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离散事件系统仿真

（英文版 · 第4版）

DISCRETE-EVENT SYSTEM SIMULATION

FOURTH EDITION

JERRY BANKS · JOHN S
BARRY L. NELSON · DAV

（美） Jerry Banks
John S. Carson II
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机械工业出版社
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出版者的话

文艺复兴以降，源远流长的科学精神和逐步形成的学术规范，使西方国家在自然科学的各个领域取得了垄断性的优势；也正是这样的传统，使美国在信息技术发展的六十多年间名家辈出、独领风骚。在商业化的进程中，美国的产业界与教育界越来越紧密地结合，计算机学科中的许多泰山北斗同时身处科研和教学的最前线，由此而产生的经典科学著作，不仅擘划了研究的范畴，还揭橥了学术的源变，既遵循学术规范，又自有学者个性，其价值并不会因年月的流逝而减退。

近年，在全球信息化大潮的推动下，我国的计算机产业发展迅猛，对专业人才的需求日益迫切。这对计算机教育界和出版界都既是机遇，也是挑战；而专业教材的建设在教育战略上显得举足轻重。在我国信息技术发展时间较短、从业人员较少的现状下，美国等发达国家在其计算机科学发展的几十年间积淀的经典教材仍有许多值得借鉴之处。因此，引进一批国外优秀计算机教材将对我国计算机教育事业的发展起积极的推动作用，也是与世界接轨、建设真正的世界一流大学的必由之路。

机械工业出版社华章图文信息有限公司较早意识到“出版要为教育服务”。自1998年开始，华章公司就将工作重点放在了遴选、移译国外优秀教材上。经过几年的不懈努力，我们与Prentice Hall，Addison-Wesley，McGraw-Hill，Morgan Kaufmann等世界著名出版公司建立了良好的合作关系，从它们现有的数百种教材中甄选出Tanenbaum，Stroustrup，Kernighan，Jim Gray等大师名家的一批经典作品，以“计算机科学丛书”为总称出版，供读者学习、研究及庋藏。大理石纹理的封面，也正体现了这套丛书的品位和格调。

“计算机科学丛书”的出版工作得到了国内外学者的鼎力襄助，国内的专家不仅提供了中肯的选题指导，还不辞劳苦地担任了翻译和审校的工作；而原书的作者也相当关注其作品在中国的传播，有的还专程为其书的中译本作序。迄今，“计算机科学丛书”已经出版了近百个品种，这些书籍在读者中树立了良好的口碑，并被许多高校采用为正式教材和参考书籍，为进一步推广与发展打下了坚实的基础。

随着学科建设的初步完善和教材改革的逐渐深化，教育界对国外计算机教材的需求和应用都步入一个新的阶段。为此，华章公司将加大引进教材的力度，在“华章教育”的总规划之下出版三个系列的计算机教材：除“计算机科学丛书”之外，对影印版的教材，则单独开辟出“经典原版书库”；同时，引进全美通行的教学辅导书“Schaum's Outlines”系列组成“全美经典学习指导系列”。为了保证这三套丛书的权威性，同时也为了更好地为学校和老师们服务，华章公司聘请了中国科学院、北京大学、清华大学、国防科技大学、复旦大学、上海交通大学、南京大学、浙江大学、中国科技大学、哈尔滨工业大学、西安交通大学、中国人民大学、北京航空航天大学、北京邮电大学、中山大学、解放军理工大学、郑州大学、湖北工学院、中国国家信息安全测评认证中心等国内重点大学和科研机构在计

算机的各个领域的著名学者组成“专家指导委员会”，为我们提供选题意见和出版监督。

这三套丛书是响应教育部提出的使用外版教材的号召，为国内高校的计算机及相关专业的教学度身订造的。其中许多教材均已为M. I. T.，Stanford，U.C. Berkeley，C. M. U.等世界名牌大学所采用。不仅涵盖了程序设计、数据结构、操作系统、计算机体系结构、数据库、编译原理、软件工程、图形学、通信与网络、离散数学等国内大学计算机专业普遍开设的核心课程，而且各具特色——有的出自语言设计者之手、有的历经三十年而不衰、有的已被全世界的几百所高校采用。在这些圆熟通博的名师大作的指引之下，读者必将在计算机科学的宫殿中由登堂而入室。

权威的作者、经典的教材、一流的译者、严格的审校、精细的编辑，这些因素使我们的图书有了质量的保证，但我们的目标是尽善尽美，而反馈的意见正是我们达到这一终极目标的重要帮助。教材的出版只是我们的后续服务的起点。华章公司欢迎老师和读者对我们的工作提出建议或给予指正，我们的联系方法如下：

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Preface

The objective of the text is to provide a basic treatment of all of the important aspects of discrete-event simulation, with particular emphasis on applications in manufacturing, services, and computing. The fourth edition, like earlier editions, is meant for an upper-level-undergraduate or master's-level introduction to simulation or for a second course with applications. We have updated the material extensively, revised some chapters completely, and added a new chapter on the simulation of computer networks. The associated website `www.bcnn.net` is now closely integrated with the text, and all students and instructors should visit the site.

Chapter 1, *Introduction to Simulation*, has been generally updated, and every example in Chapter 2, *Simulation Examples*, has an Excel spreadsheet solution on the website. Exercises have been prepared that require downloading these spreadsheet solutions and using them. To reflect the continuing evolution of simulation software, Chapter 3, *General Principles*, has been modernized to include properties and operations of current simulation languages; in Chapter 4, *Simulation Software*, simulation in Java replaces C++. We also have maintained an up-to-date discussion of the features of currently available simulation software. Simulation software changes so rapidly, however, that we point to the websites of all of the software vendors mentioned in the text.

Chapter 5, *Statistical Models in Simulation*, incorporates some additional models: the beta and negative binomial distributions and the nonstationary Poisson process. These are backed up by new material on simulating (Chapter 8, *Random-Variate Generation*) and fitting (Chapter 9, *Input Modeling*) the models. For clarity, Chapter 8 has been substantially reorganized. In Chapter 7, *Random-Number Generation*, we have deemphasized statistical testing of random-number generators since the period length of modern generators has become so long that sampling-based tests are no longer feasible.

Chapter 10, *Verification and Validation*, replaces hypothesis testing by a confidence-interval approach for input–output validation.

The core chapters on the analysis of simulation output are Chapter 11, *Output Analysis for a Single Model*, and Chapter 12, *Comparison and Evaluation of Alternative System Designs*. Chapter 11 has been significantly reorganized, and there is new material on prediction intervals and on estimating probabilities and quantiles from only summary statistics. Chapter 12 contains a new procedure for screening a large number of system designs to extract a smaller group of the best.

Chapter 13, *Simulation of Manufacturing and Material-Handling Systems*, adds an extended example and analysis of a small manufacturing system.

Chapter 14, *Simulation of Computer Systems*, replaces the discussion of C++ simulation tools for computer simulation with one focused on Java in general and on the SSFNet simulator in particular. Chapter 15, *Simulation of Computer Networks*, is new. The website has examples (in Java) of simulations discussed in this Chapter and provides extensive links to supporting material.

Discrete-Event System Simulation can serve as a textbook in the following types of courses:

1. An introductory simulation course in engineering, computer science, or management (Chapters 1–9 and selected parts of Chapters 10–12 when no companion language text is used; if a companion language text is used, skip Chapter 4, and use the application Chapters 13, 14, and 15, as appropriate);
2. A second course in simulation (all of Chapters 10–12, a companion language text, and an outside project; add Chapter 13, 14, or 15, as appropriate)

We gratefully acknowledge the cheerful aid of Gamze Tokol and Dave Goldsman in converting some of the chapters to LaTeX for those coauthors who do not speak the language, and the assistance of Feng Yang, who checked the references and exercises in many chapters.

JERRY BANKS
JOHN S. CARSON II
BARRY L. NELSON
DAVID M. NICOL

About the Authors

Jerry Banks retired in 1999 as a professor in the School of Industrial and Systems Engineering, Georgia Institute of Technology, after which he worked as senior simulation technology advisor for Brooks Automation; he is currently an independent consultant. He is the author, coauthor, editor, or coeditor of eleven books, one set of proceedings, several chapters in texts, and numerous technical papers. He is the editor of the *Handbook of Simulation*, published in 1998 by John Wiley, which won the award for Excellence in Engineering Handbooks from the Professional Scholarly Publishing Division of the Association of American Publishers, Inc. He is also author or coauthor of *Getting Started with AutoMod*, Second Edition, *Introduction to SIMAN V and CINEMA V*, *Getting Started with GPSS/H*, Second Edition, *Forecasting and Management of Technology* and *Principles of Quality Control*. He was a founding partner in the simulation-consulting firm Carson/Banks & Associates, Inc., which was purchased by AutoSimulations, Inc. (now part of Brooks Automation). He is a full member of many technical societies, among them the Institute of Industrial Engineers (IIE); he served eight years as that organization's representative to the Board of the Winter Simulation Conference, including two years as board chair. He is the recipient of the INFORMS College on Simulation Distinguished Service Award for 1999 and was named a fellow of IIE in 2002.

John S. Carson II is the consulting technical manager for the AutoMod Group at Brooks Automation. He has over 28 years experience in simulation in a wide range of application areas, including manufacturing, distribution, warehousing and material handling, transportation and rapid transit systems, port operations (container terminals and bulk handling), and health-care systems. Currently, he is involved in the design of next-generation simulation products and in the development of tools to speed up model development for semi-conductor manufacturing, distribution centers, container terminals and other areas of special interest. He co-founded and managed an

independent simulation services company for 8 years, has been an independent simulation consultant, and has taught at the Georgia Institute of Technology, the University of Florida, and the University of Wisconsin-Madison.

Barry L. Nelson is the James N. and Margie M. Krebs Professor in the Department of Industrial Engineering and Management Sciences at Northwestern University and is director of the Master of Engineering Management Program there. His research centers on the design and analysis of computer-simulation experiments on models of stochastic systems, concentrating on multivariate input modeling and output analysis and on optimization via simulation. He has published numerous papers and two books. He has served as the simulation area editor of *Operations Research* and as president of the INFORMS (then TIMS) College on Simulation, and he has held many positions for the annual Winter Simulation Conference, including program chair in 1997 and board member currently.

David M. Nicol is professor of electrical and computer engineering at the University of Illinois at Urbana-Champaign. He is a long-time contributor in the field of parallel and distributed discrete-event simulations, having written one of the early Ph.D. dissertations on the topic. He has also worked in parallel algorithms, algorithms for mapping workload in parallel architectures, performance analysis, and reliability modeling and analysis. His research contributions extend to 150 articles in leading computer-science journals and conferences. His research is driven largely by problems encountered in industry and government—he has worked closely with researchers at NASA, IBM, AT&T, Bellcore, Motorola, and the Los Alamos, Sandia, and Oak Ridge National Laboratories. His current interests lie in modeling and simulation of very large systems, particularly communications and other infrastructure, with applications in evaluating system security. From 1997 to 2003 he was the editor-in-chief of the *ACM Transactions on Modeling and Computer Simulation*. Professor Nicol is a Fellow of the IEEE.

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