The IMAGE PROCESSING Handbook

Fourth Edition

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Introduction

Image processing is used for two somewhat different purposes:

1. Improving the visual appearance of images to a human viewer
2. Preparing images for measurement of the features and structures present

The techniques that are appropriate for each of these tasks are not always the same, but there is considerable overlap. This book covers methods that are used for both tasks.

To do the best possible job, it helps to know about the uses to which the processed images will be put. For visual enhancement, this means having some familiarity with the human visual process, and an appreciation of what cues the viewer responds to in images. It is also useful to know about the printing or display process, because many images are processed in the context of reproduction or transmission.

The measurement of images generally requires that features be well defined, either by edges or unique brightness, color, texture, or some combination of these factors. The types of measurements that will be performed on entire scenes or individual features are important in determining the appropriate processing steps.

It may help to recall that image processing, similar to food processing or word processing, does not reduce the amount of data present but simply rearranges it. Some arrangements may be more appealing to the senses, and some may convey more meaning, but these two criteria may not be identical nor call for identical methods.

This handbook presents an extensive collection of image processing tools, so that the user of computer-based systems can both understand those methods provided in packaged software, and program those additions that may be needed for particular applications. Comparisons are presented of different algorithms that may be used for similar purposes, using a selection of representative pictures from light and electron microscopes, as well as macroscopic, remote sensing and astronomical images.

In revising the book for this new edition, I tried to respond to some of the comments and requests of readers and reviewers. New chapters on the measurement of images and the subsequent interpretation of the data were added in the second edition, and a section on surface images was added in the third edition. New chapters in this edition discuss in some depth the

stereological interpretation of measurements on sections through three-dimensional structures, and the various logical approaches to feature classification. The sections on the ever-advancing hardware for image capture and printing have been expanded and information added on the newest technologies. More examples have been added in every chapter, and the reference list was expanded and brought up to date.

As in past editions, I resisted suggestions to put "more of the math" into the book. Excellent texts are available on image processing, compression, mathematical morphology, etc. that provide as much rigor and as many derivations as may be needed. Many of them are referenced here, but the thrust of this book remains teaching by example. Few people learn the principles of image processing from the equations. Just as we use images to "do science," so most of us use images to learn about many things, including imaging itself. The hope is that, by seeing what various operations do to representative images, you will discover how and why to use them. Then, if you need to look up the mathematical foundations, they will be easier to understand.

The reader is encouraged to use this book in concert with a real source of images and a computer-based system, and to freely experiment with different methods to determine which are most appropriate for his or her particular needs. Selection of image processing tools to explore images when you do not know the contents beforehand is a much more difficult task than using tools to make it easier for another viewer or a measurement program to see the same things you have discovered. It places greater demand on computing speed and the interactive nature of the interface, but it particularly requires that you become a very analytical observer of images. If you can learn to see what the computer sees, you will become a better viewer and obtain the best possible images, suitable for further processing and analysis.

To facilitate this hands-on learning process, I collaborated with my son, Chris Russ, to produce a CD-ROM that can be used as a companion to this book. The Image Processing Tool Kit contains more than 300 images, many of them the examples from the book, plus nearly 200 Photoshop-compatible plug-ins that implement many of the algorithms discussed here. These can be used with Adobe Photoshop® or any of the numerous programs (some of them free), which implement the Photoshop plug-in interface, on either Macintosh or Windows computers. Information about the CD-ROM is available on-line at http://ReindeerGraphics.com/

Acknowledgments

All the image processing and the creation of the resulting figures included in this book were performed on an Apple Macintosh® computer. Many of the images were acquired directly from various microscopes and other sources using color or monochrome video cameras and digitized directly into the computer. Others were digitized using a digital camera (most with a Polaroid DMC), and some were obtained using a 36-bit color scanner (Agfa), often from images supplied by many co-workers and researchers. These are acknowledged wherever the origin of an image could be determined. A few examples, taken from the literature, are individually referenced.

The book was delivered to the publisher in digital form (on a writable CD), without intermediate hard copy, negatives, or prints of the images, etc. Among other things, this means that the author must bear full responsibility for any errors because no traditional typesetting was involved. (It has also forced me to learn more than I ever hoped to know about some aspects of this technology!) However, going directly from disk file to print also shortens the

time needed in production and helps to keep costs down, while preserving the full quality of the images. Grateful acknowledgment is made of the efforts by the editors at CRC Press to educate me and to accommodate the unusually large number of illustrations in this book (about 2000 figures and a quarter of a million words).

Special thanks are due to Chris Russ (Reindeer Games Inc., Asheville, NC), who has helped to program many of these algorithms and contributed invaluable comments, and to Helen Adams, who has proofread many pages, endured many discussions, and provided the moral support that make writing projects such as this possible.

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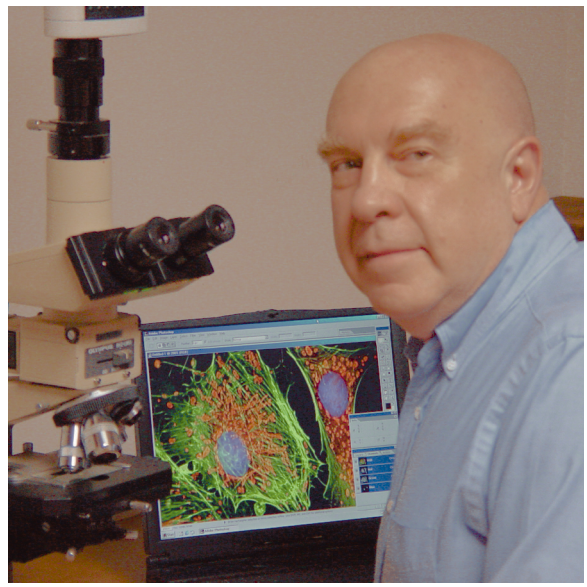

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