Chapter

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'A picture says a thousand words'

No human being is safe from suffering a disease throughout life, which, eventually, could lead to his/her death. Study of diseases has long been, and still is, one of the most important focuses of research in the world, showing that early diagnosis is often the only hope of recovery for patients. This is leading to a vastly increased demand for screening, treatment and monitoring of patients.

Medical imaging appears among the most important diagnostic tools, providing visualization of the internals of the human body, which facilitates the labor of the clinician. Currently a large number of imaging modalities are available for clinical practice, among which, X-ray, computed tomography (CT), ultrasound, magnetic resonance imaging (MRI) and nuclear imaging are the ones being used by clinicians on a daily basis. Such techniques are also extremely important for clinical research in order to better understand the natural history of a disease, and monitor the progression or regression of a condition over time. Besides, medical imaging is, frequently, the key for the development of adequate drug therapies, since it permits direct visualization of the changes that occur in the human body in response to specific treatments.

The human observer plays a crucial role in the interpretation of medical image data. However, such image data are not always easy to interpret with the naked eye, due to different factors, such as bad image quality. In fact, the human eye is not fit to perform accurate measurements in medical images, and in clinical practice many diagnostic and treatment decisions are taken based on visual estimates of the severity of a disease. Besides, with the advent of tomographic imaging techniques such as MRI and CT, which provide high-dimensional image data, the amount of data per examination has increased enormously, making the manual analysis impractical. This accentuates the need for a shift in the image analysis from manually assessed images towards computer-based methods. These methods should aim at assisting medical experts by providing them with accurate and reproducible quantitative measurements derived from the images.

To derive measurements from image data, it is often necessary to outline the objects of interest in the data, which is referred to as image segmentation. This can be performed manually, semi-automatically or fully automatically. Nevertheless, the role of the human operator is crucial in interpreting the quantitative measurements provided by the computer, and the human observer must be able to intervene in the segmentation process in case the automated results are inconsistent or contradict human perception and common sense.

Image segmentation has long been an important focus of research, yielding many automated methods to perform segmentation of different organs like the heart or the brain. However, many of these methods rely only on image data, which make them susceptible to variations in image quality, where information may be unreliable or missing.

According to cognitive psychology, the process of seeing is an active process in which our world is constructed from both the retinal view and prior knowledge[1,2]. This explains why, in many cases, the human observer is still capable of identifying the contours of a particular organ, even when information is missing. These thoughts are the principles on which knowledge-based methods rely, and are essential in medical image analysis in order to improve the robustness of the automated methods.

This thesis deals with computer-aided interpretation of a specific type of medical images: cardiovascular images. Specifically, the main goal of this thesis is the development of methods for the automated segmentation of the vessel wall in different vascular beds (carotids and aorta) using contrast-weighted MR sequences (T1-weighted -T1W-, T2-weighted -T2W- and proton density-weighted -PDW-) and magnetic resonance angiography (MRA), as first step towards plaque characterization and estimation of plaque burden and stenosis percentage. It seeks to develop methods to quantitatively and qualitatively analyze:

- Vessel wall thickness
- Plaque burden and degree of stenosis
- Characterization of plaque components.

Further, such methods should provide a basis for experts to answer more abstract questions, such as:

- Is the plaque vulnerable?
- Is there a relation between plaque burden and degree of stenosis?
- What is the severity of atherosclerosis?
- Which treatment is suitable to reverse the process of plaque formation?

Aspects of measurement are very critical in order to get an accurate assessment of plaque vulnerability or also plaque burden. This can be done very nicely with magnetic resonance imaging by tracing the inner and outer contour of the vessel wall and obtaining a multitude of data such as the wall thickness, the area of the lumen, and the area of the arterial wall. From those measurements, other parameters can be derived, such as plaque index (average ratio of wall area divided by the total arterial area), which are pretty robust for the analysis of a condition.

This thesis is further organized as follows. Chapter 2 presents an introduction to atherosclerosis disease, imaging modalities employed for visualization of atherosclerotic arteries and imaging processing techniques for vessel wall MR. Chapter 3 describes the use of a statistical model approach to delineate the contours of the carotid vessel wall and fibrous cap automatically, in *in vivo* MR images. In Chapter 4 different contrast-weighted MR images are combined to improve the segmentation of the vessel wall boundaries. In Chapter 5 the analysis of vessels structures focuses on the descending aorta. Chapter 6 integrates vessel wall MR and MRA into a combined algorithm to improve the robustness in the segmentation of lumen in MRA and vessel wall in MR, together with quantification of plaque burden and degree of stenosis. In Chapter 7 a two-fold study is presented: on the one hand, a three-dimensional (3D) segmentation algorithm is derived to automatically identify the boundaries of the vessel wall in a segment of the carotid artery in T1W MR images; on the other hand, the automated quantification of changes in vessel wall over time, investigating different factors that influence the accuracy and reproducibility of the measurements. Chapters 8 and 9 conclude this thesis with a summary.

References

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