FUNDAMENTALS OF MEDICAL IMAGING

Medical imaging has become a very important technology in medical diagnosis and treatment. This book explains the mathematical and physical principles of medical imaging and image processing, from how medical images are obtained to how they are used.

The book begins with an introduction to digital image processing. The following chapters explain the most important imaging modalities in use today: radiography, computed tomography, magnetic resonance imaging, ultrasonic imaging, and nuclear medicine imaging. Each chapter includes a short history of the imaging modality, the physics of the signal and its interaction with tissue, the image formation or reconstruction process, a discussion of the image quality, the different types of equipment, examples of clinical applications, a brief description of the biological effects and safety issues, and future expectations. The remainder of the book deals with image analysis and visualization for diagnosis, therapy, and surgery after images are available. Color plates complement the text, and a CD-Rom packaged with the book includes all the images in color, as well as animations.

Both students and beginning biomedical engineers will welcome this well-balanced, copiously illustrated treatment of medical imaging.

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Contents

PART TWO. MEDICAL IMAGING MODALITIES

Preface

This book explains the applied mathematical and physical principles of medical imaging and image processing. It gives a complete survey of how medical images are obtained and how they can be used for diagnosis, therapy, and surgery.

It has been written principally as a course text on medical imaging intended for graduate and last-year undergraduate students with a background in physics, mathematics, or engineering. Although a large proportion of the book covers the physical principles of imaging modalities, the emphasis is always on how the image is computed. Equipment design, clinical considerations, and image interpretation are treated in less detail. Presently, books on medical imaging fall into two groups, neither of which is suitable for this readership. The first group is the larger and comprises books directed primarily at the less numerate professions such as physicians, surgeons, and radiologic technicians. These books cover the physics and mathematics of all the major medical imaging modalities, but mostly in a superficial way. They do not allow any real understanding of these imaging modalities. The second group comprises books suitable for professional medical physicists or researchers in the field. Although these books have a numerate approach, they tend to cover the topics too deeply for the beginner and to have a narrower scope than this book.

The text reflects what I teach in class, but there is somewhat more material than I can cover in a module of 30 contact hours. This means that there is scope for the stronger student to read around the subject and also makes the book a useful purchase for those going on to do research. Nevertheless, there are no unnecessary details. Premature techniques or topics under investigation have been omitted.

The book consists of three parts. In Part One, an introduction to digital image processing is given. It summarizes the jargon used by the digital image community, the theory about linear systems needed to understand most of the medical imaging methods, and basic image operations to process digital images. Some sections may seem rather dry, but the topics are an essential basis for the subject. Nevertheless, the reader who has studied this matter elsewhere may skip the related paragraphs or chapters in this part of the book.

Part Two explains how medical images are obtained. The most important imaging modalities today are discussed: radiography, computed tomography,

magnetic resonance imaging, ultrasonic imaging, and nuclear medicine imaging. Each chapter includes (1) a short history of the imaging modality, (2) the theory about the physics of the signal and its interaction with tissue, (3) the image formation or reconstruction process, (4) a discussion of the image quality, (5) the different types of equipment today, (6) examples of the clinical use of the modality, (7) a brief description of the biologic effects and safety issues, and (8) future expectations.

Part Three deals with image analysis and visualization for diagnosis, therapy, and surgery once images are available. Medical images can, for example, be analyzed to obtain quantitative data, or they can be displayed in three dimensions and actively used to guide a surgical intervention. Most courses separate the imaging theory from the postprocessing, but I strongly believe that they should be taken together because the topics are integrated. The interest in clinical practice today goes beyond the production and diagnosis of an image, and the objective then is to calculate quantitative information or to actively use the images during patient treatment.

The field of medical imaging and image processing can also be approached from the perspective of information and communication and the supporting technology, such as hospital information systems, the electronic patient record, and PACS (picture archiving and communication systems). However, this focus would put the emphasis on informatics, such as networking, data bases, user interfaces, internet technology, and computer graphics, which is not the purpose of this book.

In the bibliography, references to untreated topics can be found as well as a list of more specialized works on a particular subdomain and some other generic textbooks related to the field of medical imaging and image processing.

Paul Suetens

Acknowledgments

My research group has largely contributed to the production of this book. Our "Laboratory for Medical Image Computing" is a joint initiative of the faculty of applied sciences and the faculty of medicine. It is quite a unique place where engineers, physicists, computer scientists, and medical doctors collaborate in an interdisciplinary team. It is located in the Department of Radiology of the University Hospital Leuven. There is a strong collaboration with other hospital departments such as nuclear medicine, cardiology, and surgery. Research is restricted to clinically relevant questions. This then explains the focus in this book, which is on current clinical practice in a modern hospital.

Each chapter was cowritten with a skilled researcher with years of expertise in the field of that particular part of the book. Before we started writing, I defined the detailed contents based on what I teach. Afterward, I carefully edited each piece of text and modified or rewrote it in order to obtain a consistent script. A preliminary version of the book was commented on by Gerrit Kemerink, University Hospital Maastricht, who used it in his course on medical imaging for the students in biomedical engineering at the Technical University Eindhoven.

The following coauthors contributed to this book:

Part One. Introduction to Digital Image Processing

- Definitions (**Koen Vande Velde**)
- Linear System Theory (**Johan Michiels**)
- Image Operations (**Koen Vande Velde**)

Part Two. Medical Imaging Modalities

- Radiography (**Koen Vande Velde**)
- X-ray Computed Tomography (**Bruno De Man**)
- Magnetic Resonance Imaging (**Johan Michiels**)
- Ultrasonic Imaging (**Jan D'hooge**)
- Nuclear Medicine Imaging (**Johan Nuyts**)

Part Three. Image Analysis and Visualization for Diagnosis, Therapy, and Surgery

- Medical Image Analysis (**Frederik Maes**)
- Image-guided Interventions (**Johan Van Cleynenbreugel**)

Guy Marchal, head of the Department of Radiology, and Luc Mortelmans, head of the Department of Nuclear Medicine of the University Hospital Leuven, contributed to the paragraphs about the clinical use and future expectations of the medical imaging modalities in their discipline. Dominique Delaere, our information manager, assisted me with the figures, illustrations, and animations; the syntactical consistency check; and the preparation of the electronic version on CD. Thanks to his degree in biomedical engineering, he also made several improvements to the content. There is no question about the tremendous help I got from all these colleagues. To all of them, thank you so much!

Paul Suetens