Fundamentals of Medical Imaging

Second Edition

Paul Suetens
Katholieke Universiteit Leuven
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Preface

This book explains the applied mathematical and physical principles of medical imaging and image processing. It gives a complete survey, accompanied by more than 300 illustrations in color, 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 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 as well by deleting unnecessary mathematical details, without giving up the depth needed for physicists and engineers. Mathematical proofs 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 any real understanding of these 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 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.

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. The theory of linear systems, described in Chapter 2 of the first edition, has been moved to an appendix. It is too high-level for the medical reader and a significant part of the engineering readers of the previous edition considered it as redundant. However, many students in physics or engineering are not familiar with linear system theory and will welcome this appendix.

 Chapters 2–6 explain how medical images are obtained. 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 biologic effects and safety issues, and (8) some future expectations. The imaging modalities have made an impressive evolution in a short time with respect to quality, size and applicability. This part of the book provides up-to-date information about these systems.

 Chapters 7 and 8 deal 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...
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because the topics are integrated. The interest in clinical practice today goes beyond the production and diagnosis of two-dimensional images, and the objective then is to calculate quantitative information or to use the images during patient treatment. The field of medical image analysis is in full progress and has become more mature during the last decade. This evolution has been taken into account in this second edition. The chapter on image-guided interventions of the first edition has been rewritten with a new focus. The emphasis now is on three-dimensional image visualization, not only to guide interventions, but also for diagnostic purposes.

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.

New also in this second edition is an appendix with exercises. By solving these exercises the student can test his or her insight into the matter of this book. Furthermore an ancillary website (www.cambridge.org/suetens) with three-dimensional animations has been produced which contains answers to the exercises.

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.
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 where engineers, physicists, computer scientists, and medical doctors collaborate in an interdisciplinary team. It has a central location in the University Hospital Leuven and is surrounded by the clinical departments of radiology, nuclear medicine, cardiology, and radiotherapy. 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 first edition of the book: Bruno De Man, Jan D’hooge, Frederik Maes, Johan Michiels, Johan Nuyts, Johan Van Cleynenbreugel and Koen Vande Velde.

This second edition came about with substantial input from Hilde Bosmans (radiography), Bruno De Man (computed tomography), Stefan Sunaert (magnetic resonance imaging), Johan Nuyts (nuclear medicine), Jan D’hooge (ultrasound), Frederik Maes and Dirk Vandermeulen (image analysis), Dirk Loeckx (exercises), Christophe Deroose, Steven Dymarkowski, Guy Marchal and Luc Mortelmans (clinical use). 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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