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DIGITAL IMAGE PROCESSING

数字图像处理

Kenneth R. Castleman 著

Pearson Education

清华大学出版社

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Perceptive Scientific Instruments, Inc.

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出 版 说 明

进入 21 世纪，世界各国的经济、科技以及综合国力的竞争将更加激烈。竞争的中心无疑是对人才的争夺。谁拥有大量高素质的人才，谁就能在竞争中取得优势。高等教育，作为培养高素质人才的事业，必然受到高度重视。目前我国高等教育的教材更新较慢，为了加快教材的更新频率，教育部正在大力促进我国高校采用国外原版教材。

清华大学出版社从 1996 年开始，与国外著名出版公司合作，影印出版了“大学计算机教育丛书（影印版）”等一系列引进图书，受到了国内读者的欢迎和支持。跨入 21 世纪，我们本着为我国高等教育教材建设服务的初衷，在已有的基础上，进一步扩大选题内容，改变图书开本尺寸，一如既往地请有关专家挑选适用于我国高校本科及研究生计算机教育的国外经典教材或著名教材，组成本套“大学计算机教育国外著名教材系列（影印版）”，以飨读者。深切期盼读者及时将使用本系列教材的效果和意见反馈给我们。更希望国内专家、教授积极向我们推荐国外计算机教育的优秀教材，以利我们把“大学计算机教育国外著名教材系列（影印版）”做得更好，更适合高校师生的需要。

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Preface

In the 16 years since the publication of my first book on this topic, there has been a major expansion in the utilization of digital image processing. Algorithms that could run only on mainframe computers in the 1960s and minicomputers in the 1970s migrated to the desktop in the 1980s. Personal computers transformed from something a few dedicated hobbyists built in the mid-1970s into a common home office component. The jargon of personal computers became a universal language that bridged the oceans between the United States, Europe, and Asia.

Public awareness of digital image processing has been greatly increased by video games, digital video special effects used in the entertainment industry, and articles in the popular press. Present trends indicate a continuation of the explosive growth of digital image-processing applications well into the next century.

Perhaps the most significant impact of digital image processing in the 1990s will be in the area of applications to real-world problems. This book is aimed at the reader who intends to use the technology for research or commercial purposes. It also provides a foundation for those who seek to advance the state of the art.

While the scope and scale of digital image-processing applications have changed dramatically, other aspects of the field have not. For example, many of the basic techniques that perform reliably in practice today are those that were first applied in the early days of digital imaging. While several exciting new theoretical areas have opened up, generally they build upon, rather than replace, what has served well in the past.

With the recent advances in computer technology, some of the issues treated in the earlier work are no longer of major concern. These are deemphasized in this book, while several

relevant new topics have been included. New examples serve to illustrate further how the theory can be applied to the type of problems that commonly occur in industry and research.

Perhaps most significantly, a set of exercises and suggestions for projects completes each chapter. These have been selected to build the insight and understanding that are most useful to one endeavoring to apply the technology to problems of the real world. The majority of the exercises and projects emulate actual situations a professional faces working in the field of digital image processing. They are intended to give the reader a head start in gaining the insight that supplements a theoretical knowledge and can come only from the experience of solving real problems. In my own estimation, one who not only knows how to solve the problems and carry out the projects, but has actually done most of them, will be ready to take his or her place on the most productive image-processing applications team.

For about 25 years, I have had the opportunity to observe the efforts of many individuals applying digital image-processing techniques to problems offered by the real world. A few of these individuals have established an enduring track record of solid success on almost every attempt. They have consistently contributed innovative and effective solutions that creatively employ the tools of the discipline.

These highly productive individuals demonstrably hold several characteristics in common. One can venture to assume that these characteristics constitute a formula for success, to whatever extent such a thing can exist in this field.

Uniformly, these successful persons have (1) a genuine interest in—even a fascination with—the technology involved, (2) a thorough understanding of the fundamentals of this highly multidisciplinary technology, (3) a conceptual type of understanding (as opposed to rote memorization of totally abstract theory), and (4) a knack for seeing problems visually, graphically, and from more than one viewpoint. In line with this last point, they often find themselves hard pressed to explain their ideas without the aid of a graph or drawing.

This book is designed to help the reader develop the last three of these traits and perhaps enhance the first as well. The selection of materials for inclusion (and, equally important, for omission), the examples used, the references cited, and the exercises and suggestions for projects are all directed toward this goal.

In the field of digital image processing, mathematical analysis forms the stable basis upon which one can make definite predictions regarding the performance of a digital imaging system. In this treatment, however, mathematics is employed more as a faithful servant than as a ruthless master. The emphasis is on developing a conceptual understanding, and the analysis is used to support this goal.

The organization of this book generally follows that of the earlier text, simply because that particular flow of development proved to serve its purpose well. The level of mathematical complexity increases gradually through the first two parts of the book. While many readers have the background in mathematics required to begin the discussion with sampling theory and the Fourier transform, others do not.

More importantly, though, many of the most important concepts can be presented without the aid of advanced mathmatics. Thus, we are able to avoid an additional element of complexity in the interest of making the learning process less burdensome and more appealing to all readers. As a general rule, topics receive attention in relation to their importance, rather than their complexity.

The field of digital image processing has now become so rich with technology that it is impossible to cover all aspects of it in a single volume of reasonable size. Hence, we concentrate upon those techniques that prove most useful in practice and leave most of the mathematical proofs to the references. Constraints of paper and ink further make it impossible to include nearly as many examples of images as would be desirable. (See [1] for an excellent source of these.)

Part 1 presents several important concepts that do not require detailed mathematical analysis for a basic understanding of them. Part 2 addresses techniques that rely more heavily upon their mathematical underpinning and elaborates analytically upon certain concepts introduced in Part 1. Part 3 addresses applications more specifically than they are addressed in earlier chapters.

A Note to Instructors. The development of this text has been accompanied by an accumulation of example digital images and problem solutions worked out in MathCAD™ [2] and WiT™ [3]. These are available from the World Wide Web site that supports this book (http://www.phoenix.net/~castlman/). The author can be reached via the publisher, through Compuserve (70214,1275), on the Internet (castleman@persci.com or castlman@phoenix.net) or Usenet (sci.image.processing).

A Note to Students. Digital imaging is a merger of several disciplines, and its nomenclature comes from many diverse fields. Often ordinary words are pressed into special new usage without warning. This can be quite confusing when it catches the reader unaware. Many of these specialized words are defined in Appendix 1. If the concept presented in a paragraph is not clear, check for a word that doesn't seem to fit. If there is one, look in the glossary or a dictionary for clarification. Frequent reference to the glossary and a dictionary is good insurance against difficulties in understanding the subject.

Image processing is best learned by a combination of study and application. One develops considerable insight by *using* the theory, working with actual imaging problems and image processing equipment. A balance between theory and practice keeps the subject interesting. Problems and projects are included at the end of each chapter for this purpose.

REFERENCES

1. G. A. Baxes, *Digital Image Processing: Principles and Applications,* Wiley, New York, 1994.
2. MathSoft, Inc., 201 Broadway, Cambridge, MA 02139.
3. Logical Vision, Ltd., 4299 Canada Way, Ste. 265, Bunaby, B.C., Canada V5G 1H3.

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