Automatic Border Detection of Cardiac Cavity Images Using Boundary and Triangle Equation

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Abstract—**In this paper, an automatic border detection of cardiac cavity in two-dimensional short axis echocardiography image is proposed. The method uses boundary and triangle equation to detect and reconstruct the border. The first step is determining the initial centers boundary. The second step is applying morphological and thresholding operations to eliminate noise and convert it into binary image. The last step is using boundary and triangle equation to detect and reconstruct the imprecise border. This technique can detect centers of boundary and border very precisely.**

Keywords-boundary detection; cardiac cavity; morphological operation; thresholding; triangle equation

I. Introduction

An automatic border detection of cardiac cavity in two-dimensional short axis echocardiography images is very useful in helping doctors to diagnose patient cardiac cavity. Various researches and methods have been conducted to detect cardiac cavity [1-6]. However, there is still room for innovation and development of methods and algorithms. Some researchers used short axis images [1, 2, 3 & 4] and others used long axis images [5 & 6]. There are others who utilized semi-automatic detection [1 & 4] and others developed fully automated detection [3 & 5].

J. W. Klinger et al [1] applied segmentation of echocardiography images using mathematical morphology. A. Laine and X. Zong [2] presented border identification that depended on the shape modeling and border reconstruction from a set of images. W. Ohyama et al [3] used ternary threshold method for detection of left ventricular endocardium. Maria et al [1 & 4] applied semi automatic detection of the left ventricular border. Jierong Cheng et al [5 & 6] used watershed segmentation for boundary detection and find the center point of the boundary.

As such, we propose a method that initially involves determining the initial centers of the boundary. Next, we apply the morphological and thresholding operations to eliminate noise and convert it into binary image. Finally, using boundary and triangle equation we detect and reconstruct the imprecise border. We believe that the proposed technique can detect centers of the boundary and border very precisely.

II. Development

There are some standard views of the cardiac cavity image, for example short axis and long axis views. In this research, we used short axis images. Fig. 1 shows the short axis image of left ventricular cardiac cavity from echocardiography.

Figure 1. The short axis image left ventricular of cardiac cavity from echocardiography.

There are various methods and algorithms to detect the border of cardiac cavity [1-6]. In this algorithm, we use boundary and triangle equation to automatically detect and reconstruct disconnecting as well as detect the center of boundary. Fig. 2 shows the diagram of the aforementioned algorithm.

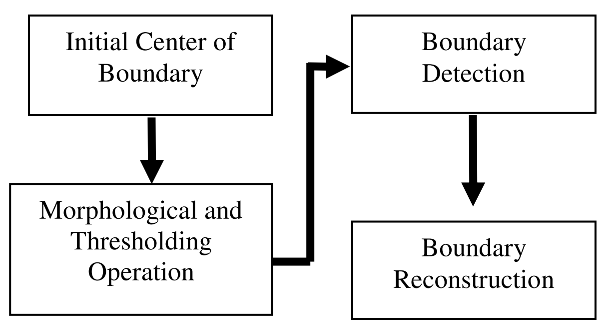

Figure 2. Schematic Diagram of the algorithm.

A. *Initial Center of Boundary*

The first step is determining the initial center of boundary of cardiac cavity. The cardiac cavity image contains considerable speckle noise, which is harmful for the boundary detection. The method to suppress noise is a smoothing operation. After applying this process, some holes still exists, which connect region of cardiac cavity to other false regions. The application of morphological operation using erosion can fill in the holes and connect boundary of cardiac cavity image.

An erosion of image *A* by structuring element B, denoted by A Θ B, is expressed as a set of points *x* where B_x can be positioned such that B is completely contained in A:

$$A \ominus B = \{x \mid B_x \subset A\}. \tag{1}$$

Where $\ominus$ denote morphological contraction, and

$$B = \begin{bmatrix} 111 \\ 111 \\ 111 \end{bmatrix}$$

B is the structuring element. After this process converts it into binary image, we use thresholding operation.

Then, the image is scanned pixel by pixel to find each connected component or boundary region of cardiac cavity. The second largest region is identified as the ventricular cardiac cavity [5].

The *x* coordinate of the center point is calculated from the sum of all *x* divided by the point. The *y* coordinate of center point is calculated from the sum of each *y* divided by the point as in equation 2 and equation 3.

$$m_x = \frac{1}{K}\sum_{k=1}^{K} x_k \tag{2}$$

$$m_y = \frac{1}{K}\sum_{k=1}^{K} y_k \tag{3}$$

$m_{(x,y)}$ is center of boundary. Result from the center boundary calculation is shown on Fig. 3.

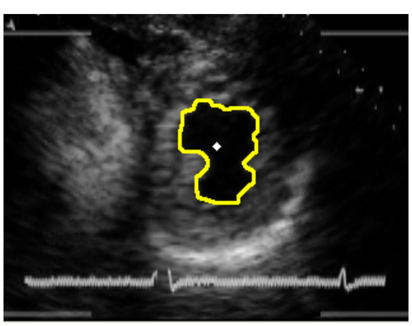

Figure 3. Result from center boundary calculation.

B. *Morphological Operation*

The second step is morphological operation, opening and closing algorithm [1]. The main function of opening and closing algorithm is to reduce speckle noise in the cardiac cavity image.

The opening algorithm involves eroding image A by B and dilation by B. Mathematically it is shown in equation 4.

$$A \circ B = (A \ominus B) \oplus B, \tag{4}$$

The closing algorithm is when image A is dilated and eroded by B

$$A \bullet B = (A \oplus B) \ominus B. \tag{5}$$

Where $\ominus$ and $\oplus$ denote erosion and dilation. The result from morphological opening and closing of cardiac cavity is shown in Fig. 4.

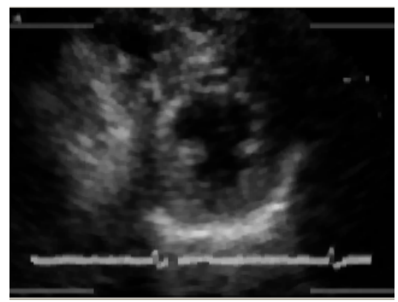

Figure 4. Result from morphological opening and closing.

C. *Threshold Operation*

The third step is the threshold operation, which converts image from gray scale to binary image. A threshold was set at a gray-level *t* to produce a binary image for each pixel position (*i, j*). In this example we use a fixed thresholding *t*=22. This number was selected from experiments on a training set and was used for all images in this research. Fig. 5 is the histogram of cardiac cavity image with a fixed value of thresholding.

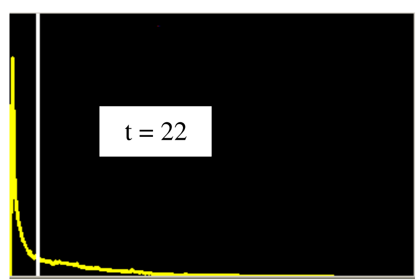

Figure 5. Histogram of cardiac cavity image and value of thresholding.

Fig. 6 (a) & (b) depict the result from thresholding operation of cardiac cavity image for a connecting region and disconnecting region boundary, respectively.

Figure 6. Results from threshold operation.

D. Boundary Detection

The forth step deals with boundary detection. First, the image is scanned pixel by pixel to find each connected region or boundary.

If the connecting region is smaller than 20 pixels and located far from the center of boundary of the image, then it is considered as not the border of cardiac cavity as shown in Fig. 7. But if the connecting region is greater than 20 pixels and close to the center of boundary, then it is considered the border of cardiac cavity as displayed in Fig. 8.

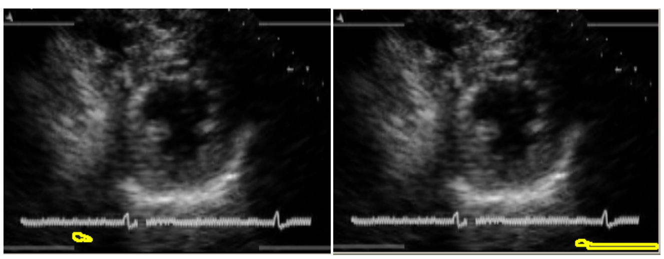

Figure 7. Connecting region smaller than 20 pixels and far from the center of image is not the border of cardiac cavity.

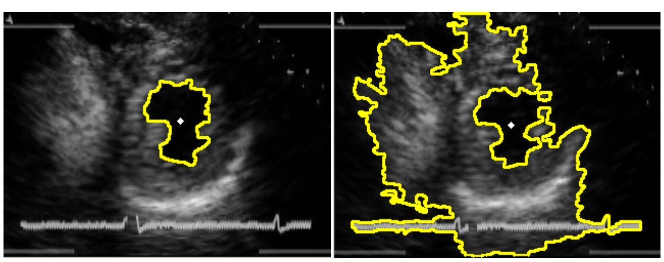

Figure 8. Result from border detection of cardiac cavity

E. Boundary Reconstruction

Boundary reconstruction is the fifth and last step. This method used triangle equation. Fig. 9 below shows a triangle, where A, B, C are the corners, and a, b, c are the distances between corners.

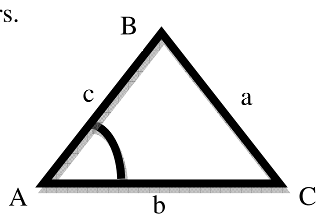

Figure 9. Triangle equation

If a, b, and c are known, then the angle of the corner can be calculated as in equation 6 and 7.

$$a^2 = b^2 + c^2 - 2bc(\cos A) \quad (6)$$

$$A = a\cos((b^2 + c^2 - a^2) / 2bc) \quad (7)$$

The results obtained from the threshold operation of cardiac cavity image in some images are closed border and the rest are unclosed border. We can make small corner angle to reconstruct enclosed border using triangle equation.

In this research, we use OpenCV Library, which is a library for computer vision. To get the boundary contour and reconstruct it, we have modified this library. Contour in this library that can be stored inside a memory storage is a sequence. A sequence in OpenCV is actually a linked list [7].

In this research, we use `cvFindContours` function to retrieve contours from the binary image and to return the number of retrieved contours. The function `cvSeqPop is used to` remove an element from the sequence and `cvSeqPopFront` function, on the other hand, is used to remove an element from the beginning of the sequence.

As aforementioned, the first step is determining the initial center boundary of cardiac cavity, therefore we can use `cvFindContours` function. The second step is cutting the contour radius that is greater than 0.5 of width size of the image and connecting two end points to each other. In this method, to cut the contour we can use `cvSeqPop` function `to` remove an element from the sequence and `cvSeqPopFront` function for removing an element from the beginning of the sequence as in Fig.10.

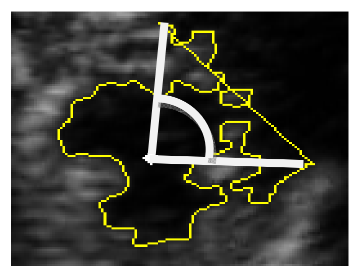

Figure 10. Center point of boundary.

Thirdly, finding the minimum corner angle of boundary in one side of the contour in which to cut the contour we can use *cvSeqPopFront* as in Fig. 11.

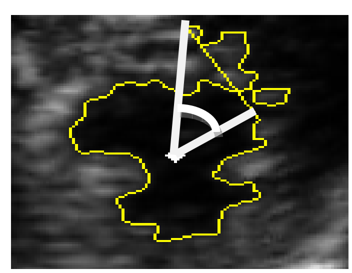

Figure 11. Creating minimum a small corner of boundary in one side of the contour

The forth step is finding the minimum corner angle of the boundary on the other side of the contour. In this method to cut the contour we can use *cvSeqPop* as in Fig. 12.

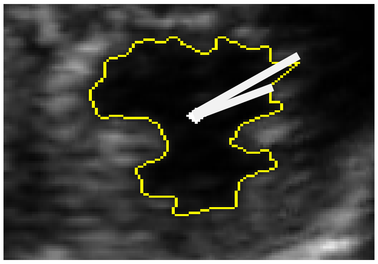

Figure 12. Sample result using *cvSeqPop* to find minimum small corner of boundary in other side of the contour

III. EXPERIMENTAL RESULT

This method used triangle equation to reconstruct enclosed border. The images show that the method is finding the minimum small corner of boundary in the contour as in Fig. 13.

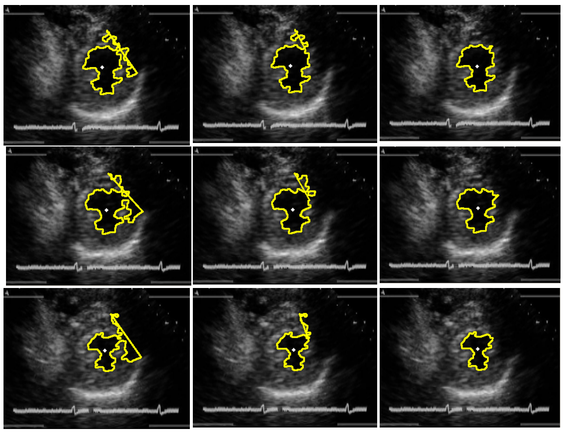

Figure 13. The method is finding the minimum small corner of boundary

Testing images in this research is a video with a process consisting of 9 repeated frames. Image size in this research is 320 wide and 240 high. The video shows that the border detection of cardiac cavity changes from large to small as in Fig. 14.

IV. CONCLUSIONS

The proposed method presents solution for automatic border detection of cardiac cavity image using boundary and triangle equation. The proposed method can automatically detect initial center of boundary and reconstruct boundary.

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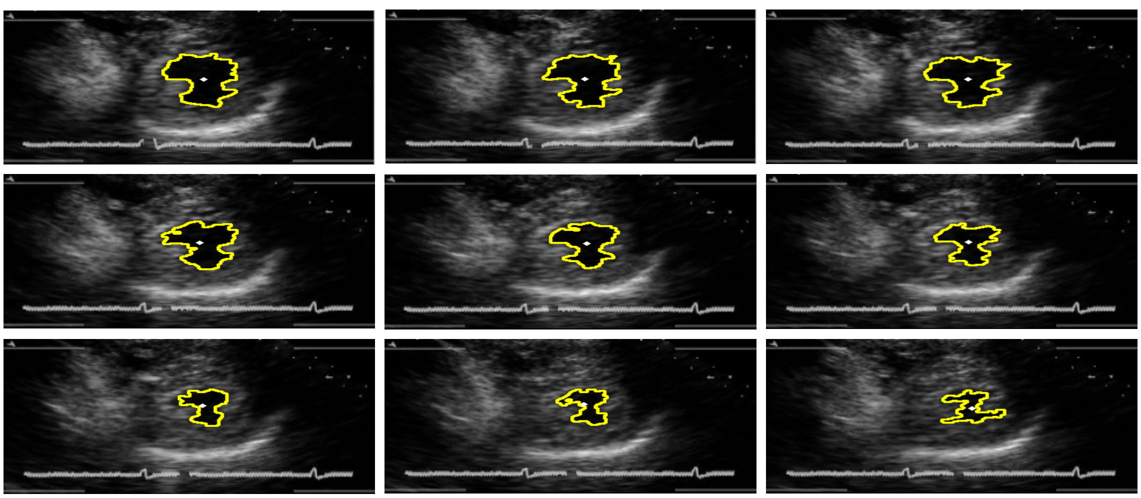

Figure 14. Border detection of cardiac cavity image