Chapter 14
Left Ventricle Segmentation and Motion Analysis in MultiSlice Computerized Tomography

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ABSTRACT
Cardiac motion analysis is an important tool for evaluating the cardiac function. Accurate motion estimation techniques are necessary for providing a set of parameters useful for diagnosis and guiding therapeutical actions. In this chapter, the problem of cardiac motion estimation is presented. A short overview of techniques based in several imaging modalities is given where the machine learning techniques have played an important role. A feasible solution for left ventricle segmentation in multislice computerized tomography (MSCT) and for estimating the left ventricle motion is presented. This method is based on the application of support vector machines (SVM), region growing and a nonrigid bidimensional correspondence algorithm used for tracking the anatomical landmarks extracted from the segmented left ventricle (LV). Some experimental results are presented and at the end of the chapter a short summary is presented.

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INTRODUCTION

Cardiac image analysis is considered as a useful tool for diagnosis, treatment and monitoring of cardiovascular diseases. Image analysis techniques enable a noninvasive assessment of cardiac function, providing morphological, dynamical and functional information (Frangi et al., 2002). Left ventricle is considered the main cavity of the heart. The accurate description of ventricular shape and motion is important, since cardiovascular disease (CVD) accounts for one third of the deaths in the world (WHO, 2002). Technological advances on images have improved the quality of patient treatment. The diagnosis accuracy has also been improved by using the information provided by several imaging modalities and advanced processing and analysis techniques (Mackay and Mensah, 2004). These modalities include Xrays angiography, echocardiography (US), magnetic resonance imaging (MRI) and more recently multislice computerized tomography (MSCT) which is a tomography imaging modality that has the necessary spatial and time resolution for representing 4D (volume + time) cardiac images. MSCT provides 3-D images of the heart with sub-millimeter isotropic spatial resolution and more than 20 temporal phases for each cardiac cycle. This fact enables non-invasive diagnosis of coronary artery disease and quantification of cardiac function including left ventricular mass, stroke volume and ejection fraction. Performing the analysis of these images is challenging due to reconstruction artifacts, gray level intensity variation along the cardiac cycle, interpatient and interphase shape variability, heart pose and location variability in the chest, variation in Field of View (FOV) as well as variations in cranio-caudal coverage (Ecabert et al., 2008).

Machine learning techniques have been used in medical imaging processing for segmentation (Ecabert et al., 2008; Fleureau et al., 2007; Zheng et al., 2008), for cardiac motion analysis, (Mishra et al., 2006) and also for improving other interpretation tasks (Wang et al., 2007). In this chapter, an application of machine learning techniques for solving the segmentation and LV motion analysis problem in MSCT images is shown.

Cardiac Motion

Cardiac motion is caused by activation of muscle fibers due to the action of an electrical signal (Guyton & Hall, 2001). This signal propagates through the conducting system, which is constituted of innervating fibers located in the heart wall. The electric stimulation occurs first at the atria, propagating later to the ventricles. The strength and velocity of contraction of cardiac muscles are variable and are affected by the length of fibers and intensity of the electrical stimulus. The motion of the heart is an almost periodical event known as the cardiac cycle, which comprises two phases: the diastolic or filling of the cavities, and the systolic or ejection of the blood (Opie, 2001). The left ventricle motion during the systolic phase is considered as the combination of five types of movements: 1) translation, 2) rotation, 3) torsion, 4) longitudinal shortening, and 5) radial contraction. These components are not uniform throughout the left ventricular cavity. For instance, the longitudinal shortening movement with respect to the anatomical axis (aortic valve-apex) is significantly asymmetric. During systole, the plane of the mitral valve descends 1 to 2 centimeters towards the apex in adults with normal cardiac function, but the apex barely moves towards the base of the heart (Marcus & Dellsperger, 1991). Out of possible motions of the heart, the longitudinal shortening and radial contraction are the most important in both ventricles, followed by the torsion (see Figure 1). The other movements are less important when the cardiac muscle is normal.
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