8, Chapter 12).

Organization of the Book

Early chapters deal with the introduction of systems and includes concepts and their underlying philosophy; step-by-step procedures for the modeling of different types of systems using appropriate modeling techniques such as the graph-theoretic approach, interpretive structural modeling, and system dynamics modeling, are also discussed.

Focus then moves to the state of the art of simulation and how simulation evolved from the pre-computer days into the modern science of today. In this part, MATLAB/Simulink programs are developed for system simulation.

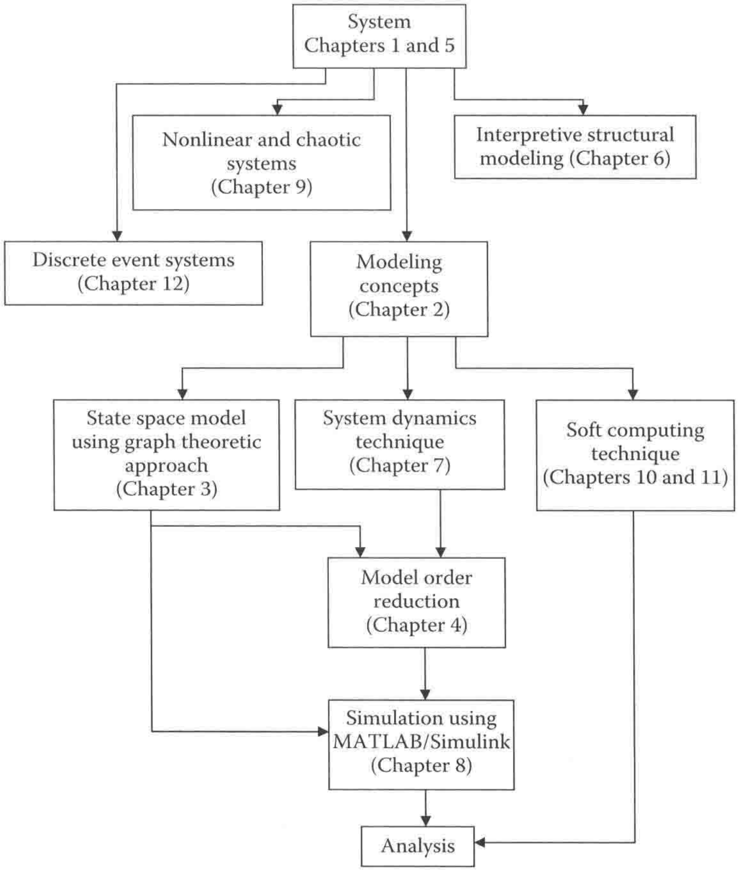


FIGURE P1
Schematic outline of the book.

We then take a fresh look at modern soft computing techniques (such as artificial neural networks [ANN], fuzzy systems, and genetic algorithms, or their combinations) for the modeling and simulation of complex and nonlinear systems.

Finally, chapters address the discrete systems modeling. The schematic outline of this book is shown in Figure P1.

Software Background

The key to the successful application of modeling and simulation techniques depends on the effective use of their software. For this, it is necessary that the student be familiar with their fundamentals. In this book, MATLAB/Simulink programming software are used. Appendix B provides some background information on MATLAB/Simulink. The MATLAB programs included in this book are easier to understand than the programs written in other programming languages such as C/C++.

MATLAB® is a registered trademark of The MathWorks, Inc. For product information, please contact:

The MathWorks, Inc.
3 Apple Hill Drive
Natick, MA 01760-2098 USA
Tel: 508 647 7000
Fax: 508-647-7001
E-mail: info@mathworks.com
Web: www.mathworks.com

Acknowledgments

I express my profound and grateful veneration to Prof. P. S. Satsangi, chairman, advisory committee on education in the Dayalbagh Educational Institute, Agra, Uttar Pradesh, India. Prof. Satsangi taught me modeling and simulation methodologies, and software engineering at the postgraduate (MTech) level and guided me during my MTech and PhD in the area of modeling and simulation. He is the fountain source of my inspiration and intuition in this area. I thank him with due reverence. I am also thankful to Prof. P. K. Kalra, Indian Institute of Technology, Kanpur, India, for the encouragement, support, and visionary ideas he provided during my research. I am very deeply indebted to Prof. O. P. Malik, University of Calgary, Alberta, Canada, for providing all the facilities in his laboratory to pursue my experimental work on modeling and control during my BOYSCAST (Better Opportunities for Young Scientists in Chosen Areas of Science and Technology) fellowship, offered by the Department of Science and Technology, Government of India, during 2001–2002, and, later, in the summer of 2005 and 2007.

I wish to express my deep gratitude to Prof. Helmut Röck and Prof. Anand Srivastava, Universitate Zu Kiel, Kiel, Germany, and to Prof. Chaudhary, Imperial College London, United Kingdom, for providing all the facilities and help during my visit to these institutions in the summer of 2007.

I would also like to thank Prof. Westwick and Garwin Hancock, University of Calgary, Alberta, Canada; Prof. P.H. Roe, system design engineering, and Prof. Shesha Jayaram, High Voltage Lab, University of Waterloo, Ontario, Canada; and S. Krishnananda at the Dayalbagh Educational Institute, Agra, Uttar Pradesh, India, for their good wishes and help extended during the preparation of this book. Thanks are also due to my colleagues Anand Sinha, Gaurav Rana, Himanshu Vijay, and Ashish Chandiok for all their help.

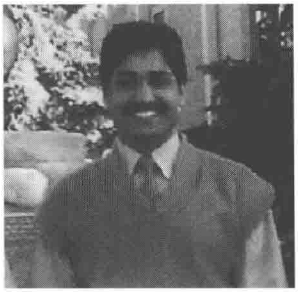
I am thankful to Jessica Vakili and Amber Donley, project coordinators; Nora Konopka, publisher of engineering and environmental science books; and other team members from Taylor & Francis who directly or indirectly helped in realizing this book.

Finally, I am grateful to my wife, Dr. Lajwanti, and my daughters, Jyoti and Swati, who had to endure many inconveniences during the course of writing this book.

I also express my deepest gratitude to many, not mentioned here, for their support in countless ways when this book was written.

Devendra K. Chaturvedi
Dayalbagh Educational Institute (Deemed University)
Agra, Uttar Pradesh, India

Author



Devendra K. Chaturvedi was born in Madhya Pradesh, India, on August 3, 1967. He graduated in electrical engineering from the Government Engineering College, Ujjain, Madhya Pradesh, India in 1988, and did his MTech in engineering systems and management in 1993. He then pursued his PhD in electrical power systems in 1998 from the Dayalbagh Educational Institute (Deemed University), Agra, India. Currently, he is working as a professor in the Department of Electrical Engineering, Dayalbagh Educational Institute (Deemed University). He has won several awards and recognition including the President's Gold Medal and the Director's Medal of the Dayalbagh Educational Institute (Deemed University) in 1993, the Tata Rao Medal in 1994, the Dr. P. S. Nigam U.P. State Power Sector Award in 2005 and 2007, the Musaddi Lal Memorial Award in 2007, and the institutional prize award in 2005 from the Institution of Engineers, India. He was awarded a BOYSCAST fellowship of the Department of Science and Technology, Government of India, in 2001.

He is a regular visiting fellow at the University of Calgary, Alberta, Canada. He has many national and international research collaborations in the area of modeling and simulations, soft computing, intelligent adaptive control systems, and optimization. He has also organized many short-term courses in the area of modeling and simulation of systems, and fuzzy systems and its applications. He serves as a consultant at the Aerial Delivery Research and Development Establishment, Agra, and at the Defense Research and Development Organisation (DRDO) lab, Government of India. He has organized many national seminars and workshops on theology; ethics, values, and social service; professional ethics; ethics, agriculture, and religion; the relationship between religion and the future of mankind; and the teachings of the *Bhagavad Gita* and the religions of saints.

He has authored a book, *Soft Computing and Its Applications to Electrical Engineering*, published by Springer, Germany (2008). He has also edited a book, *Theology, Science, and Technology: Ethics and Moral Values*, published by Vikas Publishing House, Delhi (2005).

His name is included in the *Marquis Who's Who in Engineering and Science* in Asia (2006–2007), the *Marquis Who's Who in Engineering and Science* in America (2006–2007), and the *Marquis Who's Who in World* (2006–2007). He is a fellow of the Institution of Engineers, India, and a member of many professional bodies such as the IEEE, the IEE, the Indian Society for Technical Education (ISTE), the Indian Society of Continuing Engineering Education (ISCEE), the Aeronautical Society of India, and the System Society of India.

Contents