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Improved echocardiography segmentation using active shape model and optical flow

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Abstract

Heart disease is one of the most dangerous diseases that threaten human life. The doctor uses echocardiography to analyze heart disease. The result of echocardiography test is a video that shows the movement of the heart rate. The result of echocardiography test indicates whether the patient's heart is normal or not by identifying a heart cavity area. Commonly it is determined by a doctor based on his own accuracy and experience. Therefore, many methods to do heart segmentation is appearing. But, the methods are a bit slow and less precise. Thus, a system that can help the doctor to analyze it better is needed. This research will develop a system that can analyze the heart rate-motion and automatically measure heart cavity area better than the existing method. This paper proposes an improved system for cardiac segmentation using median high boost filter to increase image quality, followed by the use of an active shape model and optical flow. The segmentation of the heart rate-motion and auto measurement of the heart cavity area is expected to help the doctor to analyze the condition of the patient with better accuracy. Experimental result validated our approach.

***Keywords**: active shape model, echocardiography, median high boost filter, optical flow*

1. Introduction

Based on data from the World Health Organization (WHO), heart disease is one of the most dangerous diseases in the world. From 1990 to 2017 WHO placed heart disease as the number one killer in the world this data from WHO in 2017. According to WHO records in 2017, deaths from heart disease and blood vessels are expected to rise to 20 million and by 2030 will rise again to 23.6 million people. Echocardiography video is used by doctors to analyze cardiac performance of patients. Echocardiography uses techniques by emitting ultrasound waves to determine the size, shape, function of the heart and the condition of the heart valves visualized into the video image. The results of the examination on echocardiography tests can only be read by the doctor so that the analysis of the state of the heart depends on the accuracy and experience of the doctor so that will cause a different analysis of each doctor in determining the true state of the heart.

In previous research [1] to determine the cardiac performance of echocardiographic video results have been implemented using several methods. Among them is to use segmentation of triangle equations. The triangle method has the fastest segmentation of 108 ms, Sigit [1]. Another research is tracking by using Optical Flow method, error generated wide heart cavity between testers with system about 0-7%, Rochmawati [2]. And using optical flow farneback yields an error value of 0.13-9.85% for the left ventricle, 2.22-10% for the aorta, and 1.98-20.79% for the left atrium Baiq [3]. The segmentation using Active Shape Model. Then in this paper using Partial Monte Carlo to calculate the area. This system has a 4.309% errors, Shaleh [4]. This methodology has present that optical flow can improvement ejection fraction measurement which focus on reconstruct left ventricle's semi-automatically, Arvina [5]. Algorithm of ASM can be maximized using dual active shape model in the Bookstein coordinates, El-Rewaidy [6]. In this paper, the algorithm of ASM using to search and tackle segmentation of tissues with nearby organs of similar intensities, Esfandiarkhani [7]. This paper proposes a robust approach based on the Active Shape Model (ASM) that is able to solve. The difficulty inherent to the LV segmentation in MRI is that the images contain outliers (i.e., observations not belonging to the LV border) due to the presence of other structures,

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Santiago [8]. The purpose of this paper is a better algorithm of ASM because the process of fitting on the ASM, the results obtained are still less well, Santiago [9].

In this paper proposes a combination of ASM and PDAF to generate a stronger segmentation of the parameter approach, El-Rewaidy [10]. In another study segmentation of the heart cavity using another method, the watershed and showed better results than the active contour [11]. In this research of cardiac cavity in two-dimensional short-axis, echocardiography image with the method uses boundary and triangle equation to detect and reconstruct the border [12]. In this paper, a new formulation of a Robust Active Shape Model (RASM) is present to 3D segmentation of the left ventricle (LV) in cardiac MRI [13]. In this paper uses combine a random forest classifier with an active shape model (ASM) to present a model-based learning segmentation algorithm to detect the left ventricle (LV) boundary of the heart from ultrasound (US) images [14]. In this paper presents a semi-automatic approach in this study that is capable of identifying the endocardial borders robustly from cine magnetic resonance images using deformation flow and optical flow [15]. This paper reports a quantification of cardiac motion in Short-Axis (SAX) MRI images using the optical flow method [16]. In this paper presents estimates the motion of cardiac ultrasound imaging and compare with several classical optical flow estimation algorithms [17, 18]. In this paper presents a mathematical model that simulates the real cardiac motion during myocardial tagging for evaluating Left Ventricular contractility for Cardiac Magnetic Resonance Imaging (MRI) sequence [19].

In this paper presents a framework using the Active Shape Model (ASM) and Optical Flow for real-time facial landmarks extraction and tracking [20]. In this paper presents a new registration method between ultrasound (US) image and Magnetic resonance imaging (MRI), using optical flow model for large deformation between US image (floating image) and MRI (reference image), and presents a novel brightness-based algorithm for computation of optical flow [21, 22]. in this paper presents Automatic segmentation of cardiac cavity images algorithm to detect and reconstruct the boundary of the cardiac cavity using Collinear and Triangle Equation [23]. In this paper presents a problem of accurate segmentation of the endocardial contours of both ventricles and the epicardium of the entire heart using Optimal Features Active Shape Model (OF-ASM) [24]. In this paper presents a segmentation the human left ventricle (LV) in ultrasonic images, using Active Shape Models (ASM) and Active Contour Models (ACM) [25]. Therefore, the new solutions needed to analyze the heart's performance quickly and accurately. In this study, we will create a system to process the heart image in echocardiography video to detect the movement of the heart cavity and the extent of the heart cavity with active shape model and optical flow from input video echocardiography parasternal short axis.

2. Research Method

In this part, we explain about the procedure to develop segmentation of cardiac image for heart disease. The procedure which involves Median High Boost Filter, Active Shape Model and Optical Flow are graphically described in a system diagram is shown Figure 1.

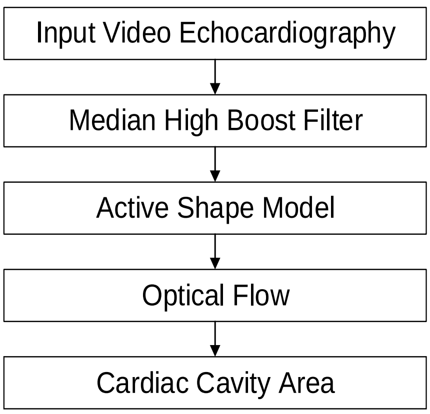


Figure 1. System diagram

2.1. Input Video Echocardiography

First, the input in this research are Videos from the heart rate movement from echocardiography test (ultrasound cardiac). In this research, we have used the short axis videos to test out our proposed segmentation technique. The example of the image comprising in short axis view from the left ventricular cardiac cavity from echocardiography that represented shown in a picture Input Video Echocardiography is shown Figure 2.

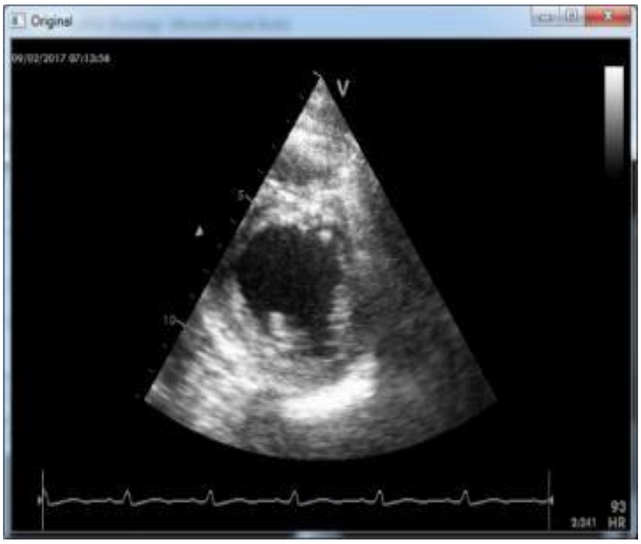


Figure 2. Input video echocardiography

2.2. Median High Boost Filter

The second step is applying Median High Boost filter to eliminate noise. The new method which is a combination between median filtering and High Boost Filter called a Median High Boost Filter that represented shown in a Median High Boost Filter diagram is shown Figure 3, Sigit [1].

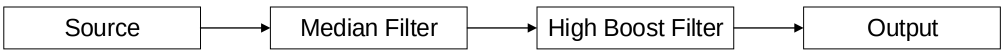


Figure 3. Median High Boost Filter

In the implementation of the high boost filter algorithm, Eva [2], which uses the spatial mask that represented is shown Figure 4 Kernel used for the High Boost Filter. To improve the high-frequency components without affecting low-frequency components using high boost filter.

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

Figure 4. Kernel used for the High Boost Filter

2.3. Active Shape Model

After Median High Boost Filter, the next step is doing segmentation. The segmentation proses is used to analyzed the heart rate motion and helped the system to measure the heart cavity area. Active Shape Model has two steps, these are training and fitting, Shaleh [4].

2.3.1. Training

The data extraction phase will produce information from the input data provided in accordance with the learning outcomes of training stages is the meaning of Training, Shaleh [4]. Training has some steps that represented shown in a diagram Step of Trainin Active Shape Model is shown Figure 5.

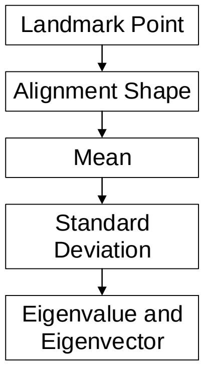


Figure 5. Step of Training Active Shape Model

2.3.1.1. Landmark Point

This step used for representation the shape into point. That point is called a “landmark point” and after we make a point we save the data in .txt file. The data is coordinate from the frame videos.

$$\tilde{X} = (x_1, y_1, \dots \dots, x_n, y_n) \tag{1}$$

The result of landmark point from twenty-five point to make a shape in the next step that represented shown in picture Landmark Point is shown Figure 6.

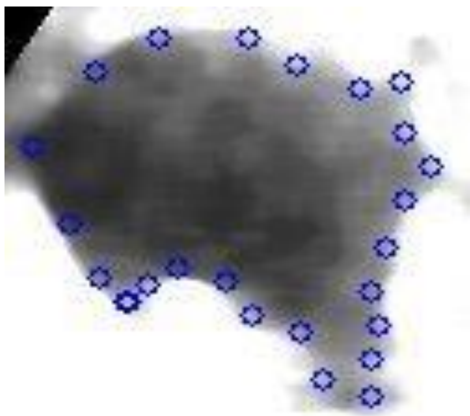


Figure 6. Landmark Point

2.3.1.2. Aligment Shape

Landmark point differences in positions too far so do the alignment to the first form by doing rotating and scaling. The formula can be represented as (2):

$$M(s,\theta)\begin{bmatrix} X_{jk} \\ Y_{jk} \end{bmatrix} = \begin{pmatrix} (s\,cos\theta)X_{jk} - (s\,sin\theta)Y_{jk} \\ (s\,sin\theta)X_{jk} + (s\,cos\theta)Y_{jk} \end{pmatrix} \tag{2}$$

from the formula. Can be represented the step for the alignment shape in a diagram Alignment Shape is shown Figure 7.

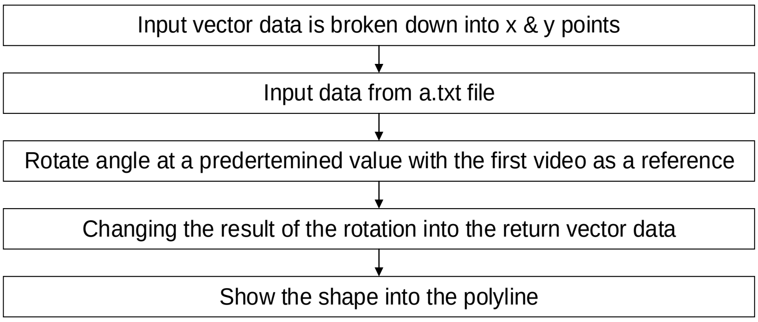


Figure 7. Alignment Shape

2.3.1.3. Mean

In this step, calculate the mean shape of all the alignment form data by using the formula below (2):

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{3}$$

2.3.1.4. Standart Deviation

Standard Deviation is getting from the reduction of the alignment shape data with the mean value. The result of the standard deviation is used to an input of the covariance matrix. The formula can be represented as (4):

$$dx_i = x_i - \bar{x} \tag{4}$$

After calculating Standard Deviation the next step is Covariance. A measure of how much two different sets of data called covariance. To determine the level of related variables varies together or how they may use the covariance. The formula can be represented as (5):

$$S = \frac{1}{N-1} dx_i dx_i^T \tag{5}$$

2.3.1.5. Eigenvalue and Eigenvector

To protect the data which have the largest variation corresponds to a linear transformation of the high-dimensional space to the low dimensional space using the eigenvector. The section representatives of eigenvectors eigenvalues are. The formula can be represented as (6):

$$Sp_k = \lambda_k p_k,\ \lambda_k \geq \lambda_{k+1} \tag{6}$$

2.3.2. Fitting

In this part, to fit the mean shape result according to the new image using the fittings. The first t-mode generates a form in training sets can be approximated by using a weighted summation means and forms of irregularities, Shaleh [4]. The Fitting formula can be represented by (7):

$$x = \bar{x} + Pb \tag{7}$$

With P=(p1, p2, ..., pt) as the first matrix eigenvectors of t and b=(b1, b1, ..., bt) as a weight vector to initialize the parameter form b (eigenvector) to zero (meaning form) [4]. The result of fitting that represented shown in picture Fitting is shown Figure 8.

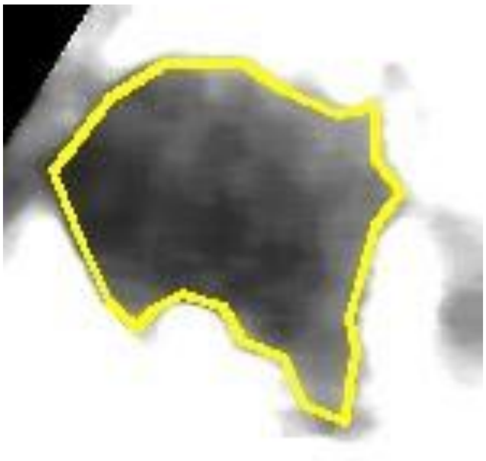


Figure 8. Fitting

2.4. Optical Flow

To predict the movement of the image based on its intensity in the image sequence is the optical flow. This will represent how far pixel motion pictures between 2 frames if applied to a 2D image. One of the methods in computer vision is used for estimating from the optical flow is the Lucas-Kanade. By combining information from several nearby pixels, Lucas Kanade's method can resolve the ambiguity, Arvina [5].

The highest layer of the pyramid is the first undertaken by a Pyramidal Lucas-Kanade. A reference starting point is the result of the Lucas-Kanade who used to work at the lower layer and continues until the lowest level. Pyramidal Lucas-Kanade algorithm can be described as follows in accordance with the working paper presented by the Bouquet in 2000 and this is the steps are taken to find the position of the point on the next frame.

a. Initialization pyramid into I & J

$$\{I^L\}\ L = 0, \dots \dots, Lm\ dan\ \{J^L\}\ L = 0, \dots \dots, Lm$$

b. Initialization first value of pyramid

$$g^{Lm} = \left[g_x^{Lm}\ g_y^{Lm}\right]^t = [0\ 0]^t$$

c. Define point of u into I^L frame

$$u^L = [Px\ \ Py]^t = \frac{u}{2^L}$$

d. Define derivative I^L into x value

$$Ix_{(x,y)} = \frac{I^L(x+1,y) - I^L(x-1,y)}{2}$$

e. Define derivative I^L into y value

$$Iy(x,y) = \frac{I^L(x,y+1) - I^L(x,y-1)}{2}$$

f. Calculate the spatial gradient matrix

$$G = \sum_{Px-wx}^{Px+wx} - \sum_{Py-wy}^{Py+wy} \begin{bmatrix} I_x^2(x,y) & Ix(x,y)\,Iy(x,y) \\ Ix(x,y)\,Iy(x,y) & I_y^2(x,y) \end{bmatrix}$$

g. initialization iteration of L-K (Lucas Kanade)

$$\overline{v^0} = [0\ 0]$$

h. Search value of the difference image

$$dI_k(x,y) = I^L(x,y) - J^L(x + g_x^L + v_x^{k-1}\ ,\ y + g_x^L + v_x^{k-1}$$

i. Search value of the image mismatch vector

$$\overline{b_k} = \sum_{x=Px-wx}^{Px+wx} \sum_{x=Py-wy}^{Py+wy} \begin{bmatrix} dIk(x,y)Ix(x,y) \\ dIk(x,y)Iy(x,y) \end{bmatrix}$$

j. Calculate the optical flow value

$$\overline{n^k} = = G^{-1}\overline{b_k}$$

k. initialization vector to the next step

$$\overline{v^k} = \overline{v^{k-1}} + \overline{n^k}$$

l. Calculate the optical flow value to L level

$$dL = \overline{v^k}$$

m. Initialization value of pyramid to next level

$$g^{L-1} = \left[g^{L-1}_{\ x}\ g_y^{L-1}\right]^t = 2(g^L + d^L)$$

n. Calculate the end of optical flow value

$$d = g^o + d^o$$

o. Search coordinate point to J

$$v = u + d$$

2.5. Cardiac Cavity Area

The last step in this research is Monte Carlo to calculate the heart cavity area. To calculate the area of the heart cavity using Monte Carlo with how to generate a random sample and then calculate the ratio of the sample between samples in the area of segmented (nd) with the total sample (ns). Monte Carlo formula can be represented as:

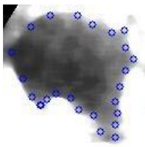
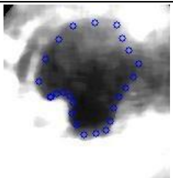
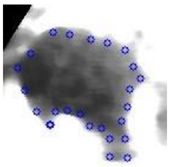
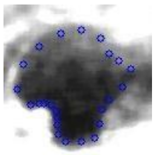
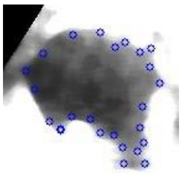
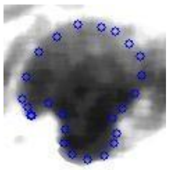
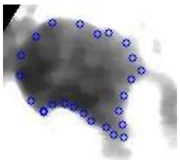
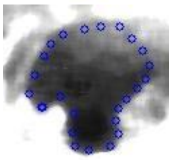
$$Area = \frac{nd}{ns} * (maxX - minX) * (maxY - minY) \tag{8}$$

Partial Monte Carlo is part of Monte Carlo algorithm. Partial Monte Carlo algorithm aims to improve calculations faster than the normal Monte Carlo by way of dividing borders into some parts and the search box on the border area, Sigit [1].

3. Results and Analysis

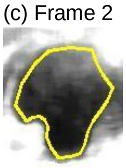
This section describes the final result of the system. Echocardiography video in short axis view is used as input. The table in this part representation all about the system with some experiment. Based on Table 1, can see that landmark point result with labeling set make a point as much 25 points to make a shape. After the training set we do the Alignment Shape to make some data training into one reference shape.

Table 1. Landmark Point

Frame	Input Video Video 1	Video 2
0		
1		
2		
3		

Based on Table 2, that can be seen from process calculate mean, standard deviation etc. We get the real shape from the heart cavity area and from this shape we do the optical flow to view the heart rate motion in video output to help the doctor analyze the heart patient.

Table 2. Result of Segmentation

Video	Result		
1	 (a) Frame 0	 (b) Frame 1	
	 (c) Frame 2	 (d) Frame 3	
2	 Frame 0	 (b) Frame 2	(a)
	 (c) Frame ke-3	 (d) Frame ke-4	

Based on Figure 9 the method of ASM and Optical Flow represented the maximum results so that when done widespread calculations using Monte Carlo method generated graph data above that is a very small error value.

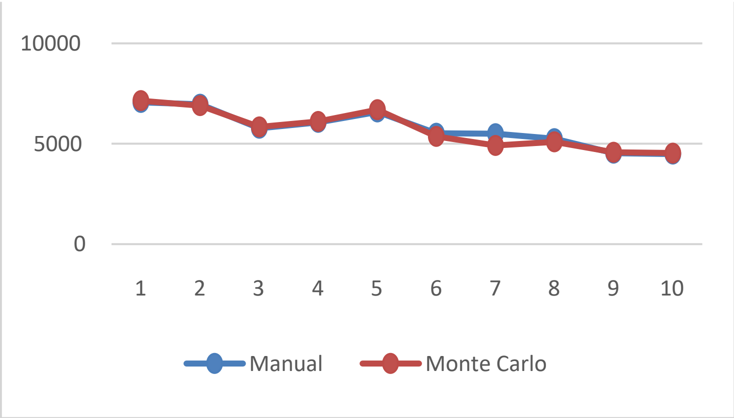


Figure 9. Chart from calculate the cavity area from the heart

4. Conclusion

The solution method is proposed to help doctors analyze heart disease is echocardiograph segmentation of videos with the combine any methods. The Median High Boost Filter is the result of research that is able to reduce noise and used to increase the light intensity value of the image. The segmentation using Active Shape Model and Optical Flow. The experimental result is able to detect heart rate-motion and heart cavity area. Methods used in this paper is effective because it is based on the results obtained is a comparison of the diagnosis made by the doctor is not much different from the results obtained from this system.

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