Preface

Hans Castorp, in Thomas Mann's Magic Mountain, keeps an x ray of his lover as it seems to him the most intimate image of her to possess. Professionals will think differently of medical images, but the fascination with the ability to see the unseeable is similar. And, of course, it is no longer just the x ray. Today, it is not sparseness, but the wealth and diversity of the many different methods of generating images of the human body that make the understanding of the depicted content difficult. At any point in time in the last 20 years, at least one or two ways of acquiring a new kind of image have been in the pipeline from research to development and application. Currently, optical coherence tomography and magnetoencephalography (MEG) are among those somewhere between development and first clinical application. At the same time, established techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) reach new heights with respect to the depicted content, image quality, or speed of acquisition, opening them to new fields in the medical sciences.

Images are not self-explanatory, however. Their interpretation requires professional skill that has to grow with the number of different imaging techniques. The many case reports and scientific articles about the use of images in diagnosis and therapy bears witness to this. Since the appearance of digital images in the 1970s, information technologies have had a part in this. The task of computer science has been and still is the quantification of information in the images by supporting the detection and delineation of structures from an image or from the fusion of information from different image sources. While certainly not having the elaborate skills of a trained professional, automatic or semi-automatic analysis algorithms have the advantage of repeatedly performing tasks of image analysis with constant quality, hence relieving the human operator from the tedious and fatiguing parts of the interpretation task.

By the standards of computer science, computer-based image analysis is an old research field, with the first applications in the 1960s. Images in general are such a fascinating subject because the data elements contain so little information while the whole image captures such a wide range of semantics. Just take a picture from your last vacation and look for information in it. It is not just Uncle Harry, but also the beauty of the background, the weather and time of day, the geographical location, and many other kinds of information that can be gained from a collection of pixels of which the only information is intensity, hue, and saturation. Consequently, a variety of methods have been developed to integrate the necessary knowledge in an interpretation algorithm for arriving at this kind of semantics.

Although medical images differ from photography in many aspects, similar techniques of image analysis can be applied to extract meaning from medical images. Moreover, the profit from applying image analysis in a medical application is immediately visible as it saves times or increases the reliability of an interpretation task needed to carry out a necessary medical procedure. It requires, however, that the method is selected adequately, applied correctly, and validated sufficiently.

This book originates from lectures about the processing and analysis of medical images for students in Computer Science and Computational Visualistics who want to specialize in Medical Imaging. The topics discussed in the lectures have been rearranged to provide a single comprehensive view on the subject. The book is structured according to potential applications in medical image analysis. It is a different perspective if compared to image analysis, where usually a bottom-up sequence from pixel information to image content is preferred. Wherever it was possible to follow the traditional structure, this has been done. However, if the methodological perspective conflicted with the view from an application perspective, the latter was chosen. The most notable difference is in the treatment of classification and clustering techniques that appears twice since different methods are suitable for segmentation in low-dimensional feature space compared to classification in high-dimensional feature space.

The book is intended for medical professionals who want to get acquainted with image analysis techniques, for professionals in medical imaging technology, and for computer scientists and electrical engineers who want to specialize in the medical applications. A medical professional may want to skip the second chapter, as he or she will be more intimately acquainted with medical images than the introduction in this chapter can provide. It may be necessary to acquire some additional background knowledge in image or signal processing. However, only the most basic material was omitted (e.g., the definition of the Fourier transform, convolution, etc.), information about which is freely available on the Internet. An engineer, on the other hand, may want to get more insight into the clinical workflow, in which analysis algorithms are integrated. The topic is presented briefly in this book, but a much better understanding is gained from collaboration with medical professionals. A beautiful algorithmic solution can be virtually useless if the constraints from the application are not adhered to.

As it was developed from course material, the book is intended for use in lectures on the processing and analysis of medical images. There are several possibilities to use subsets of the book for single courses, which can be combined. Three of the possibilities that I have tried myself are listed below (Cx refers to the chapter number).

- Medical Image Generation and Processing (Bachelor course supplemented with exercises to use Matlab or another toolbox for carrying out image processing tasks):
  - C2: Imaging techniques in detail (4 lectures),
  - C3: DICOM (1 lecture),

  - C4: Image enhancement (2 lectures),
  - C5: Feature generation (1 lecture),
  - C6: Basic segmentation techniques (2 lectures),
  - C12: Classification (1 lecture),
  - C13: Validation (1 lecture).
- Introduction to Medical Image Processing and Analysis (Bachelor course supplemented with a student's project to solve a moderately challenging image analysis task; requires background on imaging techniques):
  - C2: Review of major digital imaging techniques: x ray, CT, MRI, ultrasound, nuclear imaging (1 lecture),
  - C3: Information systems in hospitals (1 lecture),
  - C4: Image enhancement (1 lecture),
  - C6: Basic segmentation techniques (2 lectures),
  - C7: Segmentation as a classification task (1 lecture),
  - C8–C9: Introduction to graph cuts, active contours, and level sets (2 lectures),
  - C10: Rigid and nonrigid registration (2 lectures),
  - C11: Active Shape Model (1 lecture),
  - C13: Validation (1 lecture).
- Advanced Image Analysis (Master course supplemented with a seminar on hot topics in this field):
  - C7: Segmentation by using Markov random fields (1 lecture),
  - C8: Segmentation as operation on graphs (3 lectures),
  - C9: Active contours, active surfaces, level sets (4 lectures),
  - C11: Object detection with shape (4 lectures).

Most subjects are presented so that they can also be read on a cursory level, omitting derivations and details. This is intentional to allow a reader to understand the dependencies of a subject on other subjects without having to go into detail in each one of them. It should also help to teach medical image analysis on the level of a Bachelor's course.

Medical image analysis is a rewarding field for investigating, developing, and applying methods of image processing, computer vision, and pattern recognition. I hope that this book gives the reader a sense of the breadth of this area and its many challenges while providing him or her with the basic tools to take the challenge.

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