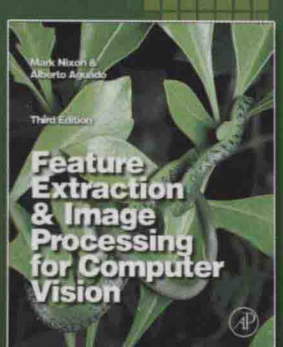
国外电子与通信教材系列

英文版

计算机视觉特征提取与图像处理（第三版）

Feature Extraction & Image Processing for Computer Vision, Third Edition



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（第三版）（英文版）

Feature Extraction & Image Processing for Computer Vision

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内容简介

本书是由英国南安普顿大学的Mark Nixon教授和Sportradar公司的Alberto S. Aguado在第二版的基础上，于2012年9月推出的最新改版之作。本次改版，主要的变化是将高级特征提取，分为固定形状匹配与可变形形状分析两部分，并增加了新的一章内容：运动对象检测与描述。具体地，在简要介绍计算机视觉的基础概念和基本的图像处理运算后，重点讨论了低级和高级的特征提取，包括边缘检测、固定形状匹配和可变形形状分析。此外，对目标描述，纹理描述、分割及分类，以及运动对象检测等都进行深入的阐述。它突出了计算机视觉的主要问题——特征提取，以清晰、简洁的语言，阐述了图像处理和计算机视觉的基础理论与技术。

本书可作为高等学校电子工程、计算机科学、计算机工程等专业本科生的双语教材，也可以作为图像、视频信号处理，模式识别和计算机视觉研究方向的博士生、硕士研究生，以及相关专业的科研工作者的参考用书。

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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。

吴佑寿

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”。

为做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，我们通过与作者联络、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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About the authors

Mark S. Nixon is a professor in Computer Vision at the University of Southampton, United Kingdom. His research interests are in image processing and computer vision. His team develops new techniques for static and moving shape extraction which have found application in biometrics and in medical image analysis. His team were early workers in automatic face recognition, later came to pioneer gait recognition and more recently joined the pioneers of ear biometrics. With Tieniu Tan and Rama Chellappa, their book *Human ID based on Gait* is part of the Springer Series on Biometrics and was published in 2005. He has chaired/program chaired many conferences (BMVC 98, AVBPA 03, IEEE Face and Gesture FG06, ICPR 04, ICB 09, and IEEE BTAS 2010) and given many invited talks. He is a Fellow IET and a Fellow IAPR.

Alberto S. Aguado is a principal programmer at Sportradar, where he works developing Image Processing and real-time multicamera 3D tracking technologies for sport events. Previously, he worked as a technology programmer for Electronic Arts and for Black Rock Disney Game Studios. He worked as a lecturer in the Centre for Vision, Speech and Signal Processing in the University of Surrey. He pursued a postdoctoral fellowship in Computer Vision at INRIA Rhône-Alpes, and he received his Ph.D. in Computer Vision/Image Processing from the University of Southampton.

Preface

What is new in the third edition?

Image processing and computer vision has been, and continues to be, subject to much research and development. The research develops into books and so the books need updating. We have always been interested to note that our book contains stock image processing and computer vision techniques which are yet to be found in other regular textbooks (OK, some is to be found in specialist books, though these rarely include much tutorial material). This has been true of the previous editions and certainly occurs here.

In this third edition, the completely new material is on new methods for low- and high-level feature extraction and description and on moving object detection, tracking, and description. We have also extended the book to use color and more modern techniques for object extraction and description especially those capitalizing on wavelets and on scale space. We have of course corrected the previous production errors and included more tutorial material where appropriate. We continue to update the references, especially to those containing modern survey material and performance comparison. As such, this book—IOHO—remains the most up-to-date text in feature extraction and image processing in computer vision.

Why did we write this book?

We always expected to be asked: "why on earth write a new book on computer vision?", and we have been. A fair question is "there are already many good books on computer vision out in the bookshops, as you will find referenced later, so why add to them?" Part of the answer is that any textbook is a snapshot of material that exists prior to it. Computer vision, the art of processing images stored within a computer, has seen a considerable amount of research by highly qualified people and the volume of research would appear even to have increased in recent years. That means a lot of new techniques have been developed, and many of the more recent approaches are yet to migrate to textbooks. It is not just the new research: part of the speedy advance in computer vision technique has left some areas covered only in scanty detail. By the nature of research, one cannot publish material on technique that is seen more to fill historical gaps, rather than to advance knowledge. This is again where a new text can contribute.

Finally, the technology itself continues to advance. This means that there is new hardware, new programming languages, and new programming environments. In particular for computer vision, the advance of technology means that computing power and memory are now relatively cheap. It is certainly considerably cheaper than when computer vision was starting as a research field. One of

the authors here notes that the laptop in which his portion of the book was written on has considerably more memory, is faster, and has bigger disk space and better graphics than the computer that served the entire university of his student days. And he is not that old! One of the more advantageous recent changes brought by progress has been the development of mathematical programming systems. These allow us to concentrate on mathematical technique itself rather than on implementation detail. There are several sophisticated flavors of which Matlab, one of the chosen vehicles here, is (arguably) the most popular. We have been using these techniques in research and in teaching, and we would argue that they have been of considerable benefit there. In research, they help us to develop technique faster and to evaluate its final implementation. For teaching, the power of a modern laptop and a mathematical system combines to show students, in lectures and in study, not only how techniques are implemented but also how and why they work with an explicit relation to conventional teaching material.

We wrote this book for these reasons. There is a host of material we could have included but chose to omit; the taxonomy and structure we use to expose the subject are of our own construction. Our apologies to other academics if it was your own, or your favorite, technique that we chose to omit. By virtue of the enormous breadth of the subject of image processing and computer vision, we restricted the focus to feature extraction and image processing in computer vision for this has been the focus of not only our research but also where the attention of established textbooks, with some exceptions, can be rather scanty. It is, however, one of the prime targets of applied computer vision, so would benefit from better attention. We have aimed to clarify some of its origins and development, while also exposing implementation using mathematical systems. As such, we have written this text with our original aims in mind and maintained the approach through the later editions.

The book and its support

Each chapter of this book presents a particular package of information concerning feature extraction in image processing and computer vision. Each package is developed from its origins and later referenced to more recent material. Naturally, there is often theoretical development prior to implementation. We have provided working implementations of most of the major techniques we describe, and applied them to process a selection of imagery. Though the focus of our work has been more in analyzing medical imagery or in biometrics (the science of recognizing people by behavioral or physiological characteristic, like face recognition), the techniques are general and can migrate to other application domains.

You will find a host of further supporting information at the book's web site http://www.ecs.soton.ac.uk/~msn/book/. First, you will find the **worksheets** (the Matlab and Mathcad implementations that support the text) so that you can study

the techniques described herein. The **demonstration** site too is there. The web site will be kept up-to-date as much as possible, for it also contains links to other material such as web sites devoted to techniques and applications as well as to available software and online literature. Finally, any errata will be reported there. It is our regret and our responsibility that these will exist, and our inducement for their reporting concerns a pint of beer. If you find an error that we don't know about (not typos like spelling, grammar, and layout) then use the "mailto" on the web site and we shall send you a pint of good English **beer**, free!

There is a certain amount of mathematics in this book. The target audience is the third- or fourth-year students of BSc/BEng/MEng in electrical or electronic engineering, software engineering, and computer science, or in mathematics or physics, and this is the level of mathematical analysis here. Computer vision can be thought of as a branch of applied mathematics, though this does not really apply to some areas within its remit and certainly applies to the material herein. The mathematics essentially concerns mainly calculus and geometry, though some of it is rather more detailed than the constraints of a conventional lecture course might allow. Certainly, not all the material here is covered in detail in undergraduate courses at Southampton.

Chapter 1 starts with an overview of computer vision hardware, software, and established material, with reference to the most sophisticated vision system yet "developed": the **human vision** system. Though the precise details of the nature of processing that allows us to see are yet to be determined, there is a considerable range of **hardware** and **software** that allow us to give a computer system the capability to acquire, process, and reason with imagery, the function of "sight." The first chapter also provides a comprehensive **bibliography** of material you can find on the subject including not only textbooks but also available software and other material. As this will no doubt be subject to change, it might well be worth consulting the web site for more up-to-date information. The preference for journal references is those which are likely to be found in local university libraries or on the Web, *IEEE Transactions* in particular. These are often subscribed to as they are relatively of low cost and are often of very high quality.

Chapter 2 concerns the basics of signal processing theory for use in computer vision. It introduces the **Fourier transform** that allows you to look at a signal in a new way, in terms of its frequency content. It also allows us to work out the minimum size of a picture to conserve information, to analyze the content in terms of frequency, and even helps to speed up some of the later vision algorithms. Unfortunately, it does involve a few equations, but it is a new way of looking at data and at signals and proves to be a rewarding topic of study in its own right. It extends to wavelets, which are a popular analysis tool in image processing.

In Chapter 3, we start to look at **basic** image processing techniques, where image points are mapped into a new value first by considering a single point in an original image and then by considering groups of points. Not only do we see common operations to make a picture's appearance better, especially for human

vision, but also we see how to reduce the effects of different types of commonly encountered image noise. We shall see some of the modern ways to remove noise and thus clean images, and we shall also look at techniques which process an image using notions of shape rather than mapping processes.

Chapter 4 concerns **low-level features** which are the techniques that describe the content of an image, at the level of a whole image rather than in distinct regions of it. One of the most important processes we shall meet is called **edge detection**. Essentially, this reduces an image to a form of a caricaturist's sketch, though without a caricaturist's exaggerations. The major techniques are presented in detail, together with descriptions of their implementation. Other image properties we can derive include measures of **curvature**, which developed into modern methods of **feature extraction**, and measures of **movement**. These are also covered in this chapter.

These edges, the curvature, or the motion need to be grouped in some way so that we can find shapes in an image and are dealt with in Chapter 5. Using basic thresholding rarely suffices for shape extraction. One of the newer approaches is to group low-level features to find an object—in a way this is object extraction without shape. Another approach to **shape extraction** concerns analyzing the **match** of low-level information to a known template of a target shape. As this can be computationally very cumbersome, we then progress to a technique that improves computational performance, while maintaining an optimal performance. The technique is known as the **Hough transform** and it has long been a popular target for researchers in computer vision who have sought to clarify its basis, improve its speed, and to increase its accuracy and robustness. Essentially, by the Hough transform, we estimate the parameters that govern a shape's appearance, where the shapes range from **lines** to **ellipse**s and even to **unknown shapes**.

In Chapter 6, some applications of shape extraction require to determine rather more than the parameters that control appearance, and require to be able to **deform** or **flex** to match the image template. For this reason, the chapter on shape extraction by matching is followed by one on **flexible shape** analysis. This is a topic that has shown considerable progress of late, especially with the introduction of **snakes** (**active contours**). The newer material is the formulation by level set methods and brings new power to shape extraction techniques. These seek to match a shape to an image by analyzing local properties. Further, we shall see how we can describe a shape by its **skeleton** though with practical difficulty which can be alleviated by **symmetry** (though this can be slow), and also how global constraints concerning the **statistics** of a shape's appearance can be used to guide final extraction.

Up to this point, we have not considered techniques that can be used to describe the shape found in an image. In Chapter 7, we shall find that the two major approaches concern techniques that describe a shape's perimeter and those that describe its area. Some of the **perimeter description** techniques, the Fourier descriptors, are even couched using Fourier transform theory that allows analysis of their frequency content. One of the major approaches to **area description**, statistical moments, also has a form of access to frequency components, though it is

of a very different nature to the Fourier analysis. One advantage is that insight into descriptive ability can be achieved by **reconstruction** which should get back to the original shape.

Chapter 8 describes **texture** analysis and also serves as a vehicle for introductory material on **pattern classification**. Texture describes patterns with no known analytical description and has been the target of considerable research in computer vision and image processing. It is used here more as a vehicle for material that precedes it, such as the Fourier transform and area descriptions though references are provided for access to other generic material. There is also introductory material on how to classify these patterns against known data, with a selection of the distance measures that can be used within that, and this is a window on a much larger area, to which appropriate pointers are given.

Finally, Chapter 9 concerns detecting and analyzing **moving objects**. Moving objects are detected by separating the foreground from the background, known as **background subtraction**. Having separated the moving components, one approach is then to follow or **track** the object as it moves within a sequence of image frames. The moving object can be described and recognized from the tracking information or by collecting together the sequence of frames to derive moving object descriptions.

The **appendices** include materials that are germane to the text, such as **camera models** and **coordinate geometry**, the method of **least squares**, a topic known as **principal components analysis**, and methods of **color description**. These are aimed to be short introductions and are appendices since they are germane to much of the material throughout but not needed directly to cover it. Other related material is referenced throughout the text, especially online material.

In this way, the text covers all major areas of feature extraction and image processing in computer vision. There is considerably more material in the subject than is presented here; for example, there is an enormous volume of material in 3D computer vision and in 2D signal processing, which is only alluded to here. Topics that are specifically not included are 3D processing, watermarking, and image coding. To include all these topics would lead to a monstrous book that no one could afford or even pick up. So we admit we give a snapshot, and we hope more that it is considered to open another window on a fascinating and rewarding subject.

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Final message

We ourselves have already benefited much by writing this book. As we already know, previous students have also benefited and contributed to it as well. It remains our hope that it does inspire people to join in this fascinating and rewarding subject that has proved to be such a source of pleasure and inspiration to its many workers.

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