Improved Segmentation of Cardiac Image Using Triangle and Partial Monte Carlo

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***Abstract*— In this paper, the segmentation of cardiac image for heart diseases is proposed. The method used Median High Boost Filter, Triangle Equation and Partial Monte Carlo. The first step is applying Median High Boost filter to eliminate noise. The second step is Triangle Equation to detect cardiac cavity and reconstruct the imprecise border. The third step is Partial Monte Carlo to measure the area of the heart cavity. This research used ultrasound to measure cardiac function. The experiments represented that the extended method is able to detect and improve the segmentation of cardiac cavity images with precise and faster. The performance segmentation for assessment errors cardiac cavity obtained an average triangle 8.18%, snake 19.94% and watershed 15.97%.**

Keywords—Cardiac; Median High Boost Filter; Triangle Equation; Partial Monte Carlo;

I. INTRODUCTION

Border detection cardiac images in short axis view is very efficient in helping doctors to diagnose patient heart diseases. Various studies and methods have been established to find cardiac cavity [1-11]. However, there is still space for novelty and expansion of methods and algorithms. To perform segmentation and detection of echocardiographic images, a number of researchers have used short axis images [1−8], while others [9, 10] have used the long axis images. In [1, 4, 6], semi-automatic detection method was used, where-as in [3, 9] a fully automated detection method was developed. It is also interesting to note that in [5, 10, 11], the active contour models or snakes algorithm has been used to perform segmentation of cardiac cavity.

In [1], Klinger et al. applied mathematical morphology to carry out the segmentation of echocardiography images. Laine and Zong [2] provided border detection that traded on the shape modeling and border rebuilding from a set of images. Ohyama et al. [3] used ternary threshold method for detection of left ventricular endocardium. Maria et al. [1, 4] used up semi-automatic detection of the left ventricular border. Chalana and David [5] presented multiple active contour models for cardiac boundary detection. Lacerda et al. [6] used up radial search for partition of cardiac images. Cheng et al. [9, 10] applied watershed segmentation for cardiac detection and located center point in borderline. Santiago et al. [12, 13] presented segmentation of the LV in three-dimensional (3-D) echocardiographic.

In this study we propose improved segmentation of cardiac image for heart diseases. The proposed method uses Median High Boost filter, Triangle Equation and Partial Monte Carlo. This technique can detect border of the cardiac cavity in the echocardiography video very precisely.

II. METHODOLOGY

In this section, we represent the procedures developed segmentation of cardiac image for heart diseases. The procedure which involves Median High Boost Filter, Triangle Equation and Partial Monte Carlo are graphically described in a schematic diagram shown in Fig. 1.

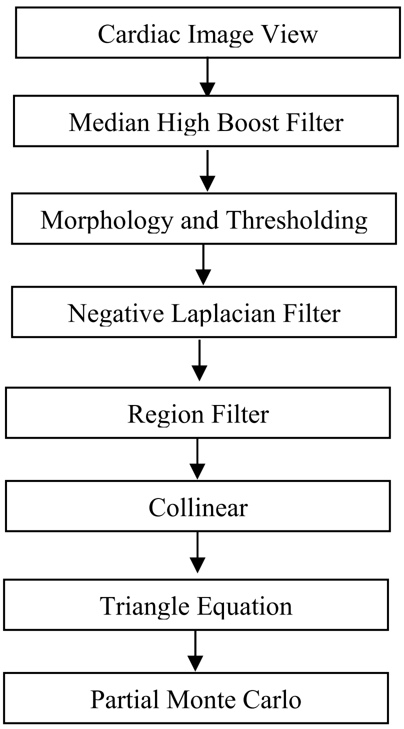


Fig.1. Schematic Diagram of the algorithm

A. Cardiac Image View

There are some standard views of the cardiac cavity video, for example short axis and long axis views. In this research, we used short axis echocardiography video. Fig. 2 represents the cardiac images in short axis view from left ventricular cardiac video.

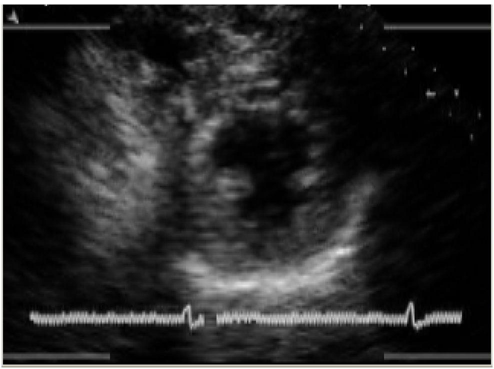


Fig.2. The cardiac images in short axis view

B. Median High Boost Filter

The first step is applying Median High Boost filter to eliminate noise. Median High Boost is a new method that is a combination between median filtering and High Boost filter as shown in Fig. 3.

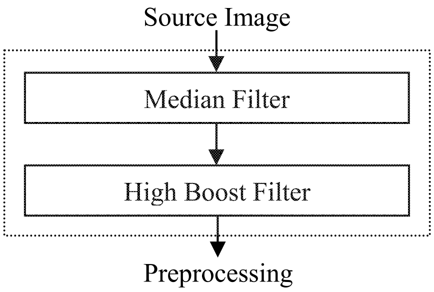


Fig. 3. Median High Boost Filter

C. Morphology and Thresholding

After the median high boost filter implementation, we subject the image to the morphological operation that basically deals with the opening and closing algorithm [1]. The main purpose of the 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 this is achieved using the mathematical notation of the opening algorithm shown in (1).

$$A \circ B = (A \ominus B) \oplus B \quad (1)$$

Where Θ and ⊕ denote erosion and dilation, respectively.

$$A \bullet B = (A \oplus B) \ominus B \quad (2)$$

The closing algorithm is implemented by dilating image A and eroding it by B. The mathematical notation of the closing algorithm is shown in (2).

D. Negative Laplacian Filter

Next, the negative Laplacian filter, which is a derivative filter, is realized to find areas of rapid change (edges) in the image. There are several ways to find an approximate discrete convolution kernel that approximates the effect of the Laplacian. A possible kernel is shown in Fig. 4 below.

0	1	0
1	-4	1
0	1	0

Fig.4 . Kernel used for negative Laplacian.

E. Region Filter

Subsequently, we use region filter with the aim to eliminate the small contours. The region filter scans the contour and calculates the area of each contour. Regions with area that is smaller than the pre-determined threshold are eliminated from the contour [6]. The threshold value was set to 25 pixels, and it was empirically determined.

F. Collinear Equation

The next step deals with the implementation of the collinear equation algorithm. The main purpose of such implementation is to optimize the number of contours by keeping and deleting some contours so that the resulted contour is closer to the actual boundary. This is achieved by finding the centroids of all existing contours using (3) as shown below.

$$\text{Centroid (C)} = \left\{ \frac{\sum_{k=1}^{n} Xk}{n}, \frac{\sum_{k=1}^{n} Yk}{n} \right\} \quad (3)$$

A collinear equation is then carried out from the center of the boundary to to the centroids of each contour by finding the slope and intercept. The collinear equation used is as shown below in (4)-(6):

$$y = wx + b \quad (4)$$

$$\text{Slope (w)} = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} \quad (5)$$

$$\text{Intercept (b)} = \bar{y} - w\,\bar{x} \quad (6)$$

G. Triangle Equation

The next step is the practice of the triangle equation method. Fig. 5 below shows a triangle, where A, B, and C are the corners. a is distance between corner B and C, b is distance between corner A and C, and c is distance between corner A and B.

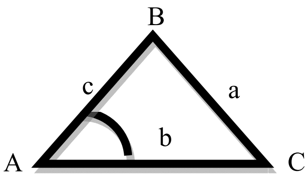


Fig. 5. Triangle equation

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

$$A = \mathrm{acos}((b^2 + c^2 - a^2) / 2bc) \quad (8)$$

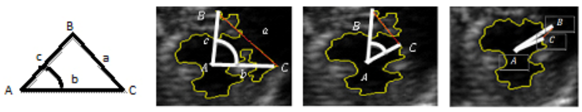
The previous process produces an image showing the cardiac cavity with open and closed boundaries. The boundary is closed when all points are connected, as shown in Fig. 6(a). The boundary is open if there are disconnected points or endpoints, as shown in Fig. 6(b).

(a) (b)

Fig. 6. Boundary of cardiac cavity. (a) Close boundary. (b) Open boundary.

The boundary of the cardiac cavity can be obtained directly if the contour is closed, but if the boundary of the cardiac cavity is open, it can be obtained by using the triangle equation according to the following steps.

1. The first step is to determine the approximate center of the region that seems to be enclosed by the boundary, which can be done by calculating the centroid. This point is denoted as point A in Fig. 7(a).
2. The two endpoints of the boundary are located and are marked as points B and C in the same figure. The triangle BAC is formed from these three points with sides a, b and c.
3. The gap in the boundary is minimized by first fixing one of the end points, such as point B in Fig. 7(b), and allowing point C to transverse inward along the boundary until the point at which the angle BAC is minimized is found. A similar action is then performed for point B to obtain the result shown in Fig. 7(c).
4. The open boundary is then closed by connecting a line from point B to point C.



(a) (b) (c)

Fig. 7. Triangle Equation on the cardiac cavity image

H. Partial Monte Carlo

The last step is to implement the partial Monte Carlo. Monte Carlo methods are stochastic techniques. The main purpose of this implementation is to calculation area of cardiac cavity images. Fig. 8 shows Monte Carlo method for calculation cardiac cavity, where minX, MinY, MaxX and maxY is the square of boundary.

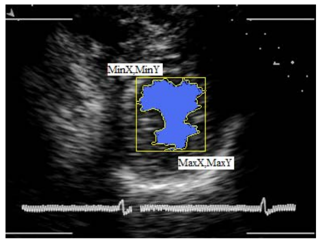


Fig. 8. Monte Carlo method for calculation cardiac cavity

If total number of shaded part (nd) and total number random in square (nt) are known, then the area can be calculated using (9).

$$\text{Area}=nd/nt*(maxX-minX)*(maxY-minY) \quad (9)$$

Partial Monte Carlo is part of Monte Carlo algorithm. The purposed of this algorithm is to improve calculation faster than normal Monte Carlo. The idea is to divide the region boundary in several sections and search box in the area of the boundary. Fig. 9 shows the partial Monte Carlo algorithm with the calculation area.

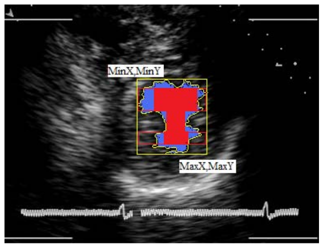


Fig. 9. The partial Monte Carlo algorithm with the calculation area

III. Experiment Result

The proposed algorithm was tested using dataset videos ultrasound from Hospital Dr. Soetomo Surabaya. The method uses Median High Boost (MHB) filter, Triangle Equation and Partial Monte Carlo. The experiment result based on preprocessing between mean, median, Gaussian, HB and MHB as shown in Fig. 10. MHB filter has the best image quality (PSNR = 57.2753) and has the ability to reduce noise (ENL = 0.5760).

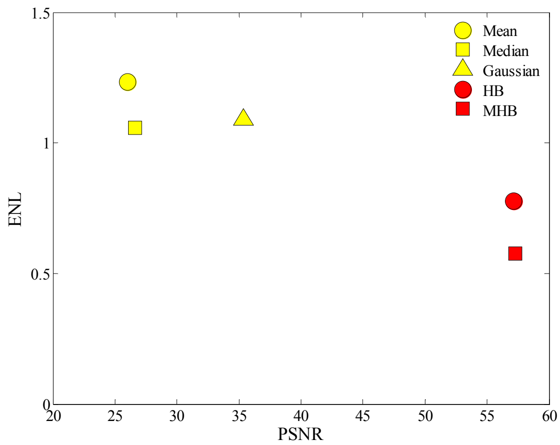


Fig. 10. The experiment result based on preprocessing

The experiment result based on segmentation between snake, watershed and triangle methods compared with the reference image shown in Fig. 11. Triangular methods produce better segmentation than snake and watershed.

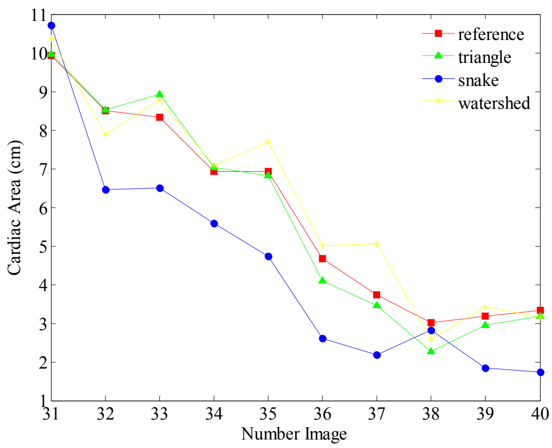


Fig. 11. The experiment result based on segmentation

Statistical analysis based on the results segmentation for 100 data as shown in Fig. 12. Shown in box plots the error for triangle method has a smaller than the snake and watershed.

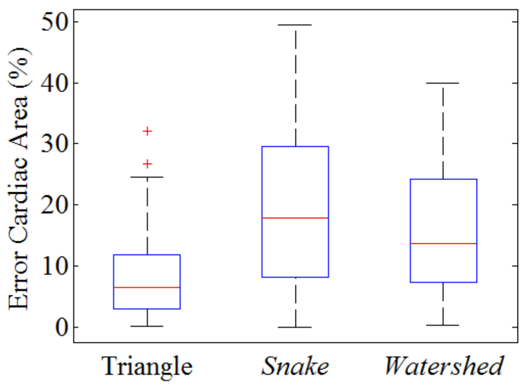


Fig. 12. Statistical analysis based on the results segmentation

In general, decisions and segmentation capabilities with comprehensive quantitative measurements showed that the border region segmentation using a triangle closer to the reference image or better result than using snake and watershed.

The performance segmentation for assessment errors heart cavity obtained an average triangle 8.18%, snake 19.94% and watershed 15.97%. This achievement shows that the segmentation using triangle method has the smallest error value. These indicate where the triangle segmentation method is better than snake and watershed.

The new method, named Partial Monte Carlo (PMC) has been created and compared to the measurement of the heart cavity area. The accuracy of the method has been compared with the PMC comprehensive measurement method Monte Carlo (MC), Simpson (SIM) and trapezoidal (TRA) of the validity of the correct size.

The experiment result based on measure cardiac area between PMC, MC, SIM and TRA methods compared with the reference image shown in Fig. 13. PMC methods produce better calculation cardiac area than MC, SIM and TRA. PMC. and MC. They have an average error of heart cavity that PMC is 0.64% and MC is 0.93%.

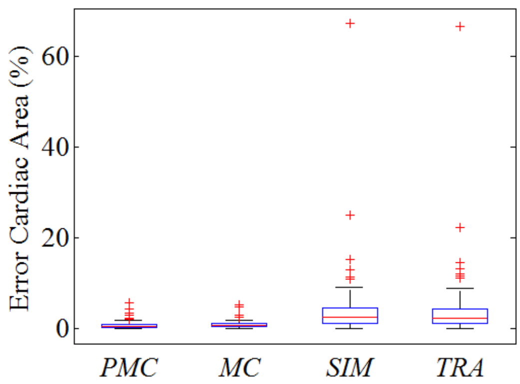


Fig. 13. The experiment result based on measurement cardiac area

The experiment result based on a faster segmentation between snake, watershed and triangle methods as shown in Fig. 14. Triangle method also have a faster segmentation than the others is 108 ms, while snake is 1119 ms and watershed is 491 ms.

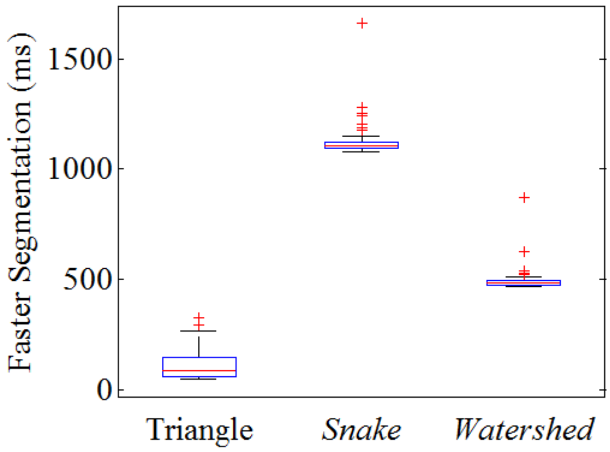


Fig. 14. The experiment result based on a faster segmentation

The result of the median high boost filter implementation is shown in Fig. 15a followed by the results after morphological operation with thresholding in Fig. 15b. In can be seen that high boost filter implementation yields an enhanced image of the cardiac cavity, which is further improved using morphological operations with thresholding. Result from the negative Laplacian filter implementation is shown in Fig. 15c, while result after region filtering is shown in Fig. 15d.

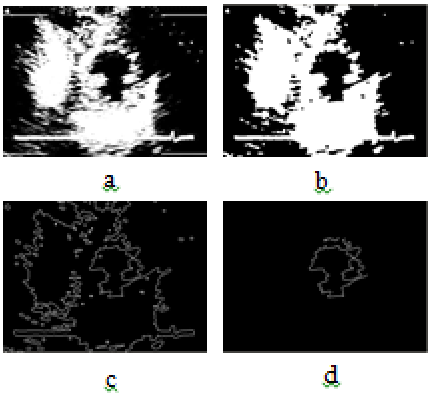


Fig. 15. Result from the median high boost filter, morphological operation, laplacian and region filter

This method used collinear equation to keep and delete some contours; hence, the resulted contour is closer to the center boundary as shown in Fig. 16.

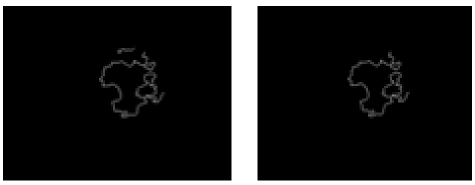


Fig. 16. The method allow one to keep and delete contour

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. 17.

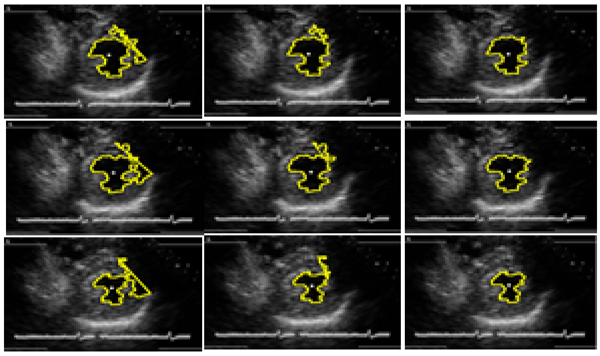


Fig. 17. The method is finding the minimum small corner of boundary

The testing images used in this research are extracted from a video recording that consists of nine repeated frames. The typical image size used is 320 pixels wide and 240 pixels high. It can be seen that the developed algorithm successfully detects and traces the boundary of the cardiac cavity in the video as it changed from large to small as depicted in Fig. 18.

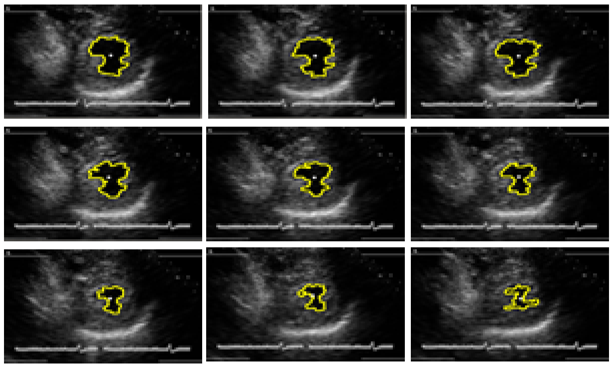


Fig. 18. Border detection of cardiac cavity image

IV. CONCLUSION

The proposed method presents solution for segmentation of echocardiograph image for heart disease. This research has produced Median High Boost Filter that is able to reduce noise and maintain image information. The segmentation using triangle equation method has the smallest error value. The performance segmentation for assessment errors cardiac cavity obtained an average triangle 8.18%, snake 19.94% and watershed 15.97%. The experiments represented that the extended method is able to detect and improve the segmentation of cardiac cavity images with precise and faster.

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