Validation of Automatic Segmentation Algorithms for Short-axis Cine Cardiac Magnetic Resonance

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Introduction

Modern short-axis (SA) cine cardiac magnetic resonance (CMR) images usually consist of 15–50 phases at 10–15 slices (150–750 images). These images are used for quantification of various ventricular functional parameters, which requires delineation of all cardiac contours. As manual delineation of these contours is prohibitively time consuming, many algorithms have been developed for automatic delineation. However, for clinical practice these algorithms are not yet accurate enough and semi-automatic segmentation algorithms are therefore often used. In this study, we have evaluated the accuracy of three automatic segmentation algorithms [1,2,3] at end diastole (ED) for a large number of patients. Additionally, we have evaluated the accuracy of the resulting segmentation from propagating the automatically obtained ED segmentation using the contour propagation algorithm described in [4].

Methods

The first automatic segmentation method for SA cine CMR uses spatiotemporal connectivity to obtain the left ventricular (LV) endocardium contour [1]. The second method uses the result of this approach to initialize a graph cut segmentation approach for obtaining LV endocardium and epicardium contours [2]. The third approach uses a histogram-based appearance modelling in combination with a geometrical template to find both LV contours [3]. These three methods are applied at the end-diastolic phase to obtain initial contours for the contour propagation algorithm, which has proven to be accurate, fast and robust [4].

The algorithms are validated on 69 SA cine CMR data sets, which included 9–14 contiguous slices and 15–50 phases. All images were 256x256 in size, covering a field of view ranging from 350x350 mm up to 480x480 mm. An expert manually delineated golden standard contours at ED and end systole (ES). Validation consisted of computing contour positioning errors and errors in the resulting ventricular functional parameters. We computed root-mean-square (RMS) positioning errors for the cardiac contours based on a point-to-point correspondence established using the Repeated Averaging Algorithm (RAA) [5]. We computed mean errors and correlation coefficients for the end diastolic volume (EDV), the end systolic volume (ESV), the stroke volume (SV) and the ejection fraction (EF). These results were computed for the resulting segmentations from propagating the ED results from method 1-3. To allow a comparison, these results were also computed for the resulting segmentation from propagating manual cardiac contours.

Results

The resulting RMS contour positioning errors are listed in table 1. The results for the ventricular functional parameters are listed in table 2. Example delineations are shown on an ED slice in figure 1.

	ED		ES	
Initialization	LV Endo	LV Epi	LV Endo	LV Epi
Method 1	3.0 ± 1.8	-	4.0 ± 2.2	-
Method 2	2.7 ± 1.8	2.9 ± 1.9	3.7 ± 2.2	3.6 ± 2.3
Method 3	2.0 ± 1.3	2.2 ± 1.4	3.1 ± 2.0	3.1 ± 2.2
Manual	-	-	2.6 ± 1.3	2.3 ± 1.4

Table 1: Resulting RMS positioning errors (mm) for the cardiac contours

Initialization	EDV (ml)	ESV (ml)	SV (ml)	EF (%)
Method 1	-17.7 (0.96)	-17.0 (0.96)	-0.7 (0.85)	7.8 (0.85)
Method 2	-13.8 (0.97)	-14.2 (0.97)	0.4 (0.84)	6.8 (0.85)
Method 3	-8.3 (0.62)	2.5 (0.81)	-10.8 (0.16)	6.8 (0.65)
Manual	-	-0.8 (0.98)	0.8 (0.71)	1.7 (0.78)

Table 2: Mean errors (correlation coefficients) for ventricular functional parameters

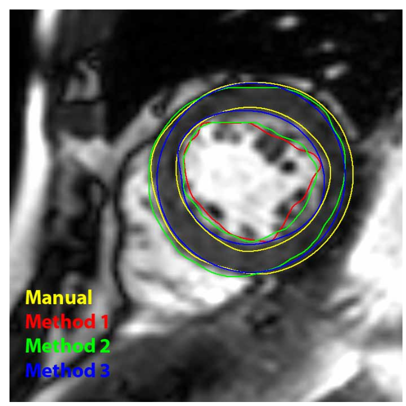

Figure 1: Example ED segmentations

Conclusions

We have tested three automatic segmentation algorithms in combination with a contour propagation method on 69 data sets. Unfortunately, the resulting cardiac contours are considerably less accurate with respect to the use of manual initialisation. Consequently, the mean errors for measurements of ventricular functional parameters are substantially larger with respect to the use the contour propagation algorithm with manual initialisation at ED.

References

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