Modified Hough Transform for Left Ventricle Myocardium Segmentation in 3D Echocardiograms

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1. INTRODUCTION

Segmentation of the left ventricular (LV) myocardium is important in analysis of stress-strain, synchrony, and wall motion. Traditional methods have found success in echocardiography, but resolution, shadowing, and parallel-beam effects present further challenges [1]. Epicardium segmentation is also complicated by nearby tissues and proximity to the image edge [2, 3].

2. METHOD

Clinical 3D+t echocardiogram sequences are acquired. 2D short-axis slices are extracted and median-filtered. Orthogonal gradient images G_x and G_y are calculated. To detect the annular cross-section of the LV, a 3D accumulator image H is defined over parameter space (c_x, c_y, r), where c_x and c_y define a potential circle center, and r is the radius. The accumulator is calculated:

$$H(c_x, c_y, r) = \sum_{\theta} \cos\theta \cdot G_x(x', y') + \sin\theta \cdot G_y(x', y')$$

Where $x' = c_x + r\cos\theta$ and $y' = c_y + r\sin\theta$. Accumulator values above zero represent circular edges with bright pixels on the inside (e.g. endocardial border), and values below zero represent the opposite (e.g. an epicardial border). For potential centers (c_x, c_y), the likely endocardial and epicardial radii are:

$$r_1 = \arg\max_{r} H(c_x, c_y, r) \qquad r_2 = \arg\min_{r > r_1} H(c_x, c_y, r)$$

Accumulator values at r_1 and r_2 determine a likelihood score:

$$s(c_x, c_y) = k\, H(c_x, c_y, r_1) - H(c_x, c_y, r_2)$$

Where k is a constant. The annular approximation of the left ventricular myocardium has center (c_x, c_y) to maximize s, and corresponding radii $r_1(c_x, c_y)$ and $r_2(c_x, c_y)$.

3. RESULTS

Twenty-five 3D+t echocardiograms were obtained from healthy volunteers with a Philips iE33 system. For each of the 275 3D images, an expert delineated the LV myocardium in every fifth short-axis slice. 5641 short-axis slices were analyzed for:

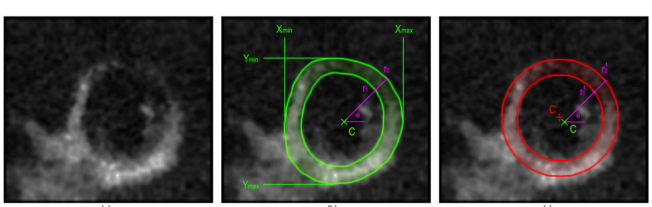

Fig. 1. Manual and Hough segmentation. (a) Short-axis slice from 3D frame. (b) Manual segmentation with center C. Radii r_1 and r_2 are measured from C. (c) Hough segmentation and center C'. r_1' and r_2' are from manual center C.

Table 1. Segmentation similarity results (mean $\pm$ stdev)

	All Slices	**Basal 80%**
ΔC	3.31 ± 2.65 mm	2.65 ± 1.88 mm
Δr_1	2.57 ± 1.78 mm	2.34 ± 1.43 mm
Δr_2	3.04 ± 2.10 mm	2.68 ± 1.68 mm
Dice's d	0.70 ± 0.17	0.75 ± 0.13

Parameter distance. Let C be the center of the manual segmentation bounding box. Distance ΔC between C and the Hough segmentation center C' was measured. For $\theta = \frac{n\pi}{4}$, the radii from C to the manual segmentation, r_1 and r_2, were compared with those to the Hough transform segmentation, r_1' and r_2' (Fig 1).

Dice's coefficient. For each slice, the manual and Hough segmentations M and H were compared by: $d = \frac{2 \cdot |M \cap H|}{|M| + |H|}$

Initialization suitability. If the Hough contour initializes a second segmentation step, that step is more likely to converge if its boundary does not have to cross a feature edge; that is, if $r_1' < r_2$ and $r_2' > r_1$. These criteria were evaluated.

Table 1 presents results for all slices and for slices in the basal 80% of the LV. The initialization criteria were met in 93.8% of slices, and 96.8% of non-apical slices.

4. CONCLUSION

Segmentations produced by the modified Hough transform fit the criteria for initialization of a subsequent segmentation step in most cases. This result was further improved when indistinct apical slices were ignored. The practical performance of these segmentations as an initialization step remains to be evaluated.

Even without further evolution, the segmentations produced by the modified Hough transform produce features that differ from the gold-standard manual segmentation by 2.5 - 3.0 mm. This compares with state-of-the-art techniques, which are capable of achieving accuracy in the range of 1.4 - 1.8 mm my considering speckle statistics and myocardial tissue characteristics [2]. This suggests that even without further evolution, the modified Hough transform method may be useful for quickly estimating physiological parameters and basic LV shape information.

5. REFERENCES

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