国外著名高等院校
信息科学与技术优秀教材

计算机科学概论
（第六版）

computer science
an overview , sixth edition

j. glenn brookshear

英文版

人民邮电出版社
www.pptph.com.cn

ADDISON WESLEY
Pearson Education
出 版 集 团

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图书在版编目（CIP）数据

计算机科学概论：第6版/（美）布鲁克希尔（Brookshear，J. G.）著.
—北京：人民邮电出版社，2002.1
国外著名高等院校信息科学与技术优秀教材
ISBN 7-115-09917-0

Ⅰ. 计… Ⅱ. 布… Ⅲ. 电子计算机—高等学校—教材—英文 Ⅳ. TP3

中国版本图书馆CIP数据核字（2001）第090605号

国外著名高等院校信息科学与技术优秀教材

计算机科学概论（第六版）

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◆ 著　　J.Glenn Brookshear
责任编辑　李　际

◆ 人民邮电出版社出版发行　北京市崇文区夕照寺街14号
邮编　100061　　电子函件　315@ pptph.com.cn
网址　http://www.pptph.com.cn
读者热线　010-67129212　010-67129211（传真）
北京汉魂图文设计有限公司制作
北京朝阳展望印刷厂印刷
新华书店总店北京发行所经销

◆ 开本：800×1000　1/16
印张：39.25
字数：775千字　　2002年1月第1版
印数：1－3 000册　　2002年1月北京第1次印刷

著作权合同登记　图字：01－2001－4832号
ISBN 7-115-09917-0/TP·2650

定价：49.00元

本书如有印装质量问题，请与本社联系　电话：（010）67129223

内 容 提 要

本书通过四部分介绍了计算机科学方面的知识：计算机硬件、软件、数据组织和计算理论等。本书还包含了数据压缩、算法分析、网络安全、设计模式、面向对象数据库系统、遗传算法和公开密钥加密等新内容。本书对这些内容的论述深浅适当，文字通俗易懂而又保持简练和准确；每一节都带有精心挑选的习题；给出的插图也颇具匠心，能够很好地表现书中阐述的内容。

本书可作为计算机科学专业的教材，也适合于其它专业的师生使用。

出版说明

2001 年，教育部印发了《关于“十五”期间普通高等教育教材建设与改革的意见》。该文件明确指出，“九五”期间原国家教委在“抓好重点教材，全面提高质量”方针指导下，调动了各方面的积极性，产生了一大批具有改革特色的新教材。然而随着科学技术的飞速发展，目前高校教材建设工作仍滞后于教学改革的实践，一些教材内容陈旧，不能满足按新的专业目录修订的教学计划和课程设置的需要。为此该文件明确强调，要加强国外教材的引进工作。当前，引进的重点是信息科学与技术和生物科学与技术两大学科的教材。要根据专业（课程）建设的需要，通过深入调查、专家论证，引进国外优秀教材。要注意引进教材的系统配套，加强对引进教材的宣传，促进引进教材的使用和推广。

邓小平同志早在 1977 年就明确指出：“要引进外国教材，吸收外国教材中有益的东西。”随着我国加入 WTO，信息产业的国际竞争将日趋激烈，我们必须尽快培养出大批具有国际竞争能力的高水平信息技术人才。教材是一个很关键的问题，国外的一些优秀教材不但内容新，而且还提供了很多新的研究方法和思考方式。引进国外原版教材，可以促进我国教学水平的提高，提高学生的英语水平和学习能力，保证我们培养出的学生具有国际水准。

为了贯彻中央“科教兴国”的方针，配合国内高等教育教材建设的需要，人民邮电出版社约请有关专家反复论证，与国外知名的教材出版公司合作，陆续引进一些信息科学与技术优秀教材。第一批教材针对计算机专业的主干核心课程，是国外著名高等院校所采用的教材，教材的作者都是在相关领域享有盛名的专家教授。这些教材内容新，反映了计算机科学技术的最新发展，对全面提高我国信息科学与技术的教学水平必将起到巨大的推动作用。

出版国外著名高等院校信息科学与技术优秀教材的工作将是一个长期的、坚持不懈的过程，我社网站（www.pptph.com.cn）上介绍了我们首批陆续推出的图书的详细情况，后续教材的引进和出版情况我们会及时在网上发布，敬请关注。希望广大教师和学生将使用中的意见和建议及时反馈给我们，我们将根据您的反馈不断改进我们的工作，推出更多更好的引进版信息科学与技术教材。

人民邮电出版社

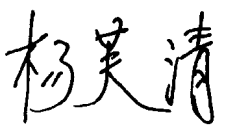
2001 年 12 月

序　言

在计算机学科的大学教育中，有一门重要的课程，即该学科各专业的学生都必须学习的一门专业基础课，在我国一般称作“计算机概论”。学生从中学进入大学，开始正规而系统地学习计算机专业课程，需要首先对计算机科学技术的基础知识有一个概括而准确的了解，否则其它任何一门专业课的教学都会遇到许多障碍。所以这门课程对于计算机软件与理论、计算机体系结构、计算机应用技术等专业的教学都是非常重要的。

J．Glenn Brookshear 著的《计算机科学概论》（Computer Science：an Overview）就是这样一本适合作为上述课程教材的好书。该书在美国哈佛大学、加州大学等各所大学被采用。自第一版之后，作者根据计算机科学技术的新发展不断地对该书进行更新和补充，目前已经出到第 6 版。书中介绍了计算机硬件、软件、数据组织和计算理论等四个方面的内容。对这些内容的论述深浅适当，文字通俗易懂而又保持简练和准确；每一节都带有精心挑选的习题；给出的插图也颇具匠心，能够很好地表现书中阐述的内容。总之，这是一本很值得引进和推广的好教材。

在我国，改革开放以来计算机科学技术的学科建设和教材建设一直在稳步发展。各高校的教师为此付出了大量心血，写作出版了许多高质量的教材。其中有许多教材不但具有很好的学术水平，而且适合我国的国情与文化背景。同时，学习和借鉴国际上先进的科学技术和优秀文化，是培养人才的需要。有选择地引进国外的优秀教材，必将有效地促进我国教育事业的健康发展。这本书的影印出版，将对我国的计算机专业基础课的教学和教材建设起到良好的作用。它也可以用于非计算机专业的计算机教学和面向计算机产业界的技术培训。



中国科学院　院士
北京大学　信息与工程科学学部　主任

To my parents
Garland and Reba Brookshear

PREFACE

This book presents an introduction to the science of computing. It reveals the breadth of the subject while including enough depth to convey an honest appreciation for the topics involved. I wrote the text with two audiences in mind.

Computer Science Majors

The first audience consists of computer science majors in the early stages of their academic careers. Students at this stage tend to equate computer science with programming and Web browsing because that is essentially all they have seen. Yet computer science is much more than this. In turn, beginning computer science students need exposure to the breadth of the subject in which they are planning to major. Providing this exposure is the purpose of this book. It gives students an overview of computer science—a foundation from which they can appreciate the relevance and interrelationships of future courses in the field.

Students of Other Disciplines

I also designed this book for majors of other disciplines. A computer science course for nonmajors should provide a fundamental understanding of the entire field. Such a background gives students the ability to relate to the technical society in which they live and to continue to learn independently—a capability that is mandatory in today's rapidly changing environment. This is the model used for survey courses in the natural sciences, and this is the model on which

this book is designed. After taking a course based on this text, students will have an understanding of computer science that will continue to pay dividends well into the future.

Organization

The text follows a bottom-up approach that progresses from the concrete to the abstract—an order that results in a sound pedagogical presentation in which each topic leads to the next. Part 1 presents issues associated with hardware. It begins by explaining how information is represented and recorded in machines and how these techniques affect the machine's characteristics (Chapter 1). It then describes how machines manipulate data by means of machine language programs (Chapter 2).

In Part 2 the text advances to topics associated with software, beginning with how the activities of a machine are coordinated by an operating system and how this coordination of activities is expanding to incorporate entire networks and internetworks (Chapter 3). At this point students will have obtained a useful understanding of a typical computer system. In fact, Chapters 1 through 3 could be used as a text for a short course titled "What Every Savvy Computer User Should Know."

Part 2 continues by addressing issues of software development, including the topics of algorithm development and analysis (Chapter 4), programming languages and programming paradigms (Chapter 5), and software engineering (Chapter 6).

Part 3 expands on the ideas in Part 2 by considering the relationship between algorithms and data storage organizations. In particular, this part includes an introduction to data structures (Chapter 7), the rudiments of file storage (Chapter 8), and an overview of database systems (Chapter 9).

The plot culminates in Part 4 by investigating the ultimate capabilities of machines. This part begins with a chapter on artificial intelligence, which explores techniques used to produce computers that exhibit the ability to perceive and reason (Chapter 10). It closes by examining the constraints inherent in algorithmic systems and the boundaries that these constraints place on the capabilities of machines (Chapter 11).

In addition to this overall plot, there are several themes woven throughout the text. One is that computer science is dynamic. The text repeatedly presents topics in a historical perspective, discusses the state of the art, and indicates directions of current research. Another theme is the role of abstraction and the way in which abstract tools are used to control complexity. Indeed, even the book's organization reinforces this theme by presenting topics in an order of progressing abstraction—hardware provides abstract tools used by system software, and system software provides abstract tools used by application software.

To the Student

I was introduced to the field of computing during my tour in the US Navy back in the late 1960s and early 1970s. (Yes, that makes me old—but it will happen to you also.) I spent most of these Navy days maintaining the system software at the Navy's computer installation in London, England. After my tour was completed, I returned to school and finished my PhD in 1975. I've been teaching computer science and mathematics ever since.

A lot has changed in computer science over the years, but a lot has remained the same. In particular, computer science was, and still is, fascinating. There are a lot of awesome things going on out there. The development of the Internet, progress in artificial intelligence, and the ability to collect and disseminate information in unheard of proportions are only some of the things that will affect your life. You live in an exciting, changing world, and you have the opportunity to be a part of the action. Take it! The more you learn, the better prepared you will be. This book will provide a foundation, but it is not the end. Read it, and then read more. One of the most rewarding skills you can develop is the ability to learn on your own.

To the Instructor

There is more material in this text than can normally be covered in a single semester so do not hesitate to skip topics that do not fit your course objectives. I wrote the book to be used as a course resource—not as a course definition. You will find that, although the entire text follows a plot, the topics are covered in an independent manner that allows you to pick and choose as you desire. I have used asterisks in the table of contents at the beginning of each chapter to indicate those sections that I suggest as optional, but these are certainly not cast in stone. I also suggest that you consider covering some topics as reading assignments. I think we underrate students when we assume that we have to explain everything in class. I often assign an entire chapter as a reading assignment and then use class time to explain certain points or to expand portions of the text from my own experiences.

I have already explained that the text follows a bottom-up, concrete-to-abstract organization, but I want to expand on this a bit. As academics we too often assume that students will appreciate our perspective of a subject—often one that we have developed over years of working in a field. As teachers we do better by presenting material from the student's perspective. This is why the text starts with data representation/storage and builds from there. Today's students are familiar with magnetic disks, modems, and CDs, and I find that they respond to learning how these devices work. I see them discovering answers to many of their "why" questions and learning to view the course as practical rather than theoretical. From this beginning it is natural to investigate the software that controls these devices and then to consider how they can develop

their own software. This leads into such abstract issues as algorithm development, representation, and complexity, which is the heart of most traditional introductory computer science courses.

We are all aware that students learn a lot more than we teach them directly, and the lessons they learn indirectly are often better absorbed than those that are studied explicitly. This is significant when it comes to "teaching" problem solving. Students do not learn to solve problems by studying problem-solving methodologies as an isolated subject. They learn to solve problems by solving problems. So I have included numerous problems throughout the text. I encourage you to use them and to expand on them.

Another topic that I place in this same category is that of professionalism, ethics, and social responsibility. I do not believe that this material should be presented as an isolated subject. Instead, it should surface when it is relevant, which is the approach I have taken in this text. In particular, you will find that Sections 0.5, 3.7, 6.1, 6.7, 9.6, 10.1, and 10.7 present such topics as security, privacy, liability, and social awareness in the context of networking, database systems, software engineering, and artificial intelligence. You will also find that each chapter includes a collection of questions called *Social Issues* that challenge students to think about the relationship between the material in the text and the society in which they live.

Pedagogical Features

This text is the product of many years of teaching. As a result, it is rich in pedagogical aids. Paramount is the abundance of problems to enhance the student's participation. Each section within a chapter closes with *Questions/Exercises* to challenge students to think independently. This feature reviews the material just discussed, extends the previous discussion, or hints at related topics to be covered later. These questions are answered in Appendix F.

Moreover, each chapter (except for the introductory chapter) closes with two sets of problems. The first of these is a set of *Chapter Review Problems* that are designed to serve as "homework" problems in that they cover the material from the entire chapter and are not answered in the text. Following these problems is a set of questions called *Social Issues* that are designed for thought and discussion. Many of them can be used to launch research assignments culminating in short written or oral reports.

Each chapter also ends with a list called *Additional Reading* that contains references to other materials relating to the subject of the chapter. The Web site, described later in this preface, is also a good place to look for related material.

Web Site

This text is supported by a Web site at `http://www.awlonline.com/brookshear`. At this site you will find materials for both students and teachers—including supporting software, laboratory manuals in a variety of programming

languages, links to additional topics of interest, and links to materials developed by other users of the text.

The Sixth Edition

Although this sixth edition maintains the same chapter-by-chapter structure as previous editions, topics have been added, some have been deleted, and much of the remaining material has been rewritten to provide an up-to-date and relevant picture of the science of computing. The following is a summary of the major changes reflected in this edition.

The subject of data compression has moved from Chapter 2 to the new Section 1.8. This new section also contains material on LZ77 and image representation including GIF and JPEG. The material on analysis of algorithms that used to be in Chapter 11 has been expanded and moved to Chapter 4 (Algorithms). Chapter 4 has been made more accessible by removing the quick sort. Section 5.5 on object-oriented programming has been added to Chapter 5 (Programming Languages). Some of this material used to appear in Chapter 7. Most of Chapter 6 (Software Engineering) has been rewritten. It now includes an introduction to design patterns and a new section on testing. Chapter 7 (Data Structures) has a new Section 7.7 that introduces indirect addressing at the machine language level. Chapter 8 (File Structures) has been rewritten to be more accessible by avoiding an overload of examples in specific languages. Section 9.4 on object-oriented database systems has been rewritten and Section 9.6 on the social impact of database technology is new. Chapter 10 (Artificial Intelligence) has two new sections—Section 10.5 (Genetic algorithms) and Section 10.7 (Considering the Consequences). Moreover, the old sections 10.3, 10.4, and 10.5 have been streamlined and combined into one. Section 11.6 (Public Key Encryption) has been added to Chapter 11 (Theory of Computation).

In addition to these changes to chapter contents, I have added a bit of spice to the entire text by means of side boxes that help link the material in the text to the real world. Many of these include references to Web sites where additional information is available.

Acknowledgments

I first thank those of you who have supported this book by reading and using it in previous editions. I am honored.

With each new edition, the list of those who have contributed to the book grows. Today this list includes J. M. Adams, C. M. Allen, D. C. S. Allison, B. Auernheimer, P. Bankston, M. Barnard, K. Bowyer, P. W. Brashear, C. M. Brown, B. Calloni, M. Clancy, R. T. Close, D. H. Cooley, F. Deek, M. J. Duncan, S. Fox, N. E. Gibbs, J. D. Harris, D. Hascom, L. Heath, P. Henderson, L. Hunt, L. A. Jehn, K. Korb, G. Krenz, J. Liu, T. J. Long, C. May,

S. J. Merrill, J. C. Moyer, M. Murphy, J. P. Myers, Jr., D. S. Noonan, S. Olariu, G. Rice, N. Rickert, C. Riedesel, J. B. Rogers, G. Saito, W. Savitch, R. Schlafly, J. C. Schlimmer, S. Sells, J. C. Simms, M. C. Slattery, J. Slimick, J. A. Slomka, D. Smith, J. Solderitsch, R. Steigerwald, L. Steinberg, W. J. Taffe, J. Talburt, P. Tromovitch, E. Wright, and M. Ziegler. To these individuals I give my sincere thanks.

I also thank my friends at Addison-Wesley whose efforts are reflected within these pages. They do a great job of turning a raw manuscript into a superb book. In particular, Lisa Kalner and Amy Rose were the two who had to put up with me on a daily basis. They have lots of stories they could tell.

And, I thank my wife Earlene for all the support she has given me over the years. I survived a heart attack on the morning of December 11, 1998 because she got me to the hospital in time.

J. G. B.

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