Chapter 8
Model-Based Image Segmentation for Image-Guided Interventions

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Abstract
Medical image segmentation plays an important role in the field of image-guided surgery and minimally invasive interventions. By creating three-dimensional anatomical models from individual patients, training, planning, and computer guidance during surgery can be improved. This chapter briefly describes the most frequently used image segmentation techniques, shows examples of their application and potential in the field of image-guided surgery and interventions, and discusses future trends.

8.1 Introduction
Image segmentation is one of the central research themes in biomedical image analysis, and with the increasing number of imaging studies, both in biomedical research and clinical practice, the necessity for automated biomedical image segmentation methods is expanding.

In medical imaging, the extraction of three-dimensional static or dynamic models of patient anatomy or pathology is of particular interest. These models facilitate visualization that is tailored to the diagnostic task, quantification for diagnostic purposes, or therapy planning, monitoring, and guidance of interventions or surgery.

The increasing relevance of biomedical imaging only partially explains why medical image segmentation continues to be an active research field; the major reason is that the field poses substantial difficulties. The variability in patient anatomy and pathology, the complexity and sheer size of state-of-the-art medical imaging data, with the requirements of accuracy, reproducibility, and robustness imposed by the application domain, make medical image segmentation a very challenging task.
When using image segmentation in the field of image-guided surgery and minimally invasive interventions, additional challenges are faced, including time constraints, compromised intraoperative image quality, and deforming anatomy. Despite these challenges, image segmentation is increasingly used as an invaluable tool for training, preoperative planning, and image guidance during surgery and interventions, and its role is expected to increase.

A large body of literature has been devoted to medical image segmentation. These different approaches can roughly be categorized into two classes. The first class, low-level image segmentation, uses image features to define regions or to classify voxels into tissue types. Thresholding, region growing, clustering methods, (trained) classifiers, and morphology-based segmentation fall within this category. The second class consists of model-based approaches, which aim to fit models to the image data. Examples are the classical deformable models (e.g., snakes), level sets, active shape and appearance models, and atlas-(registration-) based approaches. However, this distinction is somewhat artificial, as the interest in hybrid approaches that combine both aspects is increasing. Model-based and hybrid methods probably are most popular and promising in the field of image-guided interventions. Owing to the large number of segmentation methods addressed in this chapter, we will only briefly discuss the underlying methodology and provide references to other papers for more in-depth treatment of specific approaches.

**8.2 Low-Level Image Segmentation**

The most widely used low-level image segmentation techniques, such as thresholding and region growing, are addressed in standard image processing textbooks and so are not discussed here. This section is limited to a brief discussion of tissue classification techniques, as they are increasingly used in combination with model-based image segmentation.

Classification is a pattern recognition technique, the aim of which is to partition the image into classes, on the basis of such characteristics as image intensity and/or features derived from the images. In classification techniques, a feature space is constructed, whose dimensionality is determined