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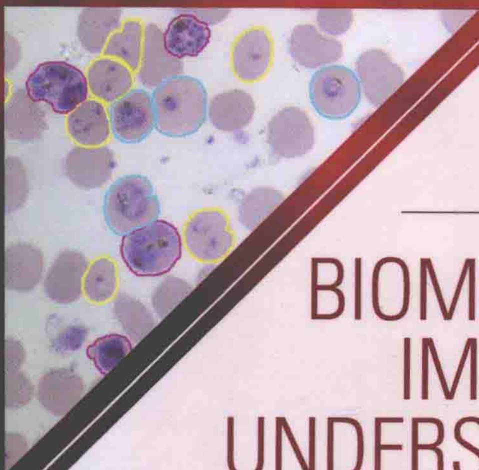
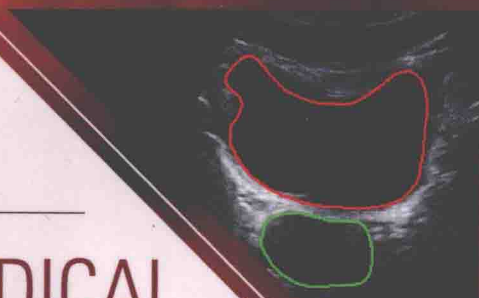
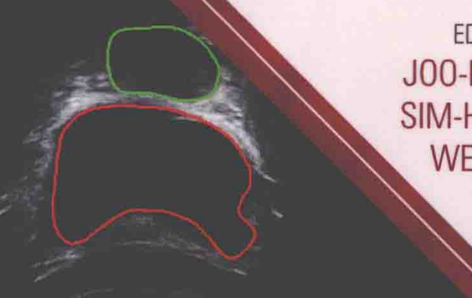


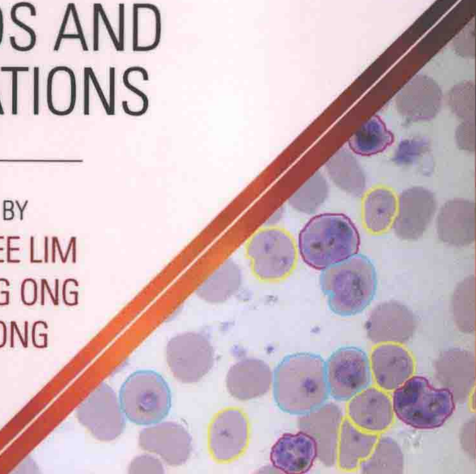


BIOMEDICAL IMAGE UNDERSTANDING

METHODS AND APPLICATIONS

EDITED BY
JOO-HWEE LIM
SIM-HENG ONG
WEI XIONG





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Methods and Applications

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PREFACE

Modern imaging devices generate enormous amounts of digital images in biological, medical, pathological, and functional applications. Computerized image analysis plays an important role in understanding and interpreting these images accurately and efficiently to assist biologists and clinicians in decision making. Being a highly multidisciplinary research field, biomedical image understanding requires knowledge, theories, methods, and techniques from computer science, engineering, mathematics as well as from biology, medicine, pathology, dentistry, and other specialized healthcare domains. Over the past decade, developments in related disciplines have rapidly advanced research and applications in biomedical image understanding.

This book is intended for researchers, teachers, and graduate students in this exciting and fast-changing field. In particular, it brings together experts to provide representative accounts of the concepts and applications in biomedical image understanding involving different image modalities of relevant anatomies for the purpose of pathology identification and assessment. The book focuses on image understanding and semantic interpretation with clear introductions to related concepts, in-depth theoretical analysis, and detailed descriptions of important biomedical applications.

The book consists of 12 chapters. Each chapter focuses on a biomedical imaging topic and is self-contained with an introduction to basic concepts, principles, methods, and a case study or application.

Part I, Introduction, contains one chapter, which is an overview of biomedical image understanding methods by Xiong et al. This chapter provides an extensive review of the taxonomy, state-of-art, and clinical applications of five important areas in biomedical image understanding: segmentation and object detection, registration and matching, object tracking, classification, and knowledge-based systems.

Part II, Segmentation and Object Detection, comprises three chapters.

Chapter 2, by Wei et al., introduces three classes of segmentation techniques widely used in medical images, namely, parametric active contours, geometric active contours, and graph-based techniques, followed by a detailed presentation of a representative example of each technique. These are, respectively, the snake, level set, and graph cut. A case study on short-axis cardiac image segmentation is used to illustrate some of the principles covered in the chapter.

A number of systemic diseases may lead to distinct changes in retinal blood vessels, which are easily observed by fundus photography. Chapter 3, by Trucco et al. focuses on three important topics in the morphometric measurement of retinal vasculature: vessel width estimation, artery–vein classification, and validation. Key concepts and challenges are presented followed by the authors' solutions and validation of results.

Chapter 4, by Lee et al., introduces readers to the diversity of bioimage informatics by presenting a variety of applications: the detection of objects using image processing approaches for diagnosis of premalignant endometrial disease, mutant detection in microscopy images of *in vitro* cultured keratinocytes, and cell and nuclei detection in microscopy images. Contrary to the image processing-based algorithms, the authors describe pattern recognition-based approaches and illustrate how they are used for detecting phenotypic changes in keratin proteins and mitotic cells in breast cancer histological images.

Part III, Registration and Matching, comprises two chapters.

Registration across different modalities is an important theme in medical image processing. In Chapter 5, Xu et al. describe the application of the Parzen-window-based method to normalized mutual information for 3D nonrigid registration. Attention is paid to the choice of kernel, which is critical to achieve good performance. The authors describe a demonstration of this approach in the computer tomography-magnetic resonance (CT-MR) nonrigid registration of liver images for MR-guided microwave thermocoagulation of liver tumors.

In the second chapter on registration, Miao and Liao describe a 2D/3D registration system for aligning a preoperative CT scan with intraoperative 2D X-ray projections of the same patient. The algorithm was specifically designed to provide accurate visualization of arterial anatomy for guidance and navigation to the surgeon in endovascular aneurysm repair. The approach can potentially be applied to a wide set of interventional procedures in orthopedics, cardiology, and neurology.

Part IV, Object Tracking, comprises one chapter. In Chapter 7, Cao et al. describe three categories of tracking techniques that are popularly used in medical image analysis: point tracking, silhouette tracking, and kernel tracking. A most representative method for each of the three general techniques is introduced in detail, namely, Bayesian tracking methods, deformable models, and harmonic phase (HARP) algorithm. A case study on cardiac motion tracking in myocardial perfusion magnetic resonance imaging (MRI) is also presented.

Part V, Classification, comprises three chapters.

In Chapter 8, Xiong et al. introduce the pattern classification techniques widely used in biomedical image understanding. A case study on a framework of blood cell image analysis is presented; the major components include good working area detection from the entire blood smear region, segmentation and recognition of blood cell images, and malaria infection detection and staging.

Liver tumor volume is an important measure of the severity of the disease. Moreover, correct pathological characterization of the tumor is crucial in deciding on the treatment options. In Chapter 9, Zhou et al. present a semiautomated method for the segmentation of liver tumors from CT scans under a hybrid support vector machine (SVM) framework and a content-based image retrieval prototype system based on multiphase CT images to support the decision making for liver tumor characterization.

Chapter 10 by Zhang et al. reports on the application of machine learning methods on computerized GSI-CT data analysis of lymph node metastasis in gastric cancer. The pipeline consists of region of interest (ROI) segmentation, feature extraction, feature selection, metric learning, and classification. Finally, the performance of the different classification models based on *k*-nearest neighbor is analyzed.

Part VI, Knowledge-based Systems, comprises two chapters.

Chapter 11, by Cloppet, explains the type of information or knowledge that can be introduced in image processing and the different ways by which they can be integrated into cutting-edge methods for biomedical image analysis. The appropriate use of information or knowledge can help to make image analysis methods more robust to variability and to interpret biomedical images in a more appropriate manner.

The active shape model (ASM) is a parametric deformable model popular for object modeling and representation. The original ASM and a modified model are presented in Chapter 12 by Li et al. Two applications of ASM in boundary detection of anatomical structures are investigated: boundary detection of optic disk in fundus images and lens structure detection in lens images.

We would like to take this opportunity to acknowledge the people who motivated and contributed to the book in one way or the other. In October 2011, Professor Kai Chang from Texas A&M University invited us to contribute a book to the series of "Biomedical Engineering and Multi-Disciplinary Integrated Systems" published by Wiley-Interscience. This motivated us to work together to plan for this book.

We would like to thank the people who had offered a great deal of help during the editing of this book. The 12 chapters are contributed by 39 authors/coauthors, whose names and affiliations are listed in the "Contributors" section. Anonymous reviewers provided constructive suggestions during the book planning in two cycles of reviewing. Each chapter was reviewed by at least two experts who provided critical comments. The authors have responded to the review comments with rebuttals and necessary changes. We are grateful to the reviewers for their hardwork: Dr. B. T. Thomas Yeo, Dr. C. K. Chui, Dr. B. N. Li, J. Cheng, Dr. Y. Wang, Dr. W. Huang, Dr. J. Zhou, Dr. L. Li, Dr. S. Lu, Dr. S. Li, Dr. J. Cheng, and Dr. Y. Gu. We also wish to thank Mr. S. C. Chia who contributed figure drawings and Dr. W. Chen who participated in technical discussions.

We have compiled in one volume a broad overview of the exciting area of biomedical image understanding. Significant progress has been made in this field in recent years, and we hope that readers will obtain a flavor of the exciting work that is being done, and at the same time enjoy reading this book as much as we have enjoyed the process of compiling it.

ACRONYMS

AAA	abdominal aortic aneurysm
AAM	active appearance model
AI	artificial intelligence
ASM	active shape model
BN	Bayesian networks
BSVC	binary support vector classifier
CBIR	content-based image retrieval
CFS	correlation feature selection
CRFs	conditional random fields
CT	computed tomography
DRR	digitally reconstructed radiography
DSA	digitally subtracted angiography
EM	expectation-maximization
EVAR	endovascular aneurysm repair
FFD	free form deformation
GD	gradient difference
GMM	Gaussian mixture model
GSI	Gemstone spectral imaging
GVF	gradient vector flow

GWA	good working areas
HARP	harmonic phase
HCC	hepatocellular carcinoma
H&E	hematein and eosin
HU	Hounsfield unit
ICA	independent component analysis
KNN	*k*-nearest neighbor
LDC	linear discriminant classifier
LV	left ventricle
MAP	maximum *a posteriori*
MDCT	multidetector-row CT
MDS	multidimensional scaling
MI	mutual information
MRF	Markov random field
MRI	magnetic resonance imaging
mRMR	minimum-redundancy-maximum-relevance
NMI	normalized mutual information
OSVC	one-class support vector classifier
PCA	principal component analysis
PDE	partial differential equations
PDF	probability density function
PDM	point distribution model
PET	positron emission tomography
PGT	pseudoground truth
RBC	red blood cell
RBF	radius basis function
RIA	retinal image analysis
RMS	root mean square
ROI	region of interest
RV	right ventricle
SBS	sequential backward selection
SFS	sequential forward selection
SMS	subspace Mumford–Shah model
SPAMM	spatially modulated magnetization

SSM	statistical shape model
SVC	support vector classifier
SVM	support vector machine
TPS	thin plate spline
VPS	volume percentage stroma
WSI	whole slide images