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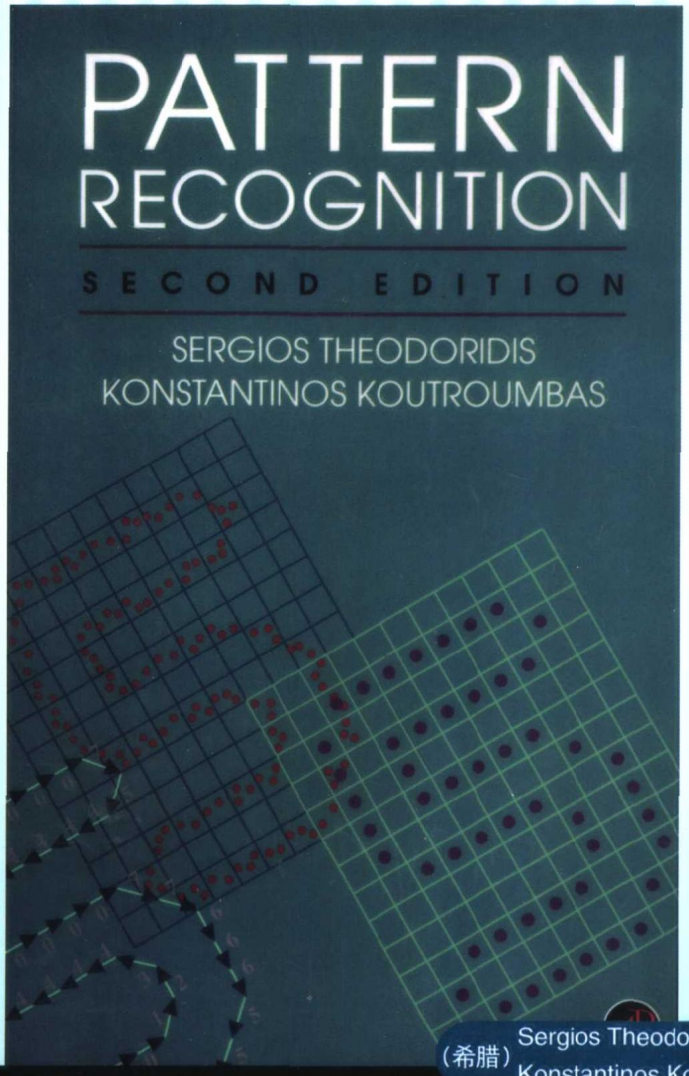

（希腊）Sergios Theodoridis
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模式识别

(英文版·第2版)

Pattern Recognition

(Second Edition)

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Sergios Theodoridis
(希腊) Konstantinos Koutroumbas 著

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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，有的还专诚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

This book is the outgrowth of our teaching advanced undergraduate and graduate courses over the past 20 years. These courses have been taught to different audiences, including students in electrical and electronics engineering, computer engineering, computer science and informatics, as well as to an interdisciplinary audience of a graduate course on automation. This experience led us to make the book as self-contained as possible and to address students with different backgrounds. As prerequisitive knowledge the reader requires only basic calculus, elementary linear algebra, and some probability theory basics. A number of mathematical tools, such as probability and statistics as well as constrained optimization, needed by various chapters, are treated in four Appendices. The book is designed to serve as a text for advanced undergraduate and graduate students, and it can be used for either a one- or a two-semester course. Furthermore, it is intended to be used as a self-study and reference book for research and for the practicing scientist/engineer. This latter audience was also our second incentive for writing this book, due to the involvement of our group in a number of projects related to pattern recognition.

The philosophy of the book is to present various pattern recognition tasks in a unified way, including image analysis, speech processing, and communication applications. Despite their differences, these areas do share common features and their study can only benefit from a unified approach. Each chapter of the book starts with the basics and moves progressively to more advanced topics and reviews up-to-date techniques. A number of problems and computer exercises are given at the end of each chapter and a solutions manual is available from the publisher. Furthermore, a number of demonstrations based on MATLAB are available via the web at the book's site, http://www.di.uoa.gr/~stpatrec.

Our intention is to update the site regularly with more and/or improved versions of these demonstrations. Suggestions are always welcome. Also at this web site, a page will be available for typos, which are unavoidable, despite frequent careful reading. The authors would appreciate readers notifying them about any typos found.

This book would have not be written without the constant support and help from a number of colleagues and students throughout the years. We are especially indebted to Prof. K. Berberidis, Dr. E. Kofidis, Prof. A. Liavas, Dr. A. Rontogiannis, Dr. A. Pikrakis, Dr. Gezerlis and Dr. K. Georgoulakis. The constant support provided by Dr. I. Kopsinis from the early stages up to the final stage, with those long nights, has been invaluable. The book improved a great deal after the careful reading and the serious comments and suggestions of Prof. G. Moustakides, Prof. V. Digalakis, Prof. T. Adali, Prof. M. Zervakis, Prof. D. Cavouras, Prof. A. Böhm, Prof. G. Glentis, Prof. E. Koutsoupias, Prof. V. Zissimopoulos, Prof. A. Likas, Dr. A. Vassiliou, Dr. N. Vassilas, Dr. V. Drakopoulos, Dr. S. Hatzispyros. We are greatly indebted to these colleagues for their time and their constructive criticisms. Our collaboration and friendship with Prof. N. Kalouptsidis have been a source of constant inspiration for all these years. We are both deeply indebted to him.

Last but not least, K. Koutroumbas would like to thank Sophia for her tolerance and support and S. Theodoridis would like to thank Despina, Eva, and Eleni, his joyful and supportive "harem."

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CHAPTER 1

INTRODUCTION

1.1 IS PATTERN RECOGNITION IMPORTANT?

Pattern recognition is the scientific discipline whose goal is the classification of *objects* into a number of categories or *classes*. Depending on the application, these objects can be images or signal waveforms or any type of measurements that need to be classified. We will refer to these objects using the generic term *patterns*. Pattern recognition has a long history, but before the 1960s it was mostly the output of theoretical research in the area of statistics. As with everything else, the advent of computers increased the demand for practical applications of pattern recognition, which in turn set new demands for further theoretical developments. As our society evolves from the industrial to its postindustrial phase, automation in industrial production and the need for information handling and retrieval are becoming increasingly important. This trend has pushed pattern recognition to the high edge of today's engineering applications and research. Pattern recognition is an integral part in most *machine intelligence* systems built for decision making.

Machine vision is an area in which pattern recognition is of importance. A machine vision system captures images via a camera and analyzes them to produce descriptions of what is imaged. A typical application of a machine vision system is in the manufacturing industry, either for automated visual inspection or for automation in the assembly line. For example, in inspection, manufactured objects on a moving conveyor may pass the inspection station, where the camera stands, and it has to be ascertained whether there is a defect. Thus, images have to be analyzed on line, and a pattern recognition system has to classify the objects into the "defect" or "non-defect" class. After that, an action has to be taken, such as to reject the offending parts. In an assembly line, different objects must be located and "recognized," that is, classified in one of a number of classes known *a priori*. Examples are the "screwdriver class," the "German key class," and so forth in a tools' manufacturing unit. Then a robot arm can place the objects in the right place.

Character (letter or number) recognition is another important area of pattern recognition, with major implications in automation and information handling. Optical character recognition (OCR) systems are already commercially available and more or less familiar to all of us. An OCR system has a "front end" device

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