Digital Image Processing for Ophthalmology

Detection of the Optic Nerve Head

© Springer Nature Switzerland AG 2022
Reprint of original edition © Morgan & Claypool 2011

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means—electronic, mechanical, photocopy, recording, or any other except for brief quotations in printed reviews, without the prior permission of the publisher.

Digital Image Processing for Ophthalmology: Detection of the Optic Nerve Head

Xiaolu Zhu, Rangaraj M. Rangayyan, and Anna L. Ells

ISBN: 978-3-031-00521-3 paperback
ISBN: 978-3-031-01649-3 ebook

DOI 10.1007/978-3-031-01649-3

A Publication in the Springer series
SYNTHESIS LECTURES ON BIOMEDICAL ENGINEERING

Lecture #40
Series Editor: John D. Enderle, *University of Connecticut*
Series ISSN
Synthesis Lectures on Biomedical Engineering
Print 1930-0328 Electronic 1930-0336

Synthesis Lectures on Biomedical Engineering

Editor
John D. Enderle, ***University of Connecticut***

Lectures in Biomedical Engineering will be comprised of 75- to 150-page publications on advanced and state-of-the-art topics that spans the field of biomedical engineering, from the atom and molecule to large diagnostic equipment. Each lecture covers, for that topic, the fundamental principles in a unified manner, develops underlying concepts needed for sequential material, and progresses to more advanced topics. Computer software and multimedia, when appropriate and available, is included for simulation, computation, visualization and design. The authors selected to write the lectures are leading experts on the subject who have extensive background in theory, application and design.
The series is designed to meet the demands of the 21st century technology and the rapid advancements in the all-encompassing field of biomedical engineering that includes biochemical, biomaterials, biomechanics, bioinstrumentation, physiological modeling, biosignal processing, bioinformatics, biocomplexity, medical and molecular imaging, rehabilitation engineering, biomimetic nano-electrokinetics, biosensors, biotechnology, clinical engineering, biomedical devices, drug discovery and delivery systems, tissue engineering, proteomics, functional genomics, molecular and cellular engineering.

Digital Image Processing for Ophthalmology: Detection of the Optic Nerve Head
Xiaolu Zhu, Rangaraj M. Rangayyan, and Anna L. Ells
2011

Modeling and Analysis of Shape with Applications in Computer-Aided Diagnosis of Breast Cancer
Denise Guliato and Rangaraj M. Rangayyan
January 2011

Analysis of Oriented Texture with Applications to the Detection of Architectural Distortion in Mammograms
Fábio J. Ayres, Rangaraj M. Rangayyan, and J. E. Leo Desautels
2010

Fundamentals of Biomedical Transport Processes
Gerald E. Miller
2010

Introductory Medical Imaging
A. A. Bharath
2008

Lung Sounds: An Advanced Signal Processing Perspective
Leontios J. Hadjileontiadis
2008

An Outline of Informational Genetics
Gérard Battail
2008

Neural Interfacing: Forging the Human-Machine Connection
Thomas D. Coates, Jr.
2008

Quantitative Neurophysiology
Joseph V. Tranquillo
2008

Tremor: From Pathogenesis to Treatment
Giuliana Grimaldi and Mario Manto
2008

Introduction to Continuum Biomechanics
Kyriacos A. Athanasiou and Roman M. Natoli
2008

The Effects of Hypergravity and Microgravity on Biomedical Experiments
Thais Russomano, Gustavo Dalmarco, and Felipe Prehn Falcão
2008

A Biosystems Approach to Industrial Patient Monitoring and Diagnostic Devices
Gail Baura
2008

Multimodal Imaging in Neurology: Special Focus on MRI Applications and MEG
Hans-Peter Müller and Jan Kassubek
2007

Estimation of Cortical Connectivity in Humans: Advanced Signal Processing Techniques
Laura Astolfi and Fabio Babiloni
2007

Brain–Machine Interface Engineering
Justin C. Sanchez and José C. Principe
2007

Introduction to Statistics for Biomedical Engineers
Kristina M. Ropella
2007

Capstone Design Courses: Producing Industry-Ready Biomedical Engineers
Jay R. Goldberg
2007

BioNanotechnology
Elisabeth S. Papazoglou and Aravind Parthasarathy
2007

Bioinstrumentation
John D. Enderle
2006

Fundamentals of Respiratory Sounds and Analysis
Zahra Moussavi
2006

Advanced Probability Theory for Biomedical Engineers
John D. Enderle, David C. Farden, and Daniel J. Krause
2006

Intermediate Probability Theory for Biomedical Engineers
John D. Enderle, David C. Farden, and Daniel J. Krause
2006

Basic Probability Theory for Biomedical Engineers
John D. Enderle, David C. Farden, and Daniel J. Krause
2006

Sensory Organ Replacement and Repair
Gerald E. Miller
2006

Artificial Organs
Gerald E. Miller
2006

Signal Processing of Random Physiological Signals
Charles S. Lessard
2006

Image and Signal Processing for Networked E-Health Applications
Ilias G. Maglogiannis, Kostas Karpouzis, and Manolis Wallace
2006

Digital Image Processing for Ophthalmology

Detection of the Optic Nerve Head

Xiaolu Zhu
University of Calgary, Calgary, Alberta, Canada

Rangaraj M. Rangayyan
University of Calgary, Calgary, Alberta, Canada

Anna L. Ells
Alberta Children's Hospital, Calgary, Alberta, Canada

SYNTHESIS LECTURES ON BIOMEDICAL ENGINEERING #40

ABSTRACT

Fundus images of the retina are color images of the eye taken by specially designed digital cameras. Ophthalmologists rely on fundus images to diagnose various diseases that affect the eye, such as diabetic retinopathy and retinopathy of prematurity.

A crucial preliminary step in the analysis of retinal images is the identification and localization of important anatomical structures, such as the optic nerve head (ONH), the macula, and the major vascular arcades. Identification of the ONH is an important initial step in the detection and analysis of the anatomical structures and pathological features in the retina. Different types of retinal pathology may be detected and analyzed via the application of appropriately designed techniques of digital image processing and pattern recognition. Computer-aided analysis of retinal images has the potential to facilitate quantitative and objective analysis of retinal lesions and abnormalities. Accurate identification and localization of retinal features and lesions could contribute to improved diagnosis, treatment, and management of retinopathy.

This book presents an introduction to diagnostic imaging of the retina and an overview of image processing techniques for ophthalmology. In particular, digital image processing algorithms and pattern analysis techniques for the detection of the ONH are described. In fundus images, the ONH usually appears as a bright region, white or yellow in color, and is indicated as the convergent area of the network of blood vessels. Use of the geometrical and intensity characteristics of the ONH, as well as the property that the ONH represents the location of entrance of the blood vessels and the optic nerve into the retina, is demonstrated in developing the methods.

The image processing techniques described in the book include morphological filters for preprocessing fundus images, filters for edge detection, the Hough transform for the detection of lines and circles, Gabor filters to detect the blood vessels, and phase portrait analysis for the detection of convergent or node-like patterns. Illustrations of application of the methods to fundus images from two publicly available databases are presented, in terms of locating the center and the boundary of the ONH. Methods for quantitative evaluation of the results of detection of the ONH using measures of overlap and free-response receiver operating characteristics are also described.

KEYWORDS

digital image processing, detection of blood vessels, detection of circles, edge detection, Gabor filter, Hough transform, morphological filters, node maps, optic disc, optic nerve head, pattern recognition, phase portraits, retinal fundus images

Xiaolu dedicates this book to her parents:
Qingqiao Wang *and* Guoyou Zhu

Contents

Preface

Large numbers of fundus images of the retina are being analyzed by ophthalmologists around the world. Digital imaging techniques and computing resources have been improving at rapid rates and finding more and more pratical applications. Over the past 20 years, researchers have been applying digital image processing techniques to ophthalmology with the aim of improved diagnosis.

This is an introductory book on digital image processing for application in ophthalmology. In particular, methods for automated detection of landmark features in retinal fundus images, such as the optic nerve head, fovea, and blood vessels are described in detail. The digital image processing techniques described include morphological filters, edge detectors, Gabor filters, the Hough transform, and phase portrait analysis. Methods for quantitative evaluation of the results of detection, such as distance measures and free-response receiver operating characteristics are also described. The image processing and quantitative evaluation techniques are not limited to medical applications.

The methods described in this book are mathematical in nature. It is assumed that the reader is proficient in advanced mathematics and familiar with basic notions of data, signal, and image processing. The methods of image modeling and analysis are suitable for inclusion in courses for students in the final year of bachelor's programs in electrical engineering, computer engineering, mathematics, physics, computer science, biomedical engineering, and bioinformatics. The techniques should also be useful to researchers in various areas of image modeling and analysis, and could be included in graduate courses on digital image processing, medical imaging, and related topics. The book is copiously illustrated with images and examples of application to facilitate efficient comprehension of the notions and methods presented.

We wish our readers success in their studies and research.

Xiaolu Zhu
Rangaraj M. Rangayyan
Anna L. Ells

Calgary, Alberta, Canada
January, 2011.

Acknowledgments

The research work described in this book was supported by the Natural Sciences and Engineering Research Council of Canada.

We thank Dr. Fábio J. Ayres for his assistance in parts of the research work described in this book.

Xiaolu Zhu
Rangaraj M. Rangayyan
Anna L. Ells

Calgary, Alberta, Canada
January, 2011.