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Automatic Segmentation and Tracking of Coronary Artery from Echocardiographic Sequences using Hough Transform and Shape Modeling

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SUMMARY

Automatic segmentation and tracking of coronary artery from ultrasound sequences is an important step in computer aided diagnosis of cardiac disease. This paper presents an automatic approach of segmentation and tracking of coronary artery in ultrasound image sequences. There are two steps in proposed approach including automatic detection and segmentation in sequences based on Hough Transform and shape modeling framework respectively. The detection step provides initial localization of the contour close to the coronary artery which indicate the outline of whole artery. Then an active contour method is used to segment the accurate boundary of the coronary artery in the first image of temporal sequences based on the initialized outline. To track the artery in image sequences, an improved shape modeling based algorithm is used to propagate in image sequences using image gradient prior. Experiments are performed on cardiac ultrasound sequences containing longitudinal coronary artery. The results show that the proposed algorithm in this paper provides a reliable way to segment and track coronary artery in ultrasound image and can be used in computer aided diagnosis of cardiac disease.

Key Words: *Echocardiographic sequences, Hough Transform, Active contour, Shape modeling, Ultrasound tacking, Computer aided diagnosis.*

1 INTRODUCTION

Among medical imaging techniques, ultrasound is particularly attractive because of its good temporal resolution, non-invasiveness and relatively low cost. However in clinical practice, analysis of ultrasound still relies on manual outlines produced by expert physicians. Although manual analysis is used so much in clinic, this process of manual outlining is time-consuming and complicated. Computer assisted techniques can provides more efficient and accurate processing for ultrasound image analysis [1]. Automatic coronary artery segmentation and tracking from cardiac ultrasound image is important in clinical practice, where visualization and measurement tools often rely on the processing results. However, robust segmentation is particularly challenging in case of the ultrasonic image because of poor quality of ultrasound image, especially in case of tracking 2D + T changes in echocardiography [2]. Until now, several segmentation and tracking approaches of cardiac boundary from ultrasound image sequences have been proposed in literatures [3] [4] [5].

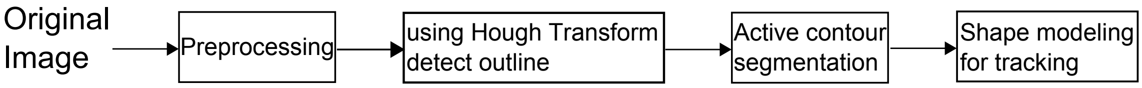

Figure 1: An overview of proposed method workflow.

2 METHODS

The input for the proposed algorithm is ultrasound image sequences incorporating the longitudinal coronary artery. The workflow of the segmentation and tracking process is summarized in fig.1 and as follows: In the original image sequences the Hough Transform algorithm is used to detect the outline of artery lumen. Then accurate boundary of artery lumen is segmented using active contour algorithm from one of the 2D ultrasound image in given sequences. The tracking step is achieved based on the initialized contour from segmentation using shape detection method.

2.1 Outline detection using Hough Transform

In order to detect the outline of coronary artery, edge points in a given image are computed by gradient based filter first. And then, the Hough Transform is applied to detect the outline [9]. Suppose that there is a line from (x_a, y_a) to (x_b, y_b) .We use Hough Transform to find distance from the origin and the angle of the line that go through the two points. The equation of the line can be written as

$$y = (\frac{\cos\theta}{\sin\theta})x + (\frac{r}{\sin\theta}) \tag{1}$$

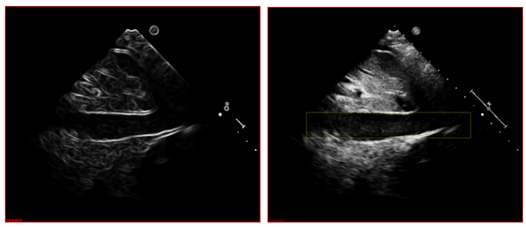

Figure 2: Detection result using Hough Transform.

Thus, the problem of detecting a line can be converted to the problem of finding concurrent curves as shown in Figure 2.

2.2 Coronary artery segmentation

When the outline of coronary artery is detected the active contour is used to segment the accurate boundary of artery lumen. The segmentation is based on active contours which are energy-minimizing method guided by internal and external forces to propagate the contour to the boundary of interest. In our case, we propose that the role of force E_{int} is to enforce the active contour on a shape feature that is characteristic on the object. In the case of coronary artery, additional force that acts to preserve contour thickness should be added. To define such force, the initialized contour $f(s) = (x(s), y(s))$ and the first and second-order continuity weighting functions $\alpha(s)$ and $\beta(s)$ are used to obtain the internal energy function. This internal force can be used to avoid leaking in ultrasound image segmentation process. Internal force can be expressed as

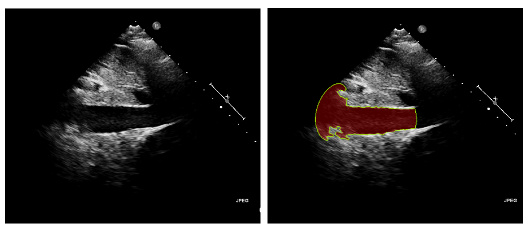

Figure 3: Segmentation result using active contour.

$$E_{int} = \sum_i \alpha(i)||f(i+1) - f(i)||^2 + \beta(i)||f(i+1) - 2f(i) + f(i-1)||^2 \tag{2}$$

The contour is attracted to the edges with large image gradient under the image force in active contour framework.The image force is computed as

$$E_{img} = -(G_{\delta} * ||\nabla I||^2)(i, j) \tag{3}$$

Then the coronary artery lumen can be segmented in the first frame of ultrasound image sequences as Figure 3 shown.

2.3 Coronary artery sequences tracking

In the next step, the shape modeling approach is used to force the initialized boundary moving closer to exact boundary of coronary artery. Then this propagation method continues tracking the boundaries in each frames boundary based on the image gradient information. Shape modeling approach can be used to segment object's shape to situations where no shape prior available. The speed function will gradually attains zero speed as it gets closer to the object boundaries and eventually come to a stop when it reach to the exact boundary. we define the speed function F to be

$$F(x, y) = \frac{-F_A}{(M_1 - M_2)} |\nabla G_{\sigma} * I(x, y)| - M \tag{4}$$

If $F_G \neq 0$, then multiply the speed function with a term k that will cause the net speed of the front to approached to zero in the neighbourhood of a desire shape which is defined as

$$k_i(x, y) = \frac{1}{1 + e^{-|\frac{\nabla G_{\sigma} * I(x,y)}{\alpha}| - \beta}} \tag{5}$$

Equation above has values that are close to zero in regions of high image gradient and values that are closer to unity in regions with relatively constant intensity.

In the tracking process, a spheroid space frame is proposed to update the exact boundary in each frames that the front can be moved by propagating the evolution function at a small set of points in the neighbourhood of the initialized contour instead of updating it at all points on the grid. In Fig.7 the spheroid depicts the tracking space and the evolution process only takes in this space.

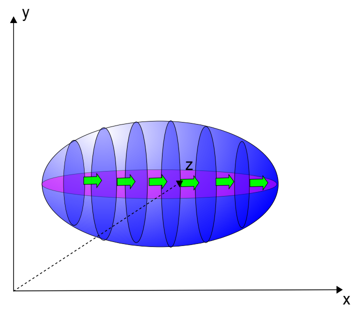

Figure 4: The spheroid space using to constrain evolution space at a small set of points.

3 RESULTS

Performance of the proposed algorithm is evaluated on 9 echocardiographic sequences with image size of $599 \times 799 \times 90$, each covering at least one complete cardiac cycle. The sequences are recorded using the *PHILIPS 5.0-MHz* transducer on the iE33 MATRIX Echocardiographic System. Results are compared between the active contour algorithms using in longitudinal coronary artery segmentation and by manual segmentation. The statistics of comparison experiments are presented in Table 1.

Table 1: Results of The Comparison between Manual and Active Contour Segmentation

	Sequence 1	Sequence 2
Distance between manual and active contour(mean/deviation)	2.2026mm/0.395mm	2.025mm/0.402mm
Correlation Coefficient Between segmented areas(mean/deviation)	0.9905	0.9560

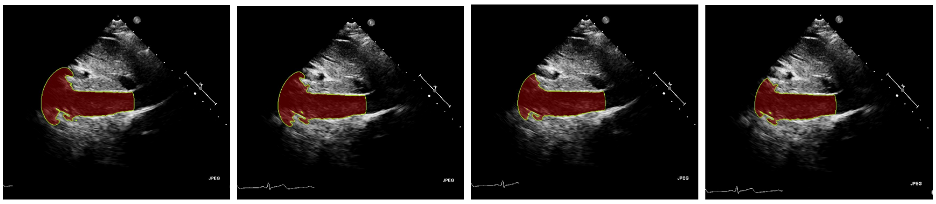

Figure 5: Tracking result of coronary artery from echocardiographic sequences in a cardiac cycle

The tracking algorithm is tested on 9 echocardiographic sequences containing long axis of coronary artery. The results show that 8 of 9 sequences can be tracked with mean below 2.5 and deviation below 0.5 respectively using MAD[6] measurement. Some inaccurate tracking is caused by low image quality. One of the tracking result is shown in Fig.5.

4 CONCLUSIONS

An automatic segmentation and tracking algorithm of coronary artery from ultrasound sequences is presented in this paper. The proposed approach combines both automatic segmentation and tracking algorithm. Hough Transform is used for automatic detection of longitudinal coronary artery. In order to segment the exact boundary of the first image from sequences, active contour is used to generate an initialized contour of the coronary artery. To track the coronary artery movement in cardiac cycle, we propose a spheroid space frame in shape modeling to update the front of boundary in a specific region. The experiments show promising reslts of segmentation and tracking on different datasets. In the future, improvement of the segmentation and tracking accuracy is the main goal of next step.

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