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算法、标准和工业实践

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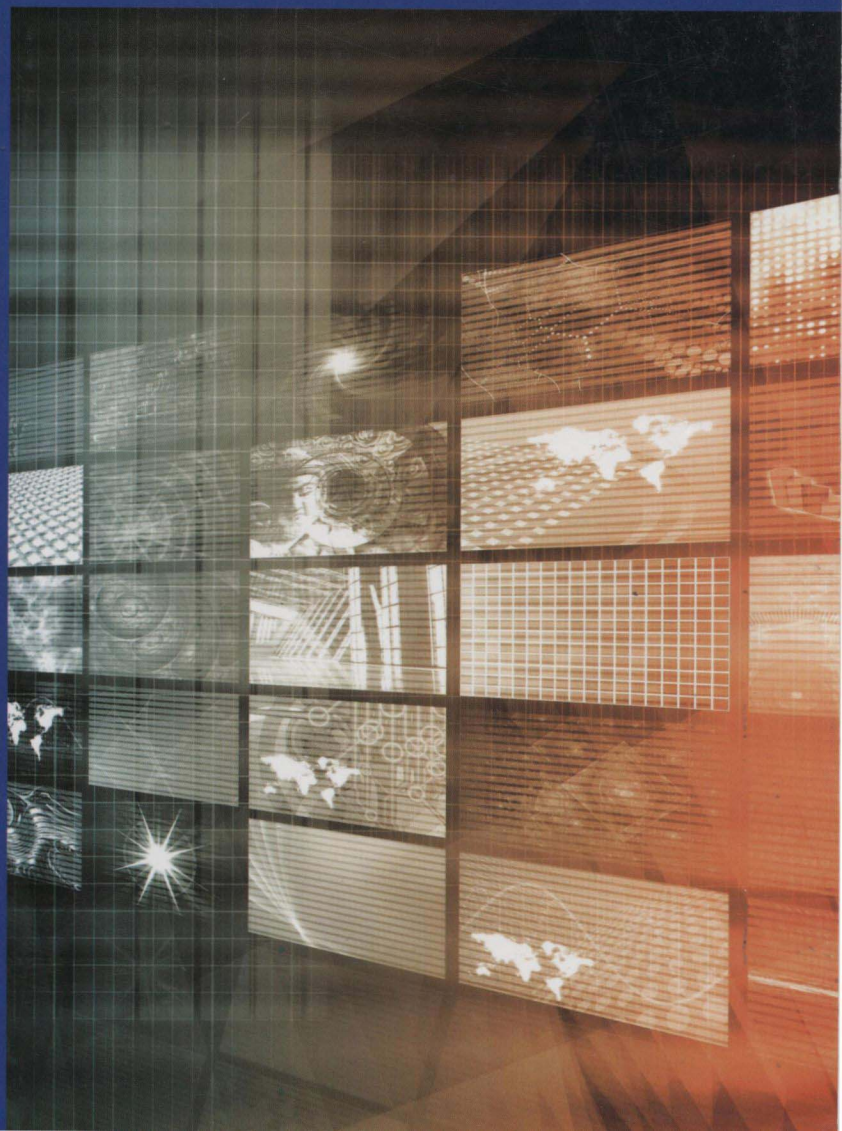
Multimedia Systems
Algorithms, Standards, and Industry Practices, China Student Edition

（英文精编版）



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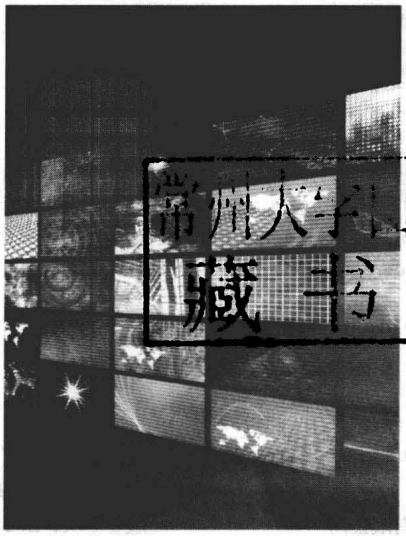

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出版者的话

文艺复兴以来，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；也正是这样的优势，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，还揭示了学术的源变，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和发展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到积极的推动作用，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公司较早意识到“出版要为教育服务”。自1998年开始，我们就将工作重点放在了遴选、移译国外优秀教材上。经过多年的不懈努力，我们与Pearson，McGraw-Hill，Elsevier，MIT，John Wiley & Sons，Cengage等世界著名出版公司建立了良好的合作关系，从他们现有的数百种教材中甄选出Andrew S. Tanenbaum，Bjarne Stroustrup，Brain W. Kernighan，Dennis Ritchie，Jim Gray，Afred V. Aho，John E. Hopcroft，Jeffrey D. Ullman，Abraham Silberschatz，William Stallings，Donald E. Knuth，John L. Hennessy，Larry L. Peterson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、研究及珍藏。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相助，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，有的还专门为其书的中译本作序。迄今，“计算机科学丛书”已经出版了近两百个品种，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。其影印版“经典原版书库”作为姊妹篇也被越来越多实施双语教学的学校所采用。

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The successful completion of any large project needs devotion, discipline, and sacrifice.

To my parents for their love and the values they instilled in me.

To my family, teachers, friends, and well wishers for their support.

To my students for their feedback and invaluable discussions.

But little did I know whose sacrifice it really was:

To my children Veebha and Shreya—

for the weekends I could not take you hiking; for the afternoons that you waited for me to play; for the evenings I did not take you swimming, bicycling, or skating; and for the nights when I couldn't be beside you when you went to bed.

To my wife Chandrani—

without whose understanding, support, and love, this book was just not possible.

Parag Havaldar

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PREFACE

SCOPE AND RATIONAL FOR ANOTHER BOOK IN MULTIMEDIA

Multimedia is now a broad "umbrella" that innovatively combines different fields of research and industry to produce practical solutions that are used on a wide scale today. Some of these fields are signal processing, imaging and color science, video and audio analysis, 2D/3D graphics, information theory, compression, networking, databases, watermarking, encryption, mobile terminals, and user interfaces. Research in each field is progressing, and our need to consume digital information has been forever changing. This has resulted in novel multimedia applications and faster dissemination of information that is constantly making our life more convenient when it comes to communication, entertainment, learning, interacting, and so on.

There are many books that address the progress of each of these above-mentioned fields individually. And although there exist books that deal with multimedia systems, most of them have been rather weighted and biased toward explaining only one or a few aspects of multimedia as a whole. For instance, many multimedia books target only the networking and distributing aspects, or only the compression and storage aspects. There is no comprehensive textbook that puts all these concepts coherently together, explaining each area sufficiently enough to understand the problems, solutions, technologies, and standards that can ultimately be used to create broad end-to-end applications in this ever-evolving field.

This book intends to serve that purpose by bringing together the different aspects of a modern multimedia pipeline from content creation, compression, distribution, and consumption on different end terminals. This book is borne out of teachings that the author has been carrying out at the University of Southern California,

feedback from students, and, more important, the author's perspectives gained from working in the industry. We discuss the issues involved in architecting an end-to-end multimedia pipeline and give plenty of examples from the industry, including digital television, IPTV, mobile deployments, Digital Rights Management solutions, digital cinema pipelines, and so on. We also provide lots of practical questions and programming assignments, which are really projects, to augment the student's understanding of the text.

TARGET AUDIENCE AND PREREQUISITES

The content, explanations, and exercises in this book have been designed for senior-level undergraduate students or graduate students in engineering and technical art disciplines.

We do not expect that you have taken courses in all of the engineering fields mentioned and most of the explanations do not assume this. However, it will be helpful to your overall understanding of the multimedia field if you are familiar with one or more of these fields. With regard to exercises, all of them have a rating between 1 and 10, with 1 being very easy, needing only a few moments to answer, whereas a 10 might turn out to be a weekend project. The programming exercises at the end of every chapter should give you hands-on experience with relevant aspects of multimedia. Although we do not assume that you are an expert programmer, you will need to know basic programming or scripting to attempt these. We also provide starter code in C++ and Java, with many sample data sets for the programming exercises. These can be found on the publisher's Web site, *www.cengage.com*, under the Student Downloads section of the book's catalog page.

ORGANIZATION

We start with an introductory chapter that takes the reader from a naïve perspective of multimedia and provides a more concrete definition of multimedia explaining the history, evolution, and current status of what multimedia is today. It also explains the three-part organization of the chapters, each with many visual figures, exercises, programming assignments (programming starter code available at *www.cengage.com*), along with solutions to selected exercises. A complete solution set is available to instructors via the Instructor Downloads section of *www.cengage.com*.

The first part of the book deals with authoring, where we explain relevant issues involved in capturing, representing, and creating content. We start with the digitization process for all media types, explaining the theoretical and practical details, issues in rendering on various display/sound devices, working of cameras, and formats of different media types. Also described are paradigms used by commercial authoring tools in the creation of rich multimedia content for different consumers on high-bandwidth digital networks to low-bandwidth mobile networks. This part also explains each media type (text, images, video, audio, graphics) from its simplistic individual

aspects to more complex content formed by the combinations, such as surround sound, spatial audio, THX, composite, and component video.

The second part is devoted to the data economics of storage and transmission of multimedia content. It first gives an overview of compression, which discusses theoretical and practical limits of information compression as well as explains a taxonomy of algorithms/standards in lossless and lossy coding. The succeeding chapters in this section discuss how these generic compression ideas are purposefully used to minimize perceptual distortion in compressing each media type (images, video, audio, and graphics) with good illustration of examples through every stage of the algorithms. Also discussed are the prominent ISO and ITU compression standards, which include JPEG, JPEG2000, MPEG-1, MPEG-2, H.264, CELP, MP3, MIDI, Topological Surgery used in MPEG-4, X3D, Java3D, and so on. In many cases, we also discuss the bit stream organization and syntax in these relevant standards. We also give examples of user interfaces and parameters exposed by industry-grade compressors for video and graphics.

The third part of the book pays attention to more recent trends and applications in multimedia. Here, we show the paradigm shift in content description/distribution using the MPEG-4 standard compared with the earlier MPEG standards. It shows examples of how MPEG-4 works, where it is currently used, and what might be possible with the standard. One chapter is also devoted to multimedia databases, where we explain the role of semantic queries and the complication involved in formulating and processing semantic queries when compared with queries in standard text databases. We show how solutions in this area have proposed the use of metadata and depict standards that use metadata such as MPEG-7, TV-Anytime, Dublin Core, MXF, DMS-1, and so on. One future requirement of media consumption will be the creation of frameworks that can seamlessly exchange multimedia data with different networks. With many different kinds and brands of commercial networks becoming commonplace today—cell phone networks, Internet, digital cable networks—we discuss the current progress in MPEG-21 to create such a framework where seamless and commercial exchange can be possible.

Finally, the last chapter concludes with a summary of the content covered in the book as well as content that was left out deliberately or because of the changing progress in the field. We also illustrate the impact that multimedia information consumption and dissemination has had in our industry and society and provide a perspective on where the multimedia industry is likely to move in future.

TEACHING

The book contains more than enough material for a one-semester course on multimedia and can also be used for a two-semester course depending on the depth that an instructor might want to go into each topic. The book has been organized into three parts that progress sequentially. However, depending on the student comfort level and exposure to prerequisites, each part could be taught individually. In the

Computer Science Department at the University of Southern California, the authors have been teaching a one-semester course to graduate students majoring in computer science, electrical engineering, industrial engineering, arts, and sciences. The first half of the course has normally covered material in varying detail from the first two parts of the book. The second half of the course has covered selected chapters from the third parts, depending on overall student interests and the new technologies that had then been in the news.

ACKNOWLEDGEMENTS

A project succeeds because of the contribution of many people. I'd like to thank students of CSCI 576 at the University of Southern California. There are very many who have gone through the course and are now part of the multimedia industry. Every semester has brought forth engaging discussions, novel ideas, and invaluable feedback that have played a pivotal role in the structure of this textbook. I would like to thank the reviewers who helped shape the contents of the manuscript with their numerous suggestions and corrections: Michael Hennessy, University of Oregon; Chung-wei Lee, Auburn University; Roberto Manduchi, University of California, Santa Cruz; Gloria Melara, California State University, Northridge; Refaat Mohamed, Western Kentucky University; Jane Ritter, University of Oregon; and Matthew Turk, University of California, Santa Barbara. Finally, Green Pen Quality Assurance provided technical editing for each chapter. This text will be more useful to students because of their combined efforts.

I would like to thank all the professionals at Cengage Learning, especially Amy Jollymore, Alyssa Pratt, and Jennifer Feltri for their efforts and organization throughout the project. The quality of the textbook would not have been possible without their meticulous oversight and timely management during the production process.

I want to thank friends and family who made it possible for me to undertake and complete this book. In life, the balance of work, family time, parental responsibilities, health, and fun is very critical. This is especially so when you are simultaneously engaged in a large project such as writing a book. My parents instilled values in me that have helped me keep that balance. They have long waited for the completion of the textbook. My daughters Shreya and Veebha have missed me many times when I disappeared in their presence with my laptop and thoughts. And last, but the very most, I could not have done this without the understanding, the support, and the smiles of my wife Chandrani.

We are happy to answer any questions about the book, receive corrections, engage in discussions regarding this evolving field, and provide additional features to help readers have a fruitful experience with the textbook. Please feel free to contact Parag Havaldar directly at havaldar@usc.edu.

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