Chapter 18

Cardiac Chamber Contour Extraction: Performance Evaluation of an Algorithm and Physicians

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ABSTRACT

Segmentation of echocardiography images presents a great challenge since such images contain strong speckle noise and artifacts. Most ultrasound segmentation methods are semi-automatic, requiring initial contour to be manually identified in the images. In this chapter, a level set algorithm based on the phase symmetry approach and on a new logarithmic-based stopping function is used to extract simultaneously the four heart cavities in a fully automatic way. The idea is to evaluate the algorithm potential for the clinical practice as an additional tool helping the physician’s decision. Thus, the extracted contours are compared with the ones sketched by four physicians using for that several metrics, namely distance error, maximum distance, pratt function, similarity angle, similarity region, hausdorff distance, accuracy, overlap, sensitivity, and specificity. The authors show that the proposed algorithm performs well, producing contours very similar to the physicians’ ones. The experimental work was based on echocardiography images of children.

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INTRODUCTION

Echocardiography is a valuable non-invasive tool for imaging the heart and surrounding intrathoracic structures and is an essential way to diagnosis heart diseases. It is important to recognize; however, that echocardiographic examination is only a part of the complete cardiac work-up. The historical information, physical examination findings, electrocardiogram, thoracic radiographs and clinical laboratory findings must be integrated with the echocardiography to arrive at the correct diagnosis and develop an adequate therapeutic plan for each patient. Two-dimensional (2D) echocardiography images are used to evaluate cardiac chamber size (especially the left ventricular one), wall thickness, wall motion, valvular anatomy, valve motion, the proximal great vessels and the pericardium.

Clinical assessment of the Left-Ventricular (LV) function is essential for evaluating the heart function of a patient with known or suspected heart disease. Automated analysis of echocardiographic images is challenging because noise and artefacts make feature detection and tracking difficult. Tracing of the epicardial and endocardial boundaries of the Left Ventricle (LV) on echocardiographic images is of primordial importance for quantification the cardiac function. Contour tracing on the End-Diastolic (ED) and End-Systolic (ES) images allows the computation of clinically important measures such as ejection fraction and regional wall thickening. Also, border tracking on all images covering the entire cardiac cycle allows quantitative interpretation of LV dynamics. Manual tracing of these borders requires an expert and besides, is a time consuming and labour intensive task, when lots of images need to be analysed.

Automatic boundary extraction from echocardiographic images thus, appears as a clinical important need to produce most effective and reliable results. In spite of many researchers have attempted to identify the LV boundaries on 2D images, automatically or semi-automatically, that goal still is a challenge. Limited clinical applicability of these methods is related to the poor quality of the images with the consequent low contrast at the boundaries or even boundary discontinuity in some frames. Almost all approaches for LV boundary extraction use some common image processing procedures, the most important ones being pre-processing and edge detection.

An overview about the human heart and congenital diseases is given in section 2. In section 3, the state of art about boundary extraction approaches applied to 2D echocardiographic images is reviewed. The fundamental segmentation strategies known as edge-based and region-based are analysed. The review also shows the use of watershed methodology combined with the active contours could be an interesting strategy for boundary detection. The tedious and time consuming manual tracing of the heart cavities associated to the intra-observer and inter-observer variability stimulated the authors to investigate an automatic segmentation technique for the simultaneous boundary extraction of the four heart cavities using 2D ultrasound images. The used level set algorithm and the Phase Symmetry for image preprocessing are given in section 3. The figures of merit used for the evaluation of algorithm versus physicians and physicians versus physicians’ performance are presented in section 4. Two methodologies have been used, namely contour based metric and region based metric. Also a tool to speed up the sketching of contours made by physicians will be presented. The section 5 is dedicated to the results and discussion. Particular emphasize is given to the left ventricle, right atrium, and to the four cavities analyzed together. The conclusions are presented in section 6.

Overview of the Heart

The heart works as a pump sending the blood through the entire body. It is composed by four chambers. The upper chambers are named right and left atria and the lower ones are the right and left ventricles. The septum separates the atria
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