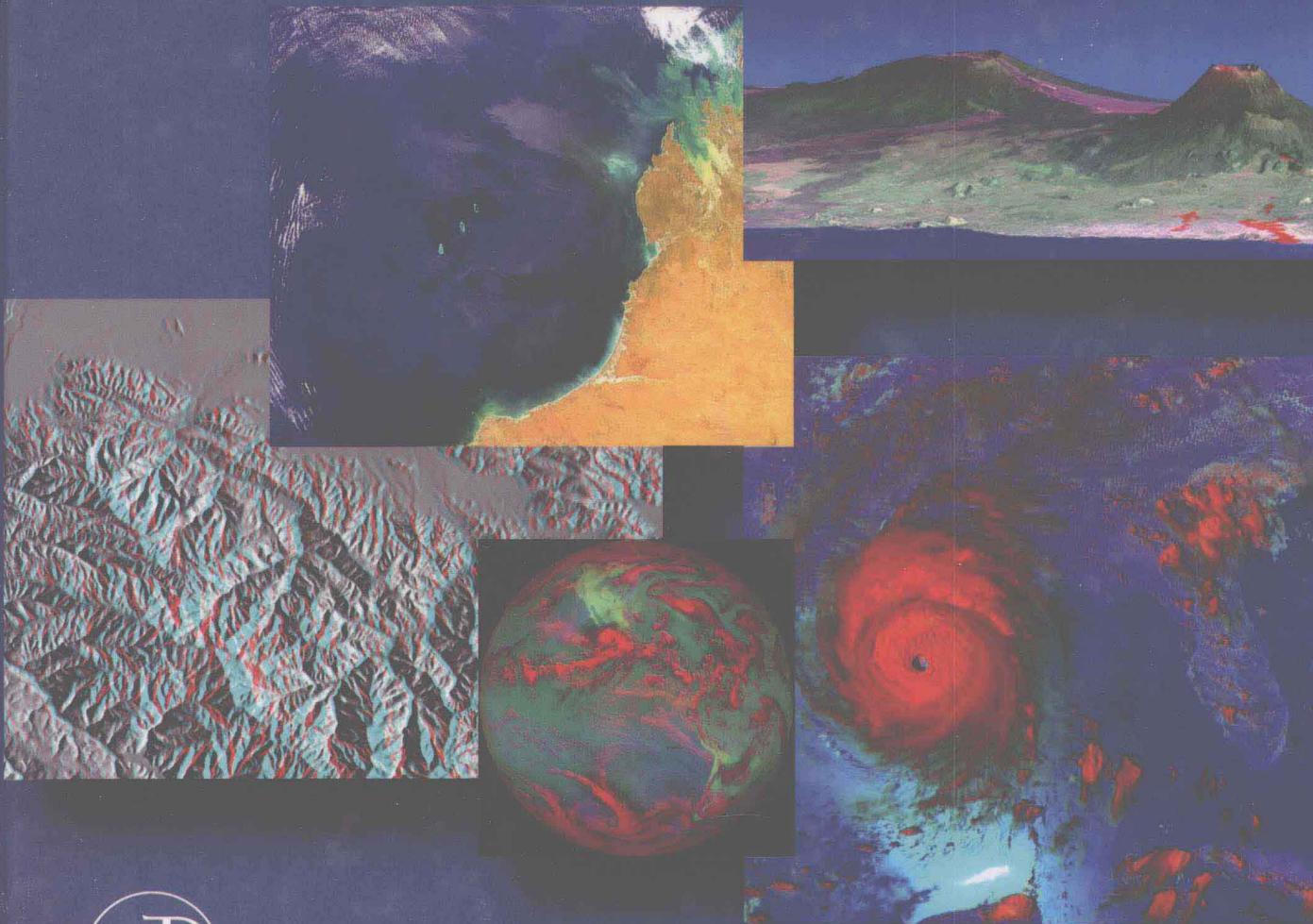


Robert A. Schowengerdt

REMOTE SENSING

Models and Methods for Image Processing

THIRD EDITION



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Third Edition

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Preface to the Third Edition

With nearly ten years since publication of the Second Edition of *Remote Sensing - Models and Methods for Image Processing*, the Third Edition provides a needed and comprehensive update. The changes include:

- Sensor updates, including the NASA satellites Terra, Aqua, and EO-1, and the commercial satellites IKONOS, OrbView, and Quickbird, with many new image examples
- Research literature updates for all topics
- New and expanded sections on
 - sensor spatial response modeling and measurement
 - MTF correction
 - atmospheric correction
 - multispectral fusion
 - noise reduction techniques
- 32 color plates, including more than 20 new to this edition, over fifteen new exercises, over forty new figures, and twenty revised figures
- Many improvements to the text and figures for improved teaching and understanding

The style of the Second Edition was retained throughout, but a new wider format permitted reorganization and rearrangement of many figures to better present concepts.

In preparing the Third Edition, I was struck (but perhaps really shouldn't have been) by two things. One is the continuing and even accelerating increase in the number of operating sensors from an expanding number of countries. In a practical sense, it was quite difficult to fit all the desired contemporary information into Fig. 1-1, and yet the figure is woefully incomplete in representing the systems currently available for remote sensing of the earth and its environment. Some anticipated future systems, such as the National Polar-orbiting Operational Environmental Satellite System (NPOESS), were deliberately excluded as their specifications may still change before launch.

The other major new realization is of the impressive amount of information available on the Internet, ranging from detailed sensor technical documentation to data itself. One is quite spoiled these days, sitting at a computer and accessing nearly all that is needed to do a book of this sort. For example, in looking for a MODIS image example of multispectral sensing of land, snow and clouds, I used a MODIS Direct Broadcast site operated by the U.S. Geological Survey (<http://modisdb.usgs.gov/>) to browse for suitable images and to download the recent images in Fig. 1-22. Another example is the Landsat-7 ETM+ image of Fig. 2-20; a search of the Internet for an ETM+ image of Lake Anna found this one at the Global Land Cover Facility at the University of Maryland (<http://glcf.umd.edu/>). Moreover, nearly all of my “library” research for this edition was done online using journal and conference paper databases, and government and commercial satellite websites. It almost makes you wonder if books are obsolete!

As was the case for the Second Edition, I’m indebted to many colleagues for their assistance in preparing the Third Edition. Among them are Ken Ando and John Vampola of Raytheon and Bill Rappoport of Goodrich Electro-Optical Systems who provided illustrations and information on real sensor focal planes, George Lemeschewsky of the U.S. Geological Survey for image examples and technical advice on multispectral image fusion and restoration, Jim Storey of USGS EROS/SAIC for discussions and technical input on countless topics throughout the book, and James Shepherd of Manaaki Whenua Landcare Research, New Zealand, and Dr. Rudolf Richter of the DLR/DFD, Germany, for kindly providing digital image files for publication of their work. I also want to thank the reviewers of my book proposal who provided many useful comments on topics to include and organization matters, and colleagues who took the time to send corrections to the Second Edition, which I’ve included in the new volume. In the end, however, I accept full responsibility for the material and any errors in the Third Edition.

I also thank the editors and production personnel at Elsevier and Alan Rose and Tim Donar of Multiscience Press for their patience and collaboration in producing the Third Edition. Despite all the powerful computer tools and access available now to authors, creation of a real, “hold in your hand” book requires the teamwork of many capable and conscientious professionals.

At the completion of this Third Edition, it is especially important to me to acknowledge mentors throughout my life and career, including my parents, who set me on the right path, my graduate advisor, Prof. Phil Slater, who kept me on the right path and paved the way in many cases, inspiring teachers and students, and colleagues at the University of Arizona, NASA, USGS, and many other organizations who’ve made it all interesting and enjoyable. I’m especially mindful of two friends and co-authors, Prof. Steve Park and Jim Fahnestock, who died years too early. Lastly, I most appreciate my family’s support through all three editions. To one and all, thank you!

Robert A. Schowengerdt
Tucson, Arizona
June 2006

Preface to the Second Edition

This book began as a rather conservative revision of my earlier textbook, *Techniques for Image Processing and Classification in Remote Sensing*. Like many “limited” endeavors, however, it soon grew to be a much larger project! When it became clear that simply a revision would not suffice, I gave considerable thought on a new way to present the subject of image processing in the context of remote sensing. After much mental wandering about, it became clear that there was a unifying theme through many of the image processing methods used in remote sensing, namely that they are based, directly or indirectly, on *models* of physical processes. In some cases there is a direct dependence, for example, on physical models that describe orbital geometry or the reflectance of radiation. In other cases, the dependence is indirect. For example, the common assumption of data similarity implies that neighboring pixels in the space or spectral domains are likely to have similar values. The origin of this similarity is in the physical processes leading up to the acquisition of the data, and in the acquisition itself. In nearly all cases, the motivation and rationale for remote sensing image processing algorithms can be traced to an assumption of one or more such models. Thus, I settled on this viewpoint for the book.

It was obvious from the beginning that the book should be an entirely digital production. The computer tools currently available for desktop publishing easily support this, and given the subject matter, seem almost obligatory. Therefore, extensive use is made of computer-generated graphics and image processing. Nearly all figures are entirely new and produced especially for this edition. Three-dimensional graphing programs were used to visualize multidimensional data, and an assortment of desktop image processing programs was used to produce the images. These include in particular, IPT, a development version of the MacSADIE image processing software from my laboratory, and MultiSpec, a multispectral classification program from David Landgrebe’s laboratory at Purdue University.

To enhance the use of the book in the classroom, exercises are included for each chapter. They range from conceptual, “gedanken” experiments to mathematical derivations. The exercises are intended to promote an understanding of the material presented in the chapter. Extensive bibliographies of many of the subjects covered are provided in the form of tables to conserve space and provide a compact source for further information. In the references, I’ve emphasized archival journal

papers, because they are generally easiest for the reader to acquire.

Chapter 1 provides an overview of remote-sensing science and technology as of 1996. The basic parameters for optical remote sensing are established here, and the main types of scanning sensors are described. In Chapter 2, the most important optical radiation processes in remote-sensing are described mathematically. These include solar radiation, atmospheric scattering, absorption and transmission, and surface reflectance. The wavelength region from 400nm wavelength to the thermal infrared is analyzed. Sensor models for radiometric and spatial response are explained in Chapter 3. Satellite imaging geometry is also included because of its importance for image rectification and geocoding and for extraction of elevation information from stereo images.

In Chapter 4, data models provide a transition between the physical models of Chapters 2 and 3 and the image processing methods of later chapters. Spectral and spatial statistical models for remote sensing data are described. A series of imaging simulations illustrate and explain the influence of the sensor's characteristics on the data acquired by remote-sensing systems.

Chapter 5 begins the discussion of image processing methods and covers spectral transforms, including various vegetation indices, principal components and contrast enhancement. Chapter 6 includes convolution and Fourier filtering, multiresolution image pyramids and scale-space techniques such as wavelets. The latter types of image analyses appear to have considerable potential for efficient and effective spatial information extraction. The concept of image spatial decomposition into two or more components is used here to provide a link among the different spatial transforms. In Chapter 7, several examples of the use of image processing for image radiometric and geometric calibration are given. The importance of image calibration for high spectral resolution imagery ("hyperspectral") data is also discussed. The topic of multiimage fusion is addressed in Chapter 8, with reference to the spatial decomposition concept of Chapter 6. The various approaches are explained and illustrated with Landsat TM multispectral and SPOT panchromatic image fusion. An image pyramid-based scheme for digital elevation model (DEM) extraction from a stereo image pair is also described in detail. Chapter 9 is devoted to thematic classification of remote-sensing images, including the traditional statistical approaches and newer neural network and fuzzy classification methods. Techniques specifically developed for hyperspectral imagery are also described.

Some topics that one usually finds in a remote sensing image processing book, such as classification map error analysis, were deliberately excluded. This was done not only for space reasons, but also because I felt they departed too far from the main theme of the relation of image processing methods to remote sensing physical models. Likewise, classification methods such as rule-based systems that rely on higher level abstractions of the data, although effective and promising in many cases, are not described. I also view Geographic Information Systems (GIS) as being outside the scope of this work.

I'm indebted to many colleagues for their advice and assistance. In some cases, their contributions

were substantial: Phil Slater and Kurt Thome (Optical Sciences Center, University of Arizona) provided knowledgeable guidance to keep me on the right path in Chapters 2 and 3, as did Jennifer Dungan (NASA/Ames Research Center) with respect to Chapter 4. Others provided reviews of selected portions, including Chuck Hutchinson and Stuart Marsh (Office of Arid Lands Studies, University of Arizona) and Chris Hlavka (NASA/Ames Research Center). I also wish to acknowledge the insight provided by Eric Crist (Environmental Research Institute of Michigan) on the tasseled cap transformation. Many of my former and current students provided invaluable data and examples, including Dan Filiberti (Science Applications International Corporation), Steve Goisman (University of Arizona), Per Lysne (University of Arizona), Justin Paola (Oasis Research Center), and Ho-Yuen Pang (University of Arizona). Gerhard Mehlau (Photogrammetrie GMBH) supported my efforts with updated versions of IPT. Colleagues in the U. S. Geological Survey, including William Acevedo, Susan Benjamin, Brian Bennett, Rick Champion, Len Gaydos and George Lee, and Jeff Meyers of the NASA/Ames Research Center, kindly supplied image and digital elevation data that provided important examples throughout the book. I would also like to thank Peter B. Keenan, a longtime friend and colleague, for helping me collect ground truth by bicycle on a typically beautiful day in the San Francisco Bay area!

I am grateful for technical and management contributions by several editors and professional staff at Academic Press, including Lori Asbury, Sandra Lee and Bruce Washburn of the San Diego office, and Diane Grossman, Abby Heim and Zvi Ruder of the Chestnut Hill office.

Finally, I must thank my family, Amy, Andrea and Jennifer, for they sacrificed more than I did during the long hours devoted to this book. Hopefully, the result is to some degree worthy of their support.

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