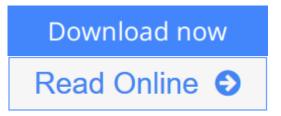# Digital Image Processing Using MATLAB

By Rafael C. Gonzalez, Richard E. Woods, Steven L. Eddins

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For Image and Computer Vision, Image Processing, and Computer Vision courses. This is the first text that provides a balanced treatment of image processing fundamentals and an introduction to software principles used in the practical application of image processing. A seamless integration of material from the leading text, Digital Image Processing by Gonzalez and Woods and the Image Processing Toolbox from Mathworks, Inc. This text works in the MATLAB computing environment; the Toolbox provides a stable, well-supported set of software tools capable of addressing a broad spectrum of applications in digital image processing. The major areas covered include intensity transformations, linear and nonlinear spatial filtering, filtering in the frequency domain, image restoration and registration, color image processing, wavelets, image data compression, morphological image processing, image segmentation, regions and boundary representation and description, and object recognition.

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Editorial Review

From the Back Cover

Digital Image Processing Using MATLAB is the first book that provides a balanced treatment of image processing fundamentals and the software principles used in their practical implementation. The book integrates material from the leading text, *Digital Image Processing* by Gonzalez and Woods, and the Image Processing Toolbox of the MathWorks. Inc., a recognized leader in scientific computing. The Image Processing Toolbox provides a stable, well-supported set of software tools for addressing a broad range of applications in digital image processing. A unique feature of this hook is its emphasis on showing how to enhance those tools by the development of new code. This is important in image processing, where there is a need for extensive experimental work in order to arrive at acceptable problem solutions.

After an introduction to the fundamentals of MATLAB programming, the book addresses the mainstream areas of image processing. Areas covered include intensity transformations, linear and nonlinear spatial filtering, filtering in the frequency domain, image restoration and registration, color image processing, wavelets, image data compression, morphological image processing, image segmentation, regions and boundary representation and description, and object recognition.

Some Highlights

- The book is self-contained.
- Over 60 new image processing functions are developed—a 35% increase over the comprehensive set of functions in the Image Processing Toolbox.
- A fully documented listing of every new function developed is included in the book.
- Using C code with MATLAB is covered in detail.
- There are 114 examples, over 400 images, and over 150 graphs and line drawings that enhance the discussion of the material.
- All MATLAB, Image Processing Toolbox, and new functions used in the book, are conveniently summarized in an appendix.
- The design of graphical user interfaces (GUIs) is covered in detail.
- A book web site provides complimentary support.

About the Author

Rafael C. Gonzalez. R.C. Gonzalez received the B.S.E.E. degree from the University of Miami in 1965 and the M.E. and Ph.D. degrees in electrical engineering from the University of Florida, Gainesville, in 1967 and 1970, respectively. He joined the Electrical and Computer Engineering Department at the University of Tennessee, Knoxville (UTK) in 1970, where he became Associate Professor in 1973, Professor in 1978, and Distinguished Service Professor in 1984. He served as Chairman of the department from 1994 through 1997. He is currently a Professor Emeritus of Electrical and Computer Engineering at UTK.

He is the founder of the Image & Pattern Analysis Laboratory and the Robotics & Computer Vision Laboratory at the University of Tennessee. He also founded Perceptics Corporation in 1982 and was its president until 1992. The last three years of this period were spent under a full-time employment contract with Westinghouse Corporation, who acquired the company in 1989. Under his direction, Perceptics became

highly successful in image processing, computer vision, and laser disk storage technologies. In its initial ten years, Perceptics introduced a series of innovative products, including: The world's first commercially-available computer vision system for automatically reading the license plate on moving vehicles; a series of large-scale image processing and archiving systems used by the U.S. Navy at six different manufacturing sites throughout the country to inspect the rocket motors of missiles in the Trident II Submarine Program; the market leading family of imaging boards for advanced Macintosh computers; and a line of :trillion-byte laser disk products.

He is a frequent consultant to industry and government in the areas of pattern recognition, image processing, and machine learning. His academic honors for work in these fields include the 1977 UTK College of Engineering Faculty Achievement Award; the 1978 UTK Chancellor's Research Scholar Award; the 1980 Magnavox Engineering Professor Award; and the 1980 M. E. Brooks Distinguished Professor Award. In 1981 he became an IBM Professor at the University of Tennessee and in 1984 he was named a Distinguished Service Professor there. He was awarded a Distinguished Alumnus Award by the University of Miami in 1985, the Phi Kappa Phi Scholar Award in 1986, and the University of Tennessee's Nathan W Dougherty Award for Excellence in Engineering in 1992. Honors for industrial accomplishment include the 1987 IEEE Outstanding Engineer Award for Commercial Development in Tennessee; the 1988 Albert Rose National Award for Excellence in Commercial Image Processing; the 1989 B. Otto Wheeley Award for Excellence in Technology Transfer; the 1989 Coopers and Lybrand Entrepreneur of the Year Award; the 1992 IEEE Region 3 Outstanding Engineer Award; and the 1993 Automated Imaging Association National Award for Technology Development.

Dr. Gonzalez is author or co-author of over 100 technical articles, two edited books, and five textbooks in the fields of pattern recognition, image processing, and robotics. His books are used in over 500 universities and research institutions throughout the world. He is listed in the prestigious Marquis *Who's Who in America, Marquis Who's Who in Engineering, Marquis Who's Who in the World,* and in 10 other national and international biographical citations. He is the co-holder of two U.S. Patents, and has been an associate editor of the *IEEE Transactions on Systems, Man and Cybernetics,* and the International Journal of Computer and Information Sciences. He is a member of numerous professional and honorary societies, including Tau Beta Pi, Phi Kappa Phi, Eta Kappa Nu, and Sigma Xi. He is also a Fellow of the IEEE.

Richard E. Woods earned his B.S., M.S., and Ph.D. degrees in Electrical Engineering from the University of Tennessee, Knoxville. His professional experiences range from entrepreneurial to the more traditional academic, consulting, governmental, and industrial pursuits. Most recently, he founded MedData Interactive, a high technology company specializing in the development of handheld computer systems for medical applications. He was also a founder and Vice President of Perceptics Corporation, where he was responsible for the development of many of the company's quantitative image analysis and autonomous decision making products.

Prior to Perceptics and MedData, Dr. Woods was an Assistant Professor of Electrical Engineering and Computer Science at the University of Tennessee and priors to that, a computer applications engineer at Union Carbide Corporation. As a consultant, he has been involved in the development of a number of special-purpose digital processors for a variety of space and military agencies, including NASA, the Ballistic Missile Systems Command, and the Oak Ridge National Laboratory.

Dr. Woods has published numerous articles related to digital signal processing and is co-author of Digital Image Processing, the leading text in the field. He is a member of several professional societies, including Tau Beta Pi, Phi Kappa Phi, and the IEEE. In 1986, he was recognized as a Distinguished Engineering Alumnus of the University of Tennessee.

Steven L. Eddins is development manager of the image processing group at The MathWorks, Inc. He led the development of several versions of the company's Image Processing Toolbox. His professional interests include building software tools that are based on the latest research in image processing algorithms, and that have a broad range of scientific and engineering applications.

Prior to joining The MathWorks, Inc. in 1993, Dr. Eddins was on the faculty of the Electrical Engineering and Computer Science Department at the University of Illinois, Chicago. There he taught graduate and senior-level classes in digital image processing, computer vision, pattern recognition, and filter design, and he performed research in the area of image compression.

Dr. Eddins holds a B.E.E. (1986) and a Ph.D. (1990), both in electrical engineering from the Georgia Institute of Technology. He is a member of the IEEE.

Solutions to problems in the field of digital image processing generally require extensive experimental work involving software simulation and testing with large sets of sample images. Although algorithm development typically is based on theoretical underpinnings, the actual implementation of these algorithms almost always requires parameter estimation and, frequently, algorithm revision and comparison of candidate solutions. Thus, selection of a flexible, comprehensive, and well-documented software development environment is a key factor that has important implications in the cost, development time, and portability of image processing solutions.

In spite of its importance, surprisingly little has been written on this aspect of the field in the form of textbook material dealing with both theoretical principles and software implementation of digital image processing concepts. This book was written for just this purpose. Its main objective is to provide a foundation for implementing image processing algorithms using modern software tools. A complementary objective was to prepare a book that is self-contained and easily readable by individuals with a basic background in digital image processing, mathematical analysis, and computer programming, all at a level typical of that found in a junior/senior curriculum in a technical discipline. Rudimentary knowledge of MATLAB also is desirable.

To achieve these objectives, we felt that two key ingredients were needed. The first was to select image processing material that is representative of material covered in a formal course of instruction in this field. The second was to select software tools that are well supported and documented, and which have a wide range of applications in the "real" world.

To meet the first objective, most of the theoretical concepts in the following chapters were selected from *Digital Image Processing* by Gonzalez and Woods, which has been the choice introductory textbook used by educators all over the world for over two decades. The software tools selected are from the MATLAB Image Processing Toolbox (IPT), which similarly occupies a position of eminence in both education and industrial applications. A basic strategy followed in the preparation of the book was to provide a seamless integration of well-established theoretical concepts and their implementation using state-of-the-art software tools.

The book is organized along the same lines as *Digital Image Processing.* In this way, the reader has easy access to a more detailed treatment of all the image processing concepts discussed here, as well as an up-to-date set of references for further reading. Following this approach made it possible to present theoretical material in a succinct manner and thus we were able to maintain a focus on the software implementation aspects of image processing problem solutions. Because it works in the MATLAB computing environment, the Image Processing Toolbox offers some significant advantages, not only f in the breadth of its

computational tools, but also because it is supported under most operating systems in use today. A unique feature of this book is its emphasis on showing how to develop new code to enhance existing MATLAB and IPT functionality This is an important feature in an area such as image processing, which, as noted earlier, is characterized by the need for extensive algorithm development and experimental work.

After an introduction to the fundamentals of MATLAB functions and programming, the book proceeds to address the mainstream areas of image processing. The major areas covered include intensity transformations, linear and nonlinear spatial filtering, filtering in the frequency domain, image restoration and registration, color image processing, wavelets, image data compression, morphological image processing, image segmentation, region and boundary representation and description, and object recognition. This material is complemented by numerous illustrations of how to solve image processing problems using MATLAB and IPT functions. In cases where a function did not exist, a new function was written and documented as part of the instructional focus of the book. Over 60 new functions are included in the following chapters. These functions increase the scope of IPT by approximately 35 percent and also serve the important purpose of further illustrating how to implement new image processing software solutions.

The material is presented in textbook format, not as a software manual. Although the book is self-contained, we have established a companion Web site (see Section 1.5) designed to provide support in a number of areas. For students following a formal course of study or individuals embarked on a program of self study, the site contains tutorials and reviews on background material, as well as projects and image databases, including all images in the book. For instructors, the site contains classroom presentation materials that include PowerPoint slides of all the images and graphics used in the book. Individuals already familiar with image processing and IPT fundamentals will find the site a useful place for up-to-date references, new implementation techniques, and a host of other support material not easily found elsewhere. All purchasers of the book are eligible to download executable files of all the new functions developed in the text.

As is true of most writing efforts of this nature, progress continues after work on the manuscript stops. For this reason, we devoted significant effort to the selection of material that we believe is fundamental, and whose value is likely to remain applicable in a rapidly evolving body of knowledge. We trust that readers of the book will benefit from this effort and thus find the material timely and useful in their work.

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