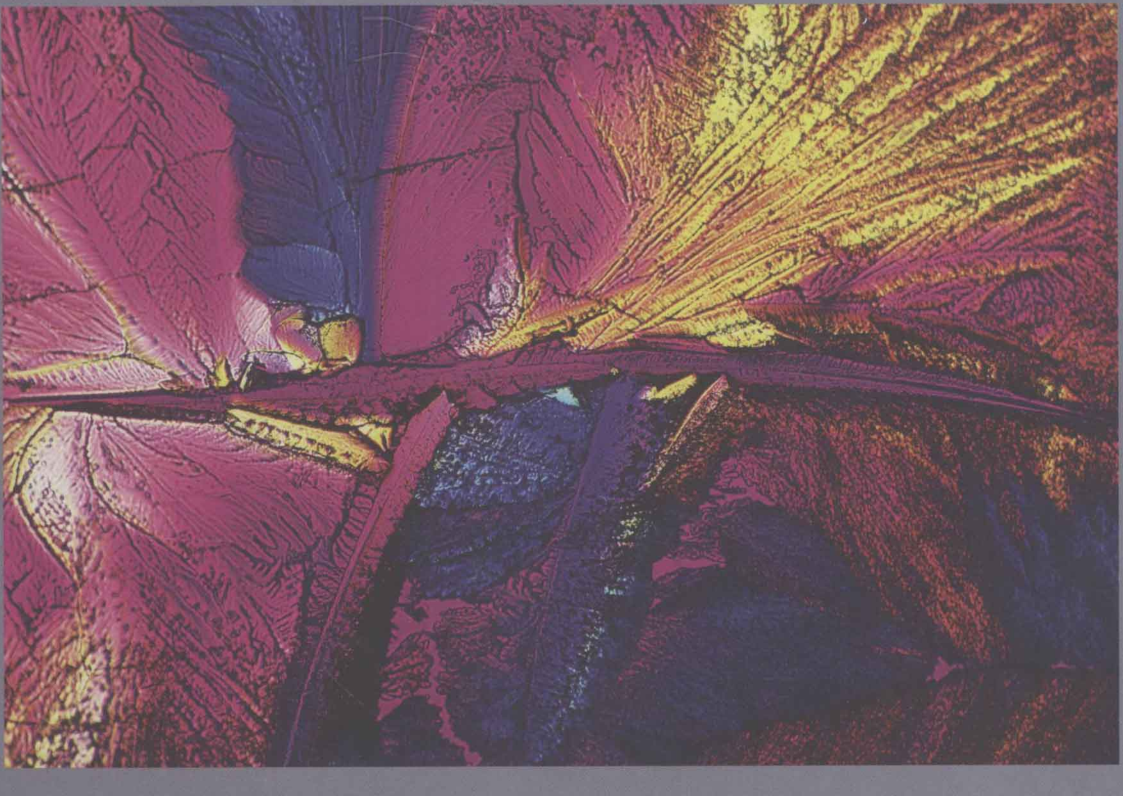
TEXTS IN COMPUTER SCIENCE

Digital Image Processing

An Algorithmic Introduction Using Java



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An Algorithmic Introduction using Java

First Edition

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Preface

This book provides a modern, self-contained introduction to digital image processing. We designed the book to be used both by learners desiring a firm foundation on which to build and practitioners in search of critical analysis and modern implementations of the most important techniques. This is the first English edition of the original German-language book, which has been widely used by:

- Scientists, and engineers who use image processing as a tool and wish to develop a deeper understanding and create custom solutions to imaging problems in their field.
- Information technology (IT) professionals wanting a self-study course featuring easily adaptable code and completely worked out examples enabling them to be productive right away.
- Faculty and students desiring an example-rich introductory textbook suitable for an advanced undergraduate or graduate level course that features exercises, projects, and examples that have been honed during our years of experience teaching this material.

While we concentrate on practical applications and concrete implementations, we do so without glossing over the important formal details and mathematics necessary for a deeper understanding of the algorithms. In preparing this text, we started from the premise that simply creating a recipe book of imaging solutions would not provide the deeper understanding needed to apply these techniques to novel problems, so instead our solutions are developed stepwise from three different perspectives: in mathematical form, as abstract pseudocode algorithms, and as complete Java programs. We use a common notation to intertwine all three perspectives—providing multiple, but linked, views of the problem and its solution.

Prerequisites

Instead of presenting digital image processing as a mathematical discipline, or strictly as signal processing, we present it from a practitioner's and programmer's perspective and with a view toward replacing many of the formalisms commonly used in other texts with constructs more readily understandable by our audience. To take full advantage of the *programming* components of this book, a knowledge of basic data structures and object-oriented programming, ideally in Java, is required. We selected Java for a number of reasons, one of which is that it is the first programming language learned by students in a wide variety of engineering curricula. Practitioners with knowledge of a related language, especially C or C++, will find the programming examples easy to follow and extend.

The software in this book is designed to work with ImageJ, a widely used programmer-extensible imaging system developed, maintained, and distributed by Wayne Rasband of the National Institutes of Health (NIH).[1] ImageJ is implemented completely in Java, and therefore runs on all major platforms, and is widely used because its "plugin"-based architecture enables it to be easily extended. While all examples run in ImageJ, they have been specifically designed to be easily ported to other environments and programming languages.

Use in research and development

This book has been especially designed for use as a textbook and as such features exercises and carefully constructed examples that supplement the detailed synthesis of the fundamental concepts and techniques. As both practitioners and developers, we know that the details required for successful understanding and application of classical techniques are often difficult to find, and for this reason we have been very careful to provide the details, many gleaned over years of practical application, necessary to successfully apply these techniques. While this should make the text particularly valuable to those in research and development, it is not designed as a comprehensive, fully cited scientific research text. On the contrary, we have carefully vetted our citations so that they can be obtained from easily accessible sources. While we have only briefly discussed the fundamentals of, or entirely omitted, topics such as hierarchical methods, wavelets, or eigenimages because of space limitations, other topics have been omitted deliberately, including advanced issues such as object recognition, image understanding, or three-dimensional computer vision. So while most techniques described in this book could be called "blind and dumb", it is our experience that straightforward, technically clean implementations of these simpler methods are essential to the success of any further domain-specific, or even "intelligent" approaches.

If you are only in search of a programming handbook for ImageJ or Java, there are certainly better sources. While the book includes a comprehensive ImageJ reference and many code examples, programming in and of itself is not our main focus. Instead it serves as just one important element for describing each technique in a precise and immediately testable way.

[1] http://rsb.info.nih.gov/ij/.

Why we wrote this book

Whether it is called signal processing, image processing, or media computation, the manipulation of digital images has been an integral part of most computer science and engineering curricula for many years. Today, with the omnipresence of all-digital work flows it has become an integral part of the required skill set for professionals in diverse disciplines. Previous to the explosion of digital media, it was often the case that a computing curriculum would offer only a single course, called "Digital Signal Processing" in engineering or "Digital Image Processing" in computing, and likely only as a graduate elective.

Today the topic has migrated into the early stages of many curricula, where it now serves as a key foundation course. This migration uncovered a problem in that many of the texts relied on as standards in the older graduate-level courses were not appropriate for beginners. The texts were usually too formal for beginners, and at the same time did not provide detailed coverage of many of the most popular methods used in actual practice. The result was that educators had a difficult time selecting a single textbook or even finding a compact collection of literature to recommend to their students. Faced with this dilemma ourselves, we wrote this book in the sincere hope of filling a need.

The contents of the following chapters can be presented in either a one- or two-semester sequence. Where it was feasible, we have added supporting material in order to make each chapter as independent as possible and provide the instructor with as much flexibility as possible when designing the course. Chapters 13–15 offer a complete introduction to the fundamental spectral techniques used in image processing and are essentially independent of the other material in the text. Depending on the goals of the instructor and the curriculum, they can be covered in as much detail as required or completely omitted.

The road map (on page VIII) provides a sequence of topics for a one- or two-semester syllabus.

One Semester: A one-semester course can be organized around either of two major themes: image *processing* or image *analysis*. While either theme integrates easily into the early semesters of a modern computer science or IT curriculum, image analysis is especially appropriate as an early foundation course in medical informatics.

Two Semesters: When the content can be presented over two semesters, it has been designed so that it can be coherently divided (as described below) into two courses (*fundamentals* and *advanced*) where the themes are grouped according to difficulty.

Supplement to the English edition

This book was translated by the authors from the second German edition (published in 2006) [17], incorporating many enhancements throughout

Road Map for One- and Two-Semester Courses	Image Processing	Image Analysis	Fundamentals	Advanced
1. Crunching Pixels	☒	☒	☒	☐
2. Digital Images	☒	☒	☒	☐
3. ImageJ	☒	☒	☒	☐
4. Histograms	☒	☐	☒	☐
5. Point Operations	☒	☐	☒	☐
6. Filters	☒	☒	☒	☐
7. Edges and Contours	☒	☒	☒	☐
8. Finding Points of Interest	☐	☒	☐	☒
9. Detecting Simple Curves	☐	☒	☐	☒
10. Morphological Filters	☒	☐	☒	☐
11. Regions in Binary Images	☐	☒	☒	☐
12. Color Images	☒	☐	☐	☒
13. Introduction to Spectral Techniques	☐	☒	☐	☒
14. The Discrete Fourier Transform in 2D	☐	☒	☐	☒
15. The Discrete Cosine Transform	☐	☐	☐	☒
16. Geometrical Image Operations	☒	☐	☐	☒
17. Image Comparison	☐	☒	☐	☒
	1 Sem.		2 Sem.	

the text. In addition to the numerous small corrections and improvements that have been made, the presentation of histogram matching in Ch. 5, geometric region properties based on moments in Ch. 11, morphological filters in Ch. 10, and interpolation methods in Ch. 16 have been completely revised. Also, a number of example programs, such as the single-pass region labeling and contour finding algorithm (Sec. 11.2.2), have been rewritten for improved clarity and to take advantage of the new language features in Java 5.

Online resources

Visit the Website for this text

www.imagingbook.com

to download supplementary materials, including the complete Java source code for the examples, the test images used in the examples, and corrections. Additional materials are available for educators, including a complete set of formulas and figures used in the text, in a format suitable for inclusion in presentations. Comments, questions, and corrections are welcome and should be addressed to

imagingbook@gmail.com

Thank you

This book would not have been possible without the understanding and support of our families. Our thanks go to Wayne Rasband (NIH) for developing ImageJ and for his truly outstanding support of the community, to our colleagues Prof. Axel Pinz (TU Graz) and Prof. Vaclav Hlavac (TU Prague) for their comments, and to all the readers of the first two editions who provided valuable input, suggestions for improvement, and encouragement as we translated this edition. The authors greatly appreciate the help of their brave Sony and Apple notebooks that performed an estimated 1.6 quadrillion (10^{15}) CPU cycles to prepare this manuscript, thereby consuming about 560 kWh of electric energy and producing 196 kg of carbon dioxide. Finally, we owe a debt of gratitude to the professionals at Springer-Verlag, Ursula Zimpfer and Jutta Maria Fleschutz, who led the German edition team, and Wayne Wheeler, Catherine Brett, and Jeffrey Taub who were responsible for the English edition.

Hagenberg, Austria / Washington DC, USA
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