Preface

Radiological sciences in the last two decades have witnessed a revolutionary progress in medical imaging and computerized medical image processing. The development and advances in multi-dimensional medical imaging modalities such as X-ray Mammography, X-ray Computed Tomography (CT), Single Photon Computed Tomography (SPECT), Positron Emission Tomography (PET), Ultrasound, Magnetic Resonance Imaging (MRI) and functional Magnetic Resonance Imaging (fMRI) have provided important radiological tools in diagnosis and treatment evaluation and intervention of critical diseases for significant improvement in health care. The development of imaging instrumentation has inspired the evolution of new computerized image reconstruction, processing and analysis methods for better understanding and interpretation of medical images. The image processing and analysis methods have been used to help physicians to make important medical decisions through physician–computer interaction. Recently, intelligent or model-based quantitative image analysis approaches have been explored for computer-aided diagnosis to improve the sensitivity and specificity of radiological tests involving medical images.

Medical imaging in diagnostic radiology has evolved as a result of the significant contributions of a number of different disciplines from basic sciences, engineering, and medicine. Computerized image reconstruction, processing and analysis methods have been developed for medical imaging applications. The application-domain knowledge has been used in developing models for accurate analysis and interpretation.

In this book, I have made an effort to cover the fundamentals of medical imaging and image reconstruction, processing and analysis along with brief descriptions of recent developments. Though the field of medical imaging and image analysis has a wide range of applications supported by a large number of advanced methods, I have tried to include the important developments in the book with examples and recent references. The contents of the book should enable a reader to establish the basic as well as advanced understanding of major approaches. The book can be used

for a senior undergraduate or graduate-level course in medical image analysis and should be helpful in preparing the reader to understand the research issues at the cutting edge. Students should have some knowledge of probability, linear systems and digital signal processing to take full advantage of the book. References are provided at the end of each chapter. Laboratory exercises for implementation in the MATLAB® environment are included. A library of selected radiological images and MATLAB interface programs demonstrating medical image processing and analysis tasks can be downloaded from a website, ftp://ftp.wiley.com/public/sci_tech_med/medical_image/. In addition, all Figures printed in the book are also available in electronic form on the website.

Chapter 1 presents an overview of medical imaging modalities and their role in radiology and medicine. It introduces the concept of a multi-disciplinary paradigm in intelligent medical image analysis. Medical imaging modalities are presented with respect to the type of signal used in image formation.

Chapter 2 describes the basic principles of image formation and reviews the essential mathematical foundation and transforms. Additional methods such as Wavelet transforms and neural networks are not described in this chapter but have been explained in later chapters with applications to medical image enhancement, segmentation and analysis.

Chapter 3 provides an overview of electromagnetic (EM) interaction of energy particles with matter and presents basic principles of detection and measurements in medical imaging.

Chapter 4 describes the principles, instrumentation and data acquisition methods of medical imaging modalities including X-ray Radiograph Imaging, X-ray Mammography, X-ray Computed Tomography, Nuclear Medicine (Single-Photon Emission Computed Tomography and Positron Emission Tomography), Magnetic Resonance Imaging, and Ultrasound Imaging.

Chapter 5 presents various image-reconstruction algorithms used and investigated in different imaging modalities. It starts with the introduction of 2-D and 3-D image reconstruction methods using the Radon Transform. The chapter then continues with the iterative and model based reconstruction methods.

Chapter 6 starts with the preliminaries in image processing and enhancements. Various methods for image smoothing and enhancement are described to improve the image quality for visual examination as well as computerized analysis.

Chapter 7 presents the image-segmentation methods for edge and region feature extraction and representation. Advanced and model-based methods for image segmentation using Wavelet transform and neural networks are described.

Chapter 8 presents feature extraction and analysis methods for qualitative and quantitative analysis and understanding. The role of using *a priori* knowledge in adaptive, model-based and interactive medical image-processing methods is emphasized. These methods are discussed for classification, quantitative analysis and interpretation for radiological images. Recent approaches with neural network based image analysis and classification are also presented.

Chapter 9 describes recent advances in multi-modality medical image registration and analysis. The emphasis is given on model-based and interactive approaches for better performance in registering multi-dimensional multi-modality brain images. Registration of brain images has been discussed in detail as an example of image registration methods.

Chapter 10 describes the two-, three- and multi-dimensional methods for image visualization. Feature-based surface and volume rendering methods as well as intelligent adaptive methods for dynamic visualization are presented. Recent advances in multi-parameter visualization with virtual reality based navigation are also presented.

Chapter 11 presents the future trends and concluding remarks on recent advances in medical imaging, processing, analysis and interpretation and their role in computer-aided diagnosis, image-guided surgery and other radiological applications. Electrical Impedance Tomography (EIT) and recent advances in multispectral optical imaging are also introduced.

Chapter 12 describes the downloading and installation instructions of a MATLAB interface and medical image databases that can be used to complete exercises and demonstrate image processing and analysis tasks presented in the book.

I would like to thank Metin Akay for his support, encouragement and comments on the book. I also like to thank my previous graduate students M. V. Ranganath, Louis Arata, Thomas Dufresne, Charles Peck, Christine Bonasso, Timothy Donnier, Anne Sicsu, Prashanth Kini, Aleksander Zavaljevski, Sven Loncaric, Alok Sarwal, and Amar Raheja. Some of the material included in this book is based on the dissertation work done by my graduate students under my supervision. Thanks are also due to Sachin Patwardhan, who implemented lab exercises in the MATLAB environment. I also like to thank Chrissy Kuhnen from IEEE Press and Naomi Fernandez from Mathworks, for their support during the entire time of writing this book.

I thank my wife Nilam and my sons Anirudh and Akshay for their support and patience during the weekends and holidays when I was writing to finish this book.

I am very pleased that the book has been adopted as a textbook at several universities for a course on medical image analysis. It is being reprinted and I hope that it will serve more students and researchers worldwide.

Newark, NJ
March, 2004

ATAM P. DHAWAN