Fundamentals of Medical Imaging

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Preface

This book explains the applied mathematical and physical principles of medical imaging and image computing. It gives a complete survey of how medical images are obtained and how they can be used for diagnosis, therapy, and surgery. It is accompanied by about 400 color illustrations and 80 video clips.[1]

It has been written principally as a course text on medical imaging intended for graduate and final-year undergraduate students with a background in physics, mathematics, or engineering. However, I have made an effort to make the textbook readable for biomedical scientists and medical practitioners by avoiding unnecessary maths, without giving up the depth needed for physicists and engineers. Mathematical proofs and details are highlighted in separate paragraphs and can be skipped without hampering a fluent reading of the text.

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 diagnosis are treated in less detail. Premature techniques or topics under investigation have been omitted.

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 a thorough understanding of the imaging modalities. The second group comprises books suitable for professional medical physicists or researchers with expertise in the field. Although these books have a numerate approach, they tend to cover the topics too deeply for the beginner and have a narrower scope than this book.

The text reflects what I teach in class, but there is more material than I can explain 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.

In Chapter 1, an introduction to digital image processing is given. It summarizes the jargon used by the digital image community, the components defining image quality, and basic image operations used to process digital images.

Chapters 2–6 explain how medical images are acquired. The most important imaging modalities today are discussed: radiography, computed tomography, magnetic resonance imaging, nuclear medicine imaging, and ultrasonic imaging. Each chapter includes (1) a short history of the imaging modality, (2) the theory of 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 in use today, (6) examples of the clinical use of the modality, (7) a brief description of the biological effects and safety issues, and (8) some future expectations. The imaging modalities have made an impressive and never-ending evolution in the last decades with respect to image quality, patient safety, tissue differentiation, and applicability. Today, medical imaging plays a role in early patient diagnosis, individual therapy planning, population screening, therapy outcome assessment and prediction, evidence-based medicine, and translational pre-clinical and clinical research. This part of the book provides up-to-date information about these systems.

Chapters 7 and 8 deal with computational analysis and visualization of medical images. Medical images can, for example, be analyzed to obtain quantitative data, or they can be displayed in three dimensions

1 www.cambridge.org/9781107159785

and used to plan and guide a surgical intervention. Most courses separate the imaging theory from the postprocessing, but I strongly believe that they should be taken together because these topics are integrated. The interest in clinical practice goes beyond the production and qualitative diagnosis of two-dimensional images, and the demand for structured reporting, calculating quantitative information, and therapy preparatory image computing increases.

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 databases, networking, internet technology, and information security, which is not the purpose of this book.

Two appendices are provided online.[2] The first is about linear system theory, which is used both in image reconstruction and in image analysis. Students in physics or engineering who are not familiar with linear system theory will welcome this appendix. The second appendix provides a list of exercises for self-assessment. It is a collection of exam questions of the previous years. The questionnaire follows the order of the chapters and concludes with a set of miscellaneous questions that require insight into the matter of multiple chapters.

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

Medical imaging and image computing are rapidly evolving fields and this edition has been updated with the latest developments in the field.

- New sections include recent X-ray detector technology; photon counting CT; dynamic (cardiac, perfusion) CT; multi-energy CT; parallel MR imaging; phase-based (susceptibility weighted, chemical shift) MRI; arterial spin labeled perfusion MRI; magnetic particle imaging; functional CT, MRI, and ultrasound imaging; time-of-flight PET; hybrid imaging (PET-CT, SPECT-CT, PET-MRI); speckle tracking echography and tissue deformation mapping; acoustic shear waves and elasticity imaging; harmonic ultrasound imaging; and transducers for 3D ultrasound imaging.
- Needless to say that the sections on current equipment, their clinical use and biological impact, and the expected developments in the domain are up to date in this edition.
- The whole chapter on medical image analysis has been totally revised and a new section on pattern recognition has been added.
- The list of exercises for self-assessment has doubled.
- As compared to the previous edition, the large majority of images have been renewed and many of them are augmented with video clips.
- Finally, many minor changes resulted from suggestions and comments from researchers, clinicians, and students.
- Some mathematical proofs and details are highlighted in separate blue boxes and can be skipped without hampering a fluent reading of the text.

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My colleagues of the Medical Imaging Research Center have directly and indirectly contributed to the production of this book. This facility is quite a unique place in the center of the University Hospital where engineers, physicists, computer scientists, bioscientists, and medical doctors collaborate in an interdisciplinary team. Research is focused on clinically relevant questions. This then explains the emphasis in this book, which is on recent imaging technology used in clinical practice.

The following colleagues and former colleagues contributed to the content of this and the previous editions of the book: Matthew Bickell, Hilde Bosmans, Daan Christiaens, Stijn De Buck, Frederik De Keyzer, Bruno De Man, Christophe Deroose, Jan D'hooge, Steven Dymarkowski, Hendra Hudyana, Dirk Loeckx, Frederik Maes, Guy Marchal, Nicholas Marshall, Johan Michiels, Luc Mortelmans, Johan Nuyts, Raymond Oyen, Efstathios Pagourelias, João Pedrosa, Ronald Peeters, David Robben, Kevin and Kristin Suetens, Stefan Sunaert, Johan Van Cleynenbreugel, Koen Vande Velde, Dirk Vandermeulen, Jens-Uwe Voigt, and Guozhi Zhang. They provided me with pieces of text, relevant clinical images, and important literature; and I had indispensable discussions with them concerning content and structure.

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