

# CARDIOVASCULAR IMAGING AND IMAGE ANALYSIS



Edited by

**AYMAN EL-BAZ | JASJIT S. SURI**



CRC Press  
Taylor & Francis Group



# Cardiovascular Imaging and Image Analysis



**Taylor & Francis**

Taylor & Francis Group

<http://taylorandfrancis.com>

# Cardiovascular Imaging and Image Analysis

**Edited by**

*Ayman El-Baz and Jasjit S. Suri*



**CRC Press**

Taylor & Francis Group

Boca Raton London New York

---

CRC Press is an imprint of the  
Taylor & Francis Group, an **informa** business

CRC Press  
Taylor & Francis Group  
6000 Broken Sound Parkway NW, Suite 300  
Boca Raton, FL 33487-2742

© 2019 by Taylor & Francis Group, LLC  
CRC Press is an imprint of Taylor & Francis Group, an Informa business  
No claim to original U.S. Government works  
Printed on acid-free paper

International Standard Book Number-13: 978-1-4987-9758-0 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access [www.copyright.com](http://www.copyright.com) (<http://www.copyright.com/>) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

**Trademark Notice:** Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

#### **Library of Congress Cataloging-in-Publication Data**

Names: El-Baz, Ayman S., editor. | Suri, Jasjit S., editor.

Title: Cardiovascular imaging and image analysis / edited by Ayman El-Baz and Jasjit S. Suri.

Description: First edition. | Boca Raton : Taylor & Francis, [2019] |

Includes bibliographical references and index.

Identifiers: LCCN 2018022105 (print) | LCCN 2018022883 (ebook) | ISBN 9780429441493 (eBook General) | ISBN 9780429806223 (Adobe PDF) | ISBN 9780429806216 (ePUB) | ISBN 9780429806209 (Mobipocket) | ISBN 9781498797580 (hardback : acid-free paper)

Subjects: LCSH: Cardiovascular system--Diseases--Diagnosis. | Diagnostic imaging.

Classification: LCC RC670 (ebook) | LCC RC670 .C365 2019 (print) | DDC 616.1/075--dc23

LC record available at <https://lccn.loc.gov/2018022105>

**Visit the Taylor & Francis Web site at**  
<http://www.taylorandfrancis.com>

**and the CRC Press Web site at**  
<http://www.crcpress.com>

## *Dedication*

---

*With love and affection to my mother and  
father, whose loving spirit sustains me still*

—**Ayman El-Baz**

*To my late loving parents, immediate  
family, and children*

—**Jasjit S. Suri**



**Taylor & Francis**

Taylor & Francis Group

<http://taylorandfrancis.com>

---

# Contents

Preface.....	ix
Acknowledgments.....	xi
About the Editors.....	xiii
Contributors.....	xv
<b>Chapter 1</b> Detection of Cerebrovascular Changes Using Magnetic Resonance Angiography.....	1
<i>Yitzhak Gebru, Guruprasad Giridharan, Mohammed Ghazal, Ali Mahmoud, Ahmed Shalaby, Ayman El-Baz</i>	
<b>Chapter 2</b> Segmentation of Blood Vessels Using Magnetic Resonance Angiography Images.....	23
<i>Ahmed Shalaby, Ali Mahmoud, Mohammed Ghazal, Jasjit S. Suri, Ayman El-Baz</i>	
<b>Chapter 3</b> Vascular Tree Segmentation from Different Image Modalities.....	43
<i>Ali Mahmoud, Ahmed Shalaby, Fatma Taher, Maryam El-Baz, Jasjit S. Suri, Ayman El-Baz</i>	
<b>Chapter 4</b> Accurate Unsupervised 3D Segmentation of Blood Vessels Using Magnetic Resonance Angiography.....	71
<i>Ahmed Shalaby, Ali Mahmoud, Samineh Mesbah, Maryam El-Baz, Jasjit S. Suri, Ayman El-Baz</i>	
<b>Chapter 5</b> An Unsupervised Parametric Mixture Model for Automatic Cerebrovascular Segmentation.....	95
<i>Mohammed Ghazal, Yasmina Al Khalil, Ayman El-Baz</i>	
<b>Chapter 6</b> Left Atrial Scarring Segmentation from Delayed-Enhancement Cardiac MRI Images: A Deep Learning Approach.....	109
<i>Guang Yang, Xiahai Zhuang, Habib Khan, Eva Nyktari, Shouvik Haldar, Lei Li, Rick Wage, Xujiong Ye, Greg Slabaugh, Raad Mohiaddin, Tom Wong, Jennifer Keegan, David Firmin</i>	
<b>Chapter 7</b> Cardiovascular Health Informatics Computing Powered by Unobtrusive Sensing Computing, Medical Image Computing, and Information Fusion Analysis.....	131
<i>Chengjin Yu, Xiuquan Du, Yanping Zhang, Heye Zhang</i>	
<b>Chapter 8</b> Automatic Segmentation of Cardiac Substructures for Radiation Oncology Applications.....	153
<i>Jinzhong Yang, Rongrong Zhou, Yangkun Luo, Zhongxing Liao</i>	



<b>Chapter 9</b>	Detection of Calcification from Abdominal Aortic Aneurysm .....	173
	<i>Safa Salahat, Ahmed Soliman, Harish Bhaskar, Tim McGloughlin, Ayman El-Baz, Naoufel Werghi</i>	
<b>Chapter 10</b>	Hermite-Based Deformable Models for Cardiac Image Segmentation .....	197
	<i>Jimena Olveres, Erik Carbajal-Degante, Boris Escalante-Ramírez, Leiner Barba-J, Lorena Vargas-Quintero, Enrique Vallejo Venegas, Lisbeth Camargo Marín, Mario Guzmán Huerta</i>	
<b>Chapter 11</b>	Cardiovascular Imaging for Early Detection of Coronary Artery Disease .....	227
	<i>Giorgos Papanastasiou, George Markousis-Mavrogenis, Sophie I. Mavrogeni</i>	
<b>Chapter 12</b>	The State-of-the-Art Echocardiography and Its Viewpoint Classifications.....	253
	<i>Xiaohong W. Gao, Wei Li, Martin Loomes, Yu Qian, Qiang Lin, Liqin Huang, Lianyi Wang</i>	
<b>Chapter 13</b>	Sensor-Enabled 3D Printed Tissue-Mimicking Phantoms: Application in Pre-Procedural Planning for Transcatheter Aortic Valve Replacement .....	283
	<i>Kan Wang, Chuck Zhang, Ben Wang, Mani A Vannan, Zhen Qian</i>	
<b>Chapter 14</b>	Cardiac Fiber Imaging with 3D Ultrasound and MR Diffusion Tensor Imaging.....	307
	<i>Xulei Qin, Baowei Fei</i>	
<b>Chapter 15</b>	Technical Advances and Clinical Perspectives in Coronary MR Imaging.....	321
	<i>Giulia Ginami, Imran Rashid, René M. Botnar, Claudia Prieto</i>	
<b>Chapter 16</b>	Hypertension and Correlation to Cerebrovascular Change: A Brief Overview .....	345
	<i>Heba Kandil, Dawn Sosnin, Ali Mahmoud, Ahmed Shalaby, Ahmed Soliman, Adel Elmaghraby, Jasjit S. Suri, Guruprasad Giridharan, Ayman El-Baz</i>	
<b>Chapter 17</b>	Predicting the Biomechanics of the Aorta Using Ultrasound.....	365
	<i>Mansour AlOmrán, Alexander Emmott, Richard L. Leask, Kevin Lachapelle</i>	
<b>Chapter 18</b>	Deep Convolutional Networks for Automated Volumetric Cardiovascular Image Segmentation: From a Design Perspective .....	385
	<i>Xin Yang, Lequan Yu, Qi Dou, Jing Qin, Pheng-Ann Heng</i>	
<b>Index</b>	.....	419

---

# Preface

This book covers the novel strategy of the state-of-the-art approaches for automated non-invasive system for early cardiovascular disease diagnostics. Cardiovascular disease is the leading cause of death for people of most ethnicities in the United States, including African Americans, Hispanics, and whites. According to the American Heart Association, cardiovascular disease accounts annually for almost 801,000 deaths in the United States, which is about 1 of every 3 deaths. This means cardiovascular disease claims more lives each year than all forms of cancer. However, early detection of cardiovascular disease increases the chances of patients' survival.

Current non-invasive cardiovascular imaging includes ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), and computed tomography (CT). Today's CAD systems can analyze images from these different modalities for detecting cardiovascular disease and determining its aggressiveness. Generally, the CAD systems analyze the images in three steps: segmentation, description or feature extraction, and classification of the status.

The main aim of this book is to help advance scientific research within the broad field of early detection of cardiovascular disease. This book focuses on major trends and challenges in this area, and it presents work aimed at identifying new techniques and their use in biomedical image analysis.



**Taylor & Francis**

Taylor & Francis Group

<http://taylorandfrancis.com>

---

# Acknowledgments

The completion of this book could not have been possible without the participation and assistance of so many people whose names cannot all be enumerated. Their contributions are sincerely appreciated and gratefully acknowledged. However, the editors would like to express their deep appreciation and indebtedness particularly to Dr. Ali H. Mahmoud for his endless support.



**Taylor & Francis**

Taylor & Francis Group

<http://taylorandfrancis.com>

---

# About the Editors



**Ayman El-Baz** is a professor, university scholar, and chair of the Bioengineering Department at the University of Louisville. Dr. El-Baz earned his bachelor's and master's degrees in electrical engineering in 1997 and 2001, respectively. He earned his doctoral degree in electrical engineering from the University of Louisville in 2006. In 2009, Dr. El-Baz was named a Coulter Fellow for his contributions to the field of biomedical translational research. Dr. El-Baz has 15 years of hands-on experience in the fields of bio-imaging modeling and noninvasive computer-assisted diagnosis systems. He has authored or coauthored more than 450 technical articles (105 journals, 15 books, 50 book chapters, 175 refereed-conference papers, 100 abstracts, and 15 U.S. patents).



**Jasjit S. Suri** is an innovator, scientist, visionary, industrialist, and internationally known world leader in biomedical engineering. Dr. Suri has spent more than 25 years in the field of biomedical engineering/devices and its management. He received his doctorate from University of Washington, Seattle, and his MBA from the Weatherhead School of Management, Case Western Reserve University, Cleveland. Dr. Suri was awarded the President's Gold Medal in 1980 and became a Fellow of the American Institute of Medical and Biological Engineering for his outstanding contributions in 2004.



**Taylor & Francis**

Taylor & Francis Group

<http://taylorandfrancis.com>