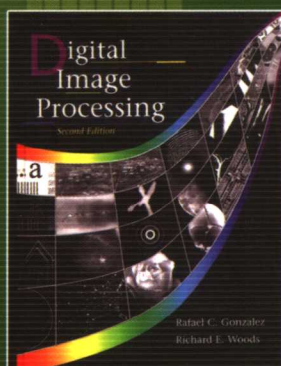


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国外优秀信息科学与技术系列教学用书

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数字图像处理

(第二版) (英文版)



Digital Image Processing
Second Edition

[美] Rafael C. Gonzalez 著
Richard E. Woods



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内 容 简 介

本书是数字图像信息处理领域的一本经典著作,是20多年来此领域最权威的教材之一。与1977年问世的本书第一版相比,进行了重要修订和扩充,增加了关于小波变换、图像形态学和彩色图像处理的章节,并新增了500多幅图像和200多幅图表。全书共分12章,首先介绍了数字图像基础、空间域和频域的图像增强;然后讨论了图像复原、彩色图像处理、小波变换及多分辨率处理和图像压缩;最后讲述了形态学图像处理、图像分割、表示与描述以及目标识别等。本书侧重于对数字图像处理基本概念和方法的介绍,并为本领域的进一步学习和研究奠定了坚实的基础。全书概念清楚、深入浅出、图文并茂,并且反映了数字图像处理领域的最新发展情况。根据作者于2007年1月10日提供的勘误表,本书内容已做了相应的修改。

本书主要适用于信号与信息处理、计算机科学与技术、自动化、电子科学与技术、通信工程、地球物理、生物工程、物理、化学、医学和遥感等领域的大学教师和科技工作者、研究生、大学本科高年级学生以及工程技术人员阅读。

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E-mail : dbqq@phei.com.cn

通信地址：北京市万寿路 173 信箱

电子工业出版社总编办公室

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序

2001年7月间,电子工业出版社的领导同志邀请各高校十几位通信领域方面的老师,商量引进国外教材问题。与会同志对出版社提出的计划十分赞同,大家认为,这对我国通信事业、特别是对高等院校通信学科的教学工作会很有好处。

教材建设是高校教学建设的主要内容之一。编写、出版一本好的教材,意味着开设了一门好的课程,甚至可能预示着一个崭新学科的诞生。20世纪40年代MIT林肯实验室出版的一套28本雷达丛书,对近代电子学科、特别是对雷达技术的推动作用,就是一个很好的例子。

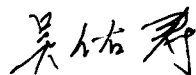
我国领导部门对教材建设一直非常重视。20世纪80年代,在原教委教材编审委员会的领导下,汇集了高等院校几百位富有教学经验的专家,编写、出版了一大批教材;很多院校还根据学校的特点和需要,陆续编写了大量的讲义和参考书。这些教材对高校的教学工作发挥了极好的作用。近年来,随着教学改革不断深入和科学技术的飞速进步,有的教材内容已比较陈旧、落后,难以适应教学的要求,特别是在电子学和通信技术发展神速、可以讲是日新月异的今天,如何适应这种情况,更是一个必须认真考虑的问题。解决这个问题,除了依靠高校的老教师和专家撰写新的符合要求的教科书外,引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,是会有好处的。

一年多来,电子工业出版社为此做了很多工作。他们成立了一个“国外电子与通信教材系列”项目组,选派了富有经验的业务骨干负责有关工作,收集了230余种通信教材和参考书的详细资料,调来了100余种原版教材样书,依靠由20余位专家组成的出版委员会,从中精选了40多种,内容丰富,覆盖了电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等方面,既可作为通信专业本科生和研究生的教学用书,也可作为有关专业人员的参考材料。此外,这批教材,有的翻译为中文,还有部分教材直接影印出版,以供教师用英语直接授课。希望这些教材的引进和出版对高校通信教学和教材改革能起一定作用。

在这里,我还要感谢参加工作的各位教授、专家、老师与参加翻译、编辑和出版的同志们。各位专家认真负责、严谨细致、不辞辛劳、不怕琐碎和精益求精的态度,充分体现了中国教育工作者和出版工作者的良好美德。

随着我国经济建设的发展和科学技术的不断进步,对高校教学工作会不断提出新的要求和希望。我想,无论如何,要做好引进国外教材的工作,一定要联系我国的实际。教材和学术专著不同,既要注意科学性、学术性,也要重视可读性,要深入浅出,便于读者自学;引进的教材要适应高校教学改革的需要,针对目前一些教材内容较为陈旧的问题,有目的地引进一些先进的和正在发展中的交叉学科的参考书;要与国内出版的教材相配套,安排好出版英文原版教材和翻译教材的比例。我们努力使这套教材能尽量满足上述要求,希望它们能放在学生们的课桌上,发挥一定的作用。

最后,预祝“国外电子与通信教材系列”项目取得成功,为我国电子与通信教学和通信产业的发展培土施肥。也恳切希望读者能对这些书籍的不足之处、特别是翻译中存在的问题,提出意见和建议,以便再版时更正。



中国工程院院士、清华大学教授
“国外电子与通信教材系列”出版委员会主任

出版说明

进入21世纪以来,我国信息产业在生产和科研方面都大大加快了发展速度,并已成为国民经济发展的支柱产业之一。但是,与世界上其他信息产业发达的国家相比,我国在技术开发、教育培训等方面都还存在着较大的差距。特别是在加入WTO后的今天,我国信息产业面临着国外竞争对手的严峻挑战。

作为我国信息产业的专业科技出版社,我们始终关注着全球电子信息技术的发展方向,始终把引进国外优秀电子与通信信息技术教材和专业书籍放在我们工作的重要位置上。在2000年至2001年间,我社先后从世界著名出版公司引进出版了40余种教材,形成了一套“国外计算机科学教材系列”,在全国高校以及科研部门中受到了欢迎和好评,得到了计算机领域的广大教师与科研工作者的充分肯定。

引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,将有助于我国信息产业培养具有国际竞争能力的技术人才,也将有助于我国国内在电子与通信教学工作中掌握和跟踪国际发展水平。根据国内信息产业的现状、教育部《关于“十五”期间普通高等教育教材建设与改革的意见》的指示精神以及高等院校老师们反映的各种意见,我们决定引进“国外电子与通信教材系列”,并随后开展了大量准备工作。此次引进的国外电子与通信教材均来自国际著名出版商,其中影印教材约占一半。教材内容涉及的学科方向包括电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等,其中既有本科专业课程教材,也有研究生课程教材,以适应不同院系、不同专业、不同层次的师生对教材的需求,广大师生可自由选择和自由组合使用。我们还将与国外出版商一起,陆续推出一些教材的教学支持资料,为授课教师提供帮助。

此外,“国外电子与通信教材系列”的引进和出版工作得到了教育部高等教育司的大力支持和帮助,其中的部分引进教材已通过“教育部高等学校电子信息科学与工程类专业教学指导委员会”的审核,并得到教育部高等教育司的批准,纳入了“教育部高等教育司推荐——国外优秀信息科学与技术系列教学用书”。

为作好该系列教材的翻译工作,我们聘请了清华大学、北京大学、北京邮电大学、南京邮电大学、东南大学、西安交通大学、天津大学、西安电子科技大学、电子科技大学、中山大学、哈尔滨工业大学、西南交通大学等著名高校的教授和骨干教师参与教材的翻译和审校工作。许多教授在国内电子与通信专业领域享有较高的声望,具有丰富的教学经验,他们的渊博学识从根本上保证了教材的翻译质量和专业学术方面的严格与准确。我们在此对他们的辛勤工作与贡献表示衷心的感谢。此外,对于编辑的选择,我们达到了专业对口;对于从英文原书中发现的错误,我们通过作者联络、从网上下载勘误表等方式,逐一进行了修订;同时,我们对审校、排版、印制质量进行了严格把关。

今后,我们将进一步加强同各高校教师的密切关系,努力引进更多的国外优秀教材和教学参考书,为我国电子与通信教材达到世界先进水平而努力。由于我们对国内外电子与通信教育的发展仍存在一些认识上的不足,在选题、翻译、出版等方面的工作中还有许多需要改进的地方,恳请广大师生和读者提出批评及建议。

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Preface

When something can be read without effort,
great effort has gone into its writing.

Enrique Jardiel Poncela

This edition is the most comprehensive revision of *Digital Image Processing* since the book first appeared in 1977. As the 1977 and 1987 editions by Gonzalez and Wintz, and the 1992 edition by Gonzalez and Woods, the present edition was prepared with students and instructors in mind. Thus, the principal objectives of the book continue to be to provide an introduction to basic concepts and methodologies for digital image processing, and to develop a foundation that can be used as the basis for further study and research in this field. To achieve these objectives, we again focused on material that we believe is fundamental and has a scope of application that is not limited to the solution of specialized problems. The mathematical complexity of the book remains at a level well within the grasp of college seniors and first-year graduate students who have introductory preparation in mathematical analysis, vectors, matrices, probability, statistics, and rudimentary computer programming.

The present edition was influenced significantly by a recent market survey conducted by Prentice Hall. The major findings of this survey were:

1. A need for more motivation in the introductory chapter regarding the spectrum of applications of digital image processing.
2. A simplification and shortening of material in the early chapters in order to “get to the subject matter” as quickly as possible.
3. A more intuitive presentation in some areas, such as image transforms and image restoration.
4. Individual chapter coverage of color image processing, wavelets, and image morphology.
5. An increase in the breadth of problems at the end of each chapter.

The reorganization that resulted in this edition is our attempt at providing a reasonable degree of balance between rigor in the presentation, the findings of the market survey, and suggestions made by students, readers, and colleagues since the last edition of the book. The major changes made in the book are as follows.

Chapter 1 was rewritten completely. The main focus of the current treatment is on examples of areas that use digital image processing. While far from exhaustive, the examples shown will leave little doubt in the reader’s mind regarding the breadth of application of digital image processing methodologies. Chapter 2 is totally new also. The focus of the presentation in this chapter is on how digital images are generated, and on the closely related concepts of

sampling, aliasing, Moiré patterns, and image zooming and shrinking. The new material and the manner in which these two chapters were reorganized address directly the first two findings in the market survey mentioned above.

Chapters 3 through 6 in the current edition cover the same concepts as Chapters 3 through 5 in the previous edition, but the scope is expanded and the presentation is totally different. In the previous edition, Chapter 3 was devoted exclusively to image transforms. One of the major changes in the book is that image transforms are now introduced when they are needed. This allowed us to begin discussion of image processing techniques much earlier than before, further addressing the second finding of the market survey. Chapters 3 and 4 in the current edition deal with image enhancement, as opposed to a single chapter (Chapter 4) in the previous edition. The new organization of this material does not imply that image enhancement is more important than other areas. Rather, we used it as an avenue to introduce spatial methods for image processing (Chapter 3), as well as the Fourier transform, the frequency domain, and image filtering (Chapter 4). Our purpose for introducing these concepts in the context of image enhancement (a subject particularly appealing to beginners) was to increase the level of intuitiveness in the presentation, thus addressing partially the third major finding in the marketing survey. This organization also gives instructors flexibility in the amount of frequency-domain material they wish to cover.

Chapter 5 also was rewritten completely in a more intuitive manner. The coverage of this topic in earlier editions of the book was based on matrix theory. Although unified and elegant, this type of presentation is difficult to follow, particularly by undergraduates. The new presentation covers essentially the same ground, but the discussion does not rely on matrix theory and is much easier to understand, due in part to numerous new examples. The price paid for this newly gained simplicity is the loss of a unified approach, in the sense that in the earlier treatment a number of restoration results could be derived from one basic formulation. On balance, however, we believe that readers (especially beginners) will find the new treatment much more appealing and easier to follow. Also, as indicated below, the old material is stored in the book Web site for easy access by individuals preferring to follow a matrix-theory formulation.

Chapter 6 dealing with color image processing is new. Interest in this area has increased significantly in the past few years as a result of growth in the use of digital images for Internet applications. Our treatment of this topic represents a significant expansion of the material from previous editions. Similarly Chapter 7, dealing with wavelets, is new. In addition to a number of signal processing applications, interest in this area is motivated by the need for more sophisticated methods for image compression, a topic that in turn is motivated by a increase in the number of images transmitted over the Internet or stored in web servers. Chapter 8 dealing with image compression was updated to include new compression methods and standards, but its fundamental structure remains the same as in the previous edition. Several image transforms, previously covered in Chapter 3 and whose principal use is compression, were moved to this chapter.

Chapter 9, dealing with image morphology, is new. It is based on a significant expansion of the material previously included as a section in the chapter on image representation and description. Chapter 10, dealing with image segmentation, has the same basic structure as before, but numerous new examples were included and a new section on segmentation by morphological watersheds was added. Chapter 11, dealing with image representation and description, was shortened slightly by the removal of the material now included in Chapter 9. New examples were added and the Hotelling transform (description by principal components), previously included in Chapter 3, was moved to this chapter. Chapter 12 dealing with object recognition was shortened by the removal of topics dealing with knowledge-based image analysis, a topic now covered in considerable detail in a number of books which we reference in Chapters 1 and 12. Experience since the last edition of *Digital Image Processing* indicates that the new, shortened coverage of object recognition is a logical place at which to conclude the book.

Although the book is totally self-contained, we have established a companion web site (see inside front cover) designed to provide support to users of the book. For students following a formal course of study or individuals embarked on a program of self study, the site contains a number of tutorial reviews on background material such as probability, statistics, vectors, and matrices, prepared at a basic level and written using the same notation as in the book. Detailed solutions to many of the exercises in the book also are provided. For instruction, the site contains suggested teaching outlines, classroom presentation materials, laboratory experiments, and various image databases (including most images from the book). In addition, part of the material removed from the previous edition is stored in the web site for easy download and classroom use, at the discretion of the instructor. A downloadable instructor's manual containing sample curricula, solutions to sample laboratory experiments, and solutions to all problems in the book is available to instructors who have adopted the book for classroom use.

This edition of *Digital Image Processing* is a reflection of the significant progress that has been made in this field in just the past decade. As is usual in a project such as this, progress continues after work on the manuscript stops. One of the reasons earlier versions of this book have been so well accepted throughout the world is their emphasis on fundamental concepts, an approach that, among other things, attempts to provide a measure of constancy in a rapidly-evolving body of knowledge. We have tried to observe that same principle in preparing this edition of the book.

R. C. G.
R. E. W.

About the Authors

Rafael C. Gonzalez

R. C. Gonzalez received the B.S.E.E. degree from the University of Miami in 1965 and the M.E. and Ph.D. degrees in electrical engineering from the University of Florida, Gainesville, in 1967 and 1970, respectively. He joined the Electrical and Computer Engineering Department at University of Tennessee, Knoxville (UTK) in 1970, where he became Associate Professor in 1973, Professor in 1978, and Distinguished Service Professor in 1984. He served as Chairman of the department from 1994 through 1997. He is currently a Professor Emeritus at UTK.

Gonzalez is the founder of the Image & Pattern Analysis Laboratory and the Robotics & Computer Vision Laboratory at the University of Tennessee. He also founded Perceptics Corporation in 1982 and was its president until 1992. The last three years of this period were spent under a full-time employment contract with Westinghouse Corporation, who acquired the company in 1989.

Under his direction, Perceptics became highly successful in image processing, computer vision, and laser disk storage technology. In its initial ten years, Perceptics introduced a series of innovative products, including: The world's first commercially-available computer vision system for automatically reading the license plate on moving vehicles; a series of large-scale image processing and archiving systems used by the U.S. Navy at six different manufacturing sites throughout the country to inspect the rocket motors of missiles in the Trident II Submarine Program; the market leading family of imaging boards for advanced Macintosh computers; and a line of trillion-byte laser disk products.

He is a frequent consultant to industry and government in the areas of pattern recognition, image processing, and machine learning. His academic honors for work in these fields include the 1977 UTK College of Engineering Faculty Achievement Award; the 1978 UTK Chancellor's Research Scholar Award; the 1980 Magnavox Engineering Professor Award; and the 1980 M.E. Brooks Distinguished Professor Award. In 1981 he became an IBM Professor at the University of Tennessee and in 1984 he was named a Distinguished Service Professor there. He was awarded a Distinguished Alumnus Award by the University of Miami in 1985, the Phi Kappa Phi Scholar Award in 1986, and the University of Tennessee's Nathan W. Dougherty Award for Excellence in Engineering in 1992.

Honors for industrial accomplishment include the 1987 IEEE Outstanding Engineer Award for Commercial Development in Tennessee; the 1988 Albert Rose Nat'l Award for Excellence in Commercial Image Processing; the 1989 B. Otto Wheelley Award for Excellence in Technology Transfer; the 1989 Coopers and Lybrand Entrepreneur of the Year Award; the 1992 IEEE Region 3 Outstanding Engineer Award; and the 1993 Automated Imaging Association National Award for Technology Development.

Gonzalez is author or co-author of over 100 technical articles, two edited books, and four textbooks in the fields of pattern recognition, image processing, and robotics. His books are used in over 500 universities and research institutions throughout the world. He is listed in the prestigious Marquis *Who's Who in America*, Marquis *Who's Who in Engineering*, Marquis *Who's Who in the World*, and in 10 other national and international biographical citations. He is the co-holder of two U.S. Patents, and has been an associate editor of the IEEE Transactions on Systems, Man and Cybernetics, and the International Journal of Computer and Information Sciences. He is a member of numerous professional and honorary societies, including Tau Beta Pi, Phi Kappa Phi, Eta Kappa Nu, and Sigma Xi. He is a Fellow of the IEEE.

Richard E. Woods

Richard E. Woods earned his B.S., M.S., and Ph.D. degrees in Electrical Engineering from the University of Tennessee, Knoxville. His professional experiences range from entrepreneurial to the more traditional academic, consulting, governmental, and industrial pursuits. Most recently, he founded MedData Interactive, a high technology company specializing in the development of handheld computer systems for medical applications. He was also a founder and Vice President of Perceptics Corporation, where he was responsible for the development of many of the company's quantitative image analysis and autonomous decision making products.

Prior to Perceptics and MedData, Dr. Woods was an Assistant Professor of Electrical Engineering and Computer Science at the University of Tennessee and prior to that, a computer applications engineer at Union Carbide Corporation. As a consultant, he has been involved in the development of a number of special-purpose digital processors for a variety of space and military agencies, including NASA, the Ballistic Missile Systems Command, and the Oak Ridge National Laboratory.

Dr. Woods has published numerous articles related to digital signal processing and is a member of several professional societies, including Tau Beta Pi, Phi Kappa Phi, and the IEEE. In 1986, he was recognized as a Distinguished Engineering Alumnus of the University of Tennessee.

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电话: 010-8825 4555
传真: 010-8825 4560
E-mail: Te_service@phei.com.cn

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