Cardiac Cavity Segmentation in Echocardiography Using Triangle Equation

Riyanto Sigit [#1], Mohd. Marzuki Mustafa [#2], Aini Hussain [#3], Oteh Maskon [*4], Ika Faizura Mohd Noh [*5]

[#] *Department of Electrical, Electronic and Systems Engineering*

Faculty of Engineering and Built Environment

Universiti Kebangsaan Malaysia

[1] riyanto@eepis-its.edu

[2] marzuki@vlsi.eng.ukm.my

[3] aini@vlsi.eng.ukm.my

[*] *Cardiology Care Unit*

Universiti Kebangsaan Malaysia Medical Center

Kuala Lumpur 56000 Malaysia

[4] auajwad@yahoo.com

[5] azuzayz@yahoo.ie

Abstract

In this paper, cardiac cavity segmentation in echocardiography is proposed. The method uses triangle equation algorithms to detect and reconstruct the border. Prior to the application of both algorithms, some preprocessings have to be carried out. The first step is high boost filter to enhance high frequency component while still keeping the low frequency component. The second step is applying morphological and thresholding operations to eliminate noise and convert the image into binary image. The third step is negative laplacian filter to apply edge detector. The fourth step is region filter to eliminate small region. The last step is using triangle equation to detect and reconstruct the imprecise border. This technique is able to perform segmentation and detect border of cardiac cavity from echocardiographics sequences.

Keywords: *cardiac cavity, high boost filter, morphology, negative laplacian, region filter, and triangle equation.*

I. INTRODUCTION

Cardiac cavity segmentation 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 [1-9]. However, there is still room for innovation and development of methods and algorithms. Some researchers used short axis images [1-6] and others used long axis images [7 & 8]. There are others who utilized semi-automatic detection [1, 4 & 6] and others developed fully automated detection [3 & 7]. Some author used active contour models or snakes to segmentation of cardiac cavity [5 & 8].

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. Vikram Chalana and David T [5] presented multiple active contour model for cardiac boundary detection. Saulo Guerreiro Lacerda et al [6] applied radial-search for segmentation of cardiac cavity. Jierong Cheng et al [7 & 8] used watershed segmentation snakes for boundary detection and find the center point of the boundary.

In our approach, three mayor steps are used to segmentation of cardiac cavity. First, pre-processing consist in enhancement is used to reduce noise and increase contrast. Secondly we used search contour to detect contour. Finally, we applied triangle equation algorithm to reconstruct the imprecise border. We believe that the proposed techniques can perform segmentation of cardiac cavity very precisely.

II. DEVELOPMENT

There are various methods and algorithms to detect the border of cardiac cavity [1-9]. In this algorithm, we use triangle equation to automatically detect and reconstruct border. The schematic diagram of the proposed technique is shown in Fig.1.
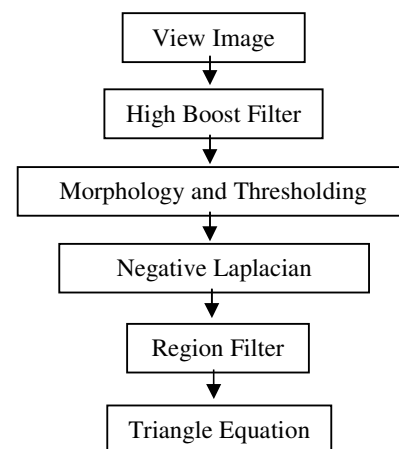
View Image

High Boost Filter

Morphology and Thresholding

Negative Laplacian

Region Filter

Triangle Equation

Fig.1. Schematic Diagram of the algorithm

A. View Image

There are some standard views of the cardiac cavity image, for example short axis and long axis views. In this research, we use short axis images. Fig.2 shows the short axis image of left ventricular cardiac cavity from echocardiography.
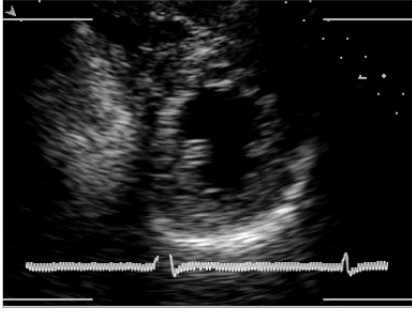

Fig.2. The short axis image left ventricular of cardiac cavity from echocardiography

B. High Boost Filter

The first step is high boost filter algorithm [6], which uses the spatial mask shown in Fig. 3. In this case, the high-boost filter can be used to enhance high frequency component while still keeping the low frequency components.

-0.1111	-0.1111	-0.1111
-0.1111	9.89	-0.1111
-0.1111	-0.1111	-0.1111

Fig.3. Mask used for the high boost filter.

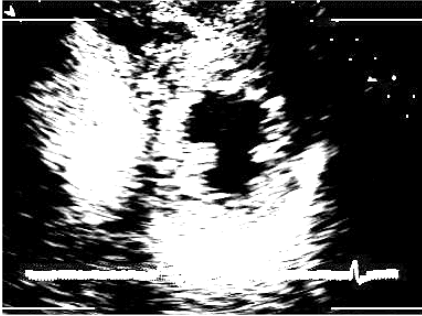The result from high boost filter of cardiac cavity is shown in Fig.4.

Fig.4. Result from high boost filter

C. Morphology and Thresholding

The second step is morphological operation, i.e. 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. Mathematical notation of the opening algorithm is shown in equation 1.

$$A \circ B = (A \ominus B) \oplus B, \qquad (1)$$

Where $\ominus$ and $\oplus$ denote erosion and dilation.

The closing algorithm is when image A is dilated and eroded by B. Mathematical notation of closing algorithm is shown in equation 2.

$$A \bullet B = (A \oplus B) \ominus B. \qquad (2)$$

The result from morphological opening and closing of cardiac cavity with thresholding is shown in Fig.5.
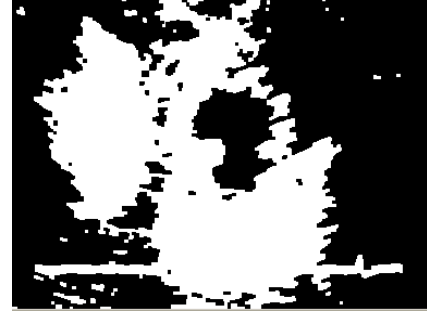

Fig.5. Result from morphological opening and closing with thresholding

D. Negative Laplacian Filter

The third step is negative laplacian filter. It is derivative filter to find areas of rapid change (edges) in an image. There are different ways to find an approximate discrete convolution kernal that approximates the effect of the Laplacian. A possible kernel is shown on Fig.6.

0	1	0
1	-4	1
0	1	0

Fig.6. Kernel used for negative Laplacian.

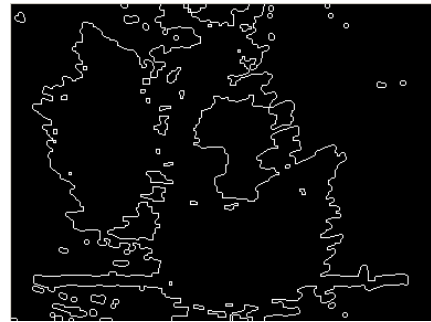The result from negative Laplacian filter is shown on Fig.7.

Fig.7. Result from negative Laplacian filter

E. Region Filter

The forth step is region filter. The main function of region filter is to eliminate small contour. The region filter scans the contour and calculated the area of each contour. Regions with area is smaller then a determined threshold are eliminates from contour [6].

The threshold value was set to 25 pixels, and was empirically determined. The result from region filter is shown on Fig.8.

Fig.8. Result from region filter

F. Triangle Equation

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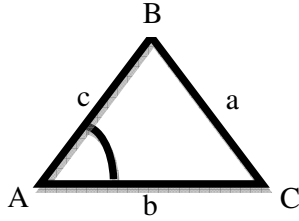

Fig.9. Triangle equation

If a, b, and c are known, then the angle of the corner can be calculated as in equation 3 and 4.

$$a^2 = b^2 + c^2 - 2bc(\cos A) \qquad (3)$$

$$A = acos((b^2 + c^2 - a^2) / 2bc) \qquad (4)$$

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.
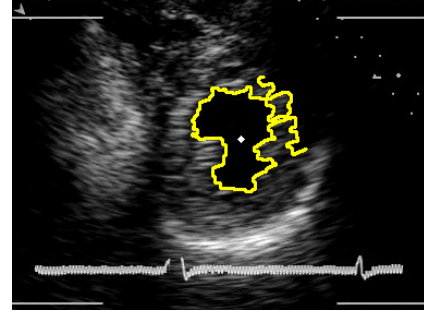

Fig.10. Center point of boundary

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 figure 11.
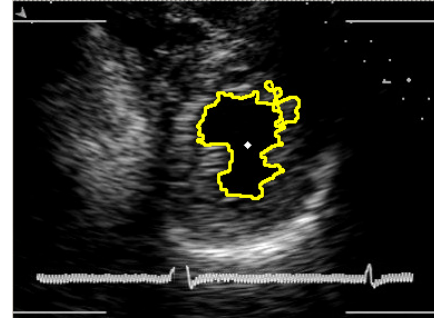

Fig.11. creating minimum a small corner of boundary in one side of the contour

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 figure 12.
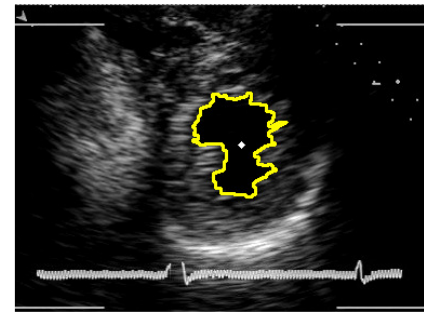

Fig.12.Sample result using *cvSeqPop* to find minimum small corner of boundary in other side of the contour

III. EXPERIMENTAL RESULT

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. 13.

IV. CONCLUSION

The proposed method presents solution for segmentation of cardiac cavity image using search contour and snakes.

ACKNOWLEDGMENT

REFERENCES

[1] J. W. Klinger, C. L. Vaughan, and T. D. Fraker, "Segmentation of echocardiographic images using mathematical morphology," *IEEE Trans.Biomed. Eng.*, vol. 35, 1988, pp. 925–934.

[2] A. Laine, and X. Zong, "Border Identification of Echocardiograms via multiscale edge detection and shape modeling," *Proc. of the IEEE Int. Conf. on Image Processing*, vol. 3, Sep. 1996, pp. 287 - 290 vol.3.

[3] W. Ohyama, T. Wakabayashi, F. Kimura, S. Tsuruoka, and K. Sekioka, "Automatic Left Ventricular Endocardium Detection in Echocardiograms Based on Ternary Thresholding Method", in *15th International Conference on Pattern Recognition (ICPR'00)*, Barcelona, Spain, 2000, pp. 320-323.

[4] Maria do Carmo dos Reis, Adson F. da Rocha, Daniel F. Vasconcelos, etc, "Semi-Automatic Detection of the Left Ventricular Border ", *30th Annual International IEEE EMBS Conference Vancouver,* British Columbia, Canada, August 20-24, 2008

[5] V. Chalana, D. T. Linker, D. R. Haynor and Y. Kim, "A Multiple Active Contour Model for Cardiac Boundary Detection on Echocardiography Sequences", IEEE Trans. on Medical Imaging, vol.15, no. 3, June 1996.

[6] Saulo Guerreiro Lacerda, Adson F. Da Rocha, Daniel F. Vasconcelos, etc, "Left Ventricle Segmentation in Echocardiography Using a Radial Search Based Image Processing Algorithm", *30th Annual International IEEE EMBS Conference Vancouver,* British Columbia, Canada, August 20-24, 2008

[7] Jierong Cheng, Say Wei Foo, and Shankar M. Krishnan, "Automatic Detection of Region of Interest and Center Point of Left Ventricle using Watershed Segmentation," *IEEE Int. Symposium on Circuits and Systems*, vol. 1, n. 2, May 2005, pp. 149-151.

[8] Jierong Cheng, Say Wei Foo, and Shankar M. Krishnan, "Watershed-Presegmented Snake for Boundary Detection and Tracking of Left Ventricle in Echocardiographic Images," *IEEE Trans. on Information Technology in Biomedicine*, vol. 10, n. 2, 2006, pp. 414-416.

[9] M. Kass, A.Witkin, and D. Terzopoulos, "Snakes: Active contour models", presented at the Int. Conf. Computer Vision, ICCV'87, London, U.K., 1987.

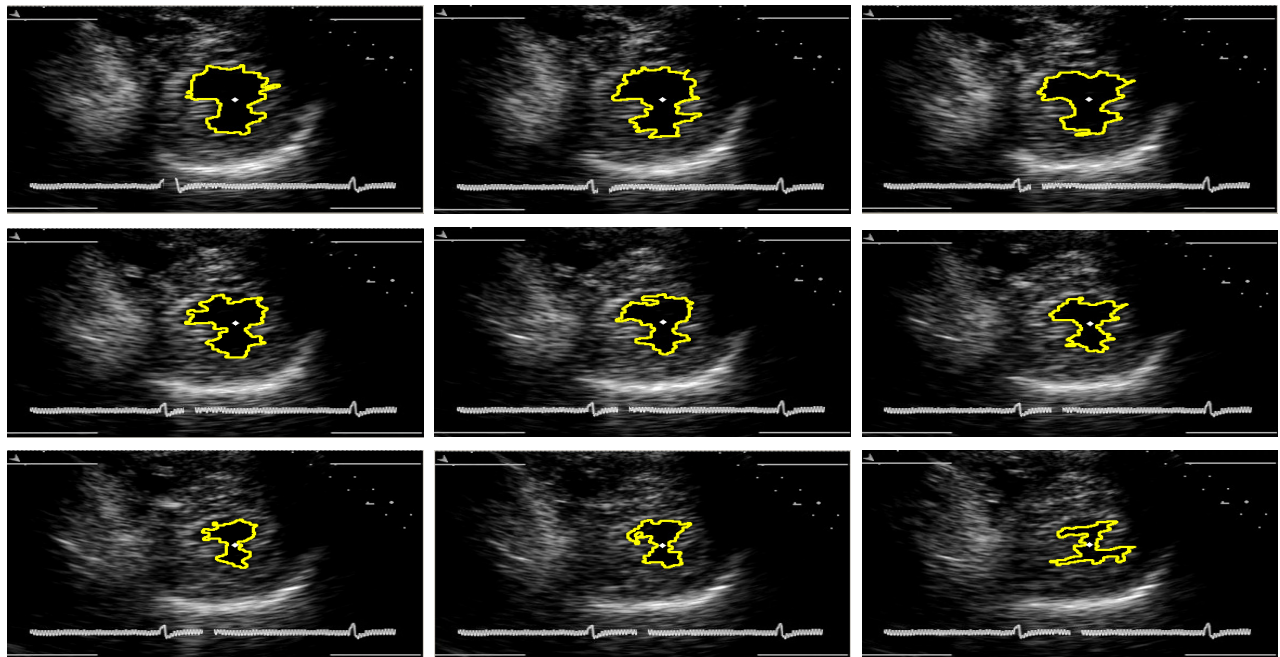[10] Gary Bradski and Adrian Kaehler, "Learning OpenCV", *O'Reilly Media*, September 2008.

Fig.13. Border detection of cardiac cavity image