Semi-Automatic Border Detection of Cardiac Cavity in Echocardiography Video

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***Abstract*—In this paper, a semi-automatic border detection of cardiac cavity in two-dimensional short axis echocardiography video is proposed. The method used b-spline and optical flow to detect, reconstruct the border and tracking the border for every frame in echocardiography video. The first step is applying median filtering to eliminate noise. The second step is determining the initial boundary of the cardiac cavity in the first frame. The third step is using optical flow method to detect cardiac cavity and reconstruct the imprecise border. This technique can detect border of the cardiac cavity in the echocardiography video very precisely.**

Keywords—-boundary detection; cardiac cavity; median filtering; b-spline; optical flow

I. Introduction

Border detection of cardiac cavity in two-dimensional short axis echocardiography videos is very useful in helping doctors to diagnose patient cardiac cavity. Various researches and methods have been conducted to detect cardiac cavity [1-7]. However, there is still room for innovation and development of methods and algorithms. There are other who utilized semi-automatic detection and others developed fully automated detection.

Riyanto Sigit [1] applied segmentation of echocardiography images using triangle equation, snake and watershed. In his paper, using triangle equation have a lower error rate for segmentation than the others. The percentage error rate using triangle equation is 18 %, while snake is 19,94 % and watershed is 15,16 %. Triangle equation method also have a faster segmentation than the others is 108 ms, while snake is 119 ms and watershed is 491 ms.

As such, we propose a method that initially involves determining the initial boundary of the cardiac cavity in the first frame. Next, we apply the median filtering to eliminate noise. Finally, using b-spline and optical flow method we detect and reconstruct the imprecise border every frame in echocardiography video. We believe that the proposed technique can detect border of the cardiac cavity in the echocardiography video very precisely.

II. Development

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. 1 shows the short axis image of left ventricular cardiac cavity from echocardiography video.

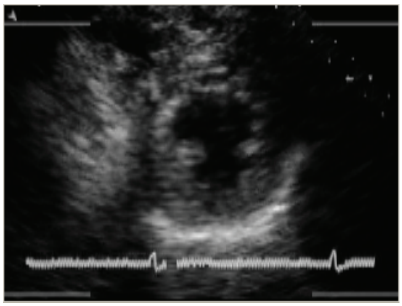


Fig. 1. The short axis image left ventricular of cardiac cavity from echocardiography video.

There are various methods and algorithms to detect the border of cardiac cavity [1-7]. In this algorithm, we use b-spline and optical flow to automatically detect and reconstruct the imprecise border every frame in echocardiography video. Fig. 2 shows the diagram of the aforementioned algorithm.

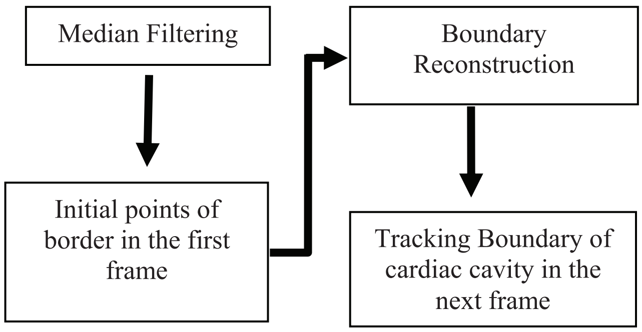


Fig. 2. Schematic Diagram of the algorithm.

A. Median Filtering

The first step is applying median filtering to reduce noise and clarify border of the cardiac cavity. Value of median filtering taken from the pixel data collection that sorted from smallest value to the largest value and taken its center value (g(x,y)). So, it makes median filtering able to clarify border of the edge. The following formula is used on Median Filtering for smoothing cardiac cavity image:

$$g(x,y) = median\left(\sum_{i=-1}^{1}\sum_{j=-1}^{1}(f(x-i),(y-j))\right) \quad (1)$$

In this paper, median filtering process using a kernel with the size 3x3. We use small size of the kernel, so it make the image smoothing process will be faster because if we use 3x3 size of the kernel, the process will filtering for every 9 pixel values every 9 pixel values in the image as shown below.

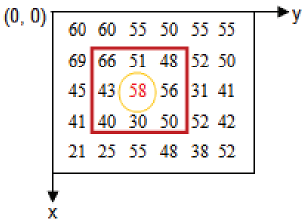
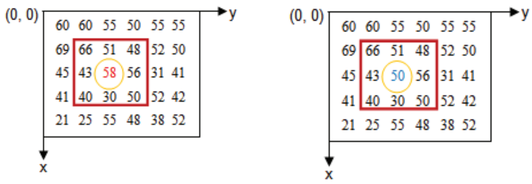


Fig. 3. Example pixel value of the image that kernel used is 3x3

When processing, 9 pixel values will be sorted from smallest value to the largest value. From that, we can find the median value of the data that has been sorted. So, the center pixel value in the kernel will be replaced with the median value that has been generated. Here are the results of the pixel values that have been made median filtering.



(a) (b)

Fig. 4. (a) Example the initial pixel value of the image (b) Example the pixel value that has been changed with the median value

Here will be shown result of the image that has been done preprocessing using median filtering on Fig. 5.

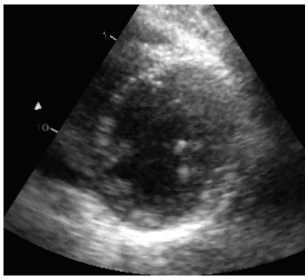


Fig. 5. Result from median filtering

B. Initial border in the first frame

The second step is initial border cardiac cavity in the first frame echocardiography video that is called segmentation. Segmentation is used to separate object from the image. Segmentation method is perfomed by semi-automatic. In this step, user will determine the starting point to detect position cardiac cavity at the end of diastole. Generally, the position points of the cardiac cavity border at time t + 1 can be written as

$$Q_{t+1} = f(Qt, Vt) \quad (2)$$

Qt (xt^1, yt^1, ..., xt^n, yt^n) is the position points of the cardiac cavity boundary at time t and v is the velocity vector of each point. The accuracy of tracking cardiac cavity boundary until the final conditions determined by method of selecting a point at the initial conditions.

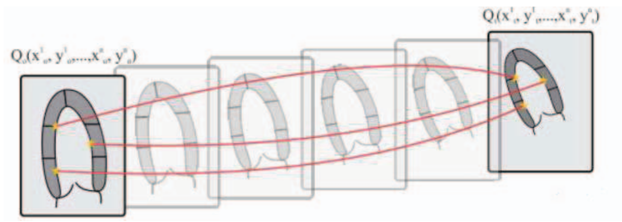


Fig. 6. Tracking points of the cardiac cavity boundary from diastole *to* sistole

Where the position of the point (x, y) is selected manually by the user at the beginning of the first frame echocardiography video. The number of points which is selection more than 10 points. The more number of points that have been selected will produce better segmentation and tracking cardiac cavity. Selection of the starting point on the view PSAX is planned according to the shape of the distribution LV segment (Left ventricle)

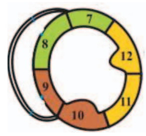
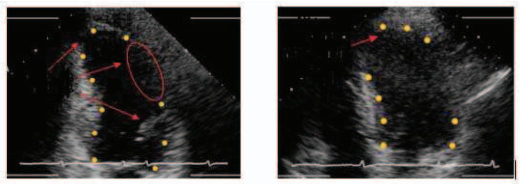


Fig. 7. Shape of the distribution LV segment

Selection of the starting point should be at the heart cavity boundary which can be determined with certainty in order to produce the accuracy of the position until the end of the frame.



(a) (b)

Fig. 8. (a) Example selecting points that can't be determined

After that, all of the points will be smoothed using B-spline to get better cardiac cavity segmentation.

C. *Boundary Reconstruction*

Boundary reconstruction is the third step. This step used b-spline method to reconstruct boundary of the cardiac cavity from the points that can not be determined its position because there are a lot of noise in the image echocardiography. By segmenting using B-spline has two advantages: (1) improve the tracking accuracy of the cardiac cavities and (2) handle the problem borders is interrupted or lost. In the B-spline, point at x = tj known as knots or break-points and every spline function of order n on the set of knots can be expressed as a linear combination of B-spline.

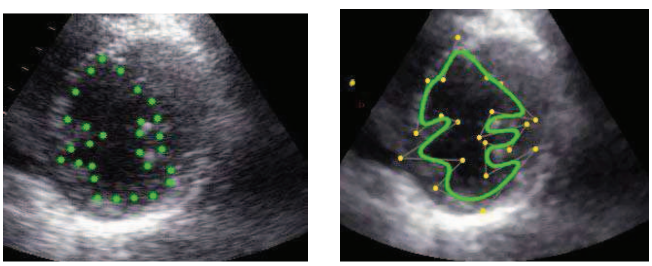
$$S_{n,t}(x) = \sum_i B_{i,n}(x) \tag{3}$$

Where i is the point of control and Bi,n (x) is a basis function on the degree n. To find the value Basis Function using the following equation

$$B_{i,1}(x) := \begin{cases} 1 & \text{if } t_i \le x < t_{i+1} \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

$$B_{i,k}(x) := \frac{x-t_i}{t_{i+k-1}-t_i}B_{i,k}(x) + \frac{t_{i+k}-x}{t_{i+k}-t_{i+1}}B_{i+1,k-1}(x) \tag{5}$$

The equation of the basis function is implementas de Boor algorithm. Fig.9 shows the result boundary of the cardiac cavity using b-spline method.



(a) (b)

Fig. 9. (a) Shows selection initial points of border in the first frame
(b) Shows b-spline method from the points

D. *Tracking Boundary of cardiac cavity in the next frame*

Tracking Boundary of cardiac cavity in the next frame is the fifth and last step. In this step, is used to cardiac cavity tracking for every frame in the echocardiography video. In this video, border of the cardiac cavity is not clear and hard to track in the next frame because of the noise caused by the reflection process of the ultrasound waves. So, in this research to tracking cardiac cavity for every frame using optical flow method.

Point tracking using optical flow method is a form of very simple point tracking which tracked object based on common features between before and after frames. This method using *Lucas-Kanade* algorithms because the method is easily applied to a subset of the points in the input image.

The disadvantage of using small local windows in *Lucas-Kanade* is that large motions can move points outside of the local window and thus become impossible for the algorithm to find. So, we also development of the "pyramidal" LK algorithm, which tracks starting from highest level of an image pyramid (lowest detail) and working down to lower levels (finer detail). Tracking over image pyramids allows large motions to be caught by local windows.

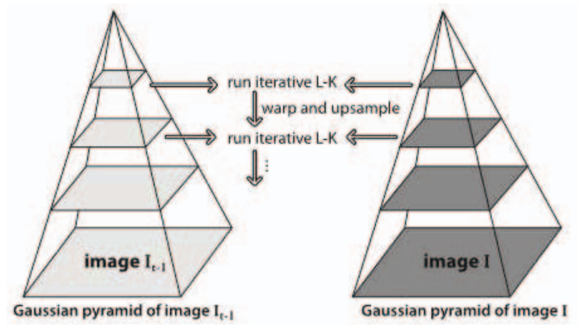


Fig. 10. Implements Pyramid Lucas-Kanade optical flow

In this research, we use *OpenCV* Library, which is a library for computer vision. To get the boundary of cardiac cavity in the next frame, we have modified this library. In this research, we use *calcOpticalFlowPyrLK* function to detect points of the border cardiac cavity in the next frame. On figure 11, show direction point movement from first frame to the next frame. This figure indicate that point of the boundary cardiac cavity moving to the left side.

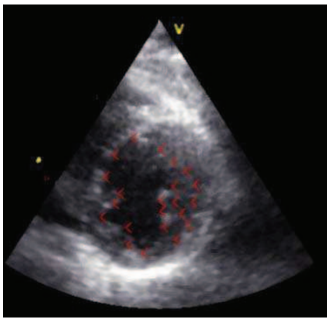


Fig. 11. Show point direction result optical flow method in the second frame

III. CONTRIBUTION

Contribution of this paper is the application of b-spline method to reconstruct border of cardiac cavity and application of optical flow methods to tracking cardiac cavity on the two-dimensional short axis echocardiography video.

IV. EXPERIMENTAL RESULT

This method used b-spline to reconstruct the border from first frame in echocardiography video. The images show that the method is finding initial point of the boundary cardiac cavity and than connect all of the points using b-spline method as in Fig. 12.

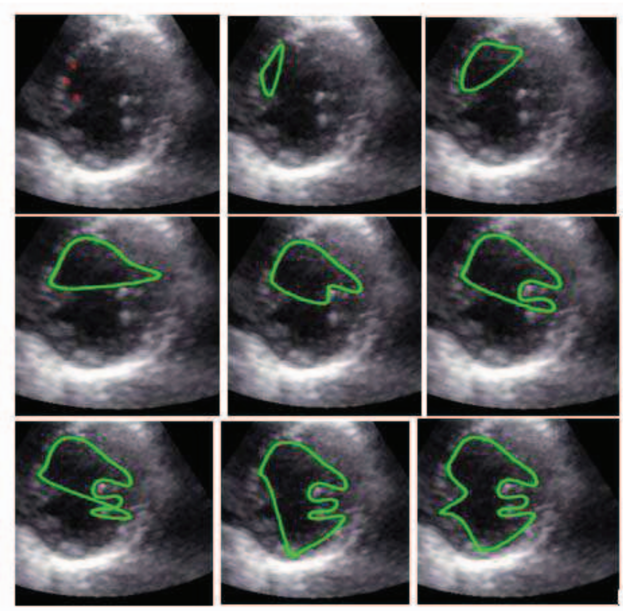


Fig. 12. The method in finding initial points of the boundary cardiac cavity and connect all of the points

Testing inital points in this research using more than 20 points. That is will be show a better reconstruct boundary cardiac cavity if we use initial points more than 20 points. This method also used optical flow method to track point of boundary cardiac cavity for every frame in echocardiography video as in Fig. 13.

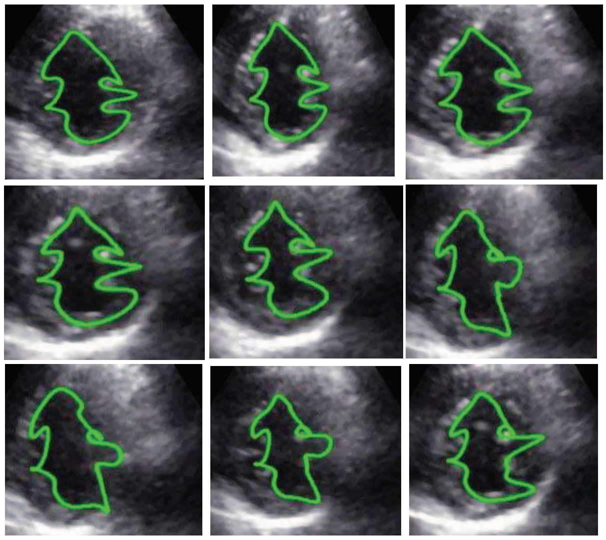


Fig. 13. Result boundary of cardiac cavity optical flow method for every frame in video

To see the effectiveness of tracking cardiac cavity using optical flow method in every frame, so we did testing the area of cardiac cavity from this system and calculate area of cardiac cavity manually from some user in every frame of echocardiography.

TABLE I. RESULTS AREA OF CARDIAC CAVITY FROM USERS

Frame	Users			Average of users
	P1	P2	P3	
SAX_3.jpg	10,5416	10,4985	10,3374	10,45917
SAX_1.jpg	10,4995	11,426	10,5778	10,83443
SAX_8.jpg	7,74899	7,14019	6,87137	7,253517
SAX_6.jpg	8,56927	8,52481	7,7915	8,295193
SAX_4.jpg	9,8049	10,3318	9,05817	9,731623
SAX_5.jpg	9,61028	8,93047	9,208	9,249583
SAX_9.jpg	7,06112	6,9534	7,10514	7,039887
SAX_2.jpg	10,9534	10,0333	10,2216	10,40277

TABLE II. RESULTS AREA OF CARDIAC CAVITY BETWEEN SYSTEM AND USERS

Frame	resut of tracking	Average of users	Error (%)	STD (standard deviation)
SAX_3.jpg	10,8188	10,45917	3,324152	0,011585

SAX_1.jpg	11,1043	10,83443	2,43029	0,263996
SAX_8.jpg	8,4019	7,253517	13,66814	0,202186
SAX_6.jpg	9,09818	8,295193	8,825794	0,190774
SAX_4.jpg	10,1439	9,731623	4,064282	0,40956
SAX_5.jpg	9,51589	9,249583	2,798547	0,116832
SAX_9.jpg	7,91062	7,039887	11,00714	0,006094
SAX_7.jpg	8,60126	8,172893	4,980278	0,08226
SAX_2.jpg	11,1109	10,40277	6,373321	0,236262

From the TABLE I. we compared testing frame of echocardiography video with 3 users. User-1(P1), User-2(P2), User-3(P3). From the table 2, we compared testing frame of echocardiography video between system and average of users. It can be seen that error between system and average of users is only less than 11 % and area of cardiac cavity which got from result of 3 users almost same with the average standard deviation is 0.18. This indicates that this method is effective to tracking cardiac cavity in echocardiography video.

V. Conclusions

The proposed method presents solution for semi-automatic border detection of cardiac cavity in echocardiography video. The proposed method can semi-automatically detect initial points of first boundary, reconstruct boundary and automatically tracking boundary for every frame.

Acknowledgment

The authors would like to thank the government of Indonesia (DIKTI) for the funding of this research through research grant

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