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Left Ventricular Movement Feature Extraction: A New Method for Classifying Heart Condition in Four-Chamber and Two-Chamber Views

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Abstract: The American heart association recommends examining four heart angles, i.e., the long axis, short axis, two-chamber, and a four-chamber section of the left ventricle, during the inspection of hearts' condition. Currently, left ventricle observation to assess the heart's condition is commonly done manually. No studies have performed an extraction of features from the movement of the left ventricular wall in the four-chamber and two-chamber views. The presence of an automatic method in observing and evaluating the left ventricle condition will help experts diagnose heart conditions. *Methods:* This study proposes an automatic tracking method for the left ventricular heart cavity, thereby obtaining the value of heart movement to build a classification system. It involves several stages: image preprocessing, image segmentation, tracking, feature extraction, classification, and validation. *Results:* The initial preprocessing stage produces images that have clear differences between the heart wall and the left ventricle. This clear distinction becomes the characteristic in separating the left ventricle from the heart wall, thus obtaining a contour using the segmentation method. The obtained contour line is then used as a good-feature using the intersection line. This research uses 24 good-features points which are only defined in the first frame. Furthermore, all frames will be processed using the optical flow Lucas-Kanade method to track the movement of the heart wall. *Conclusion:* Each good-feature produces four features values: direction (positive and negative) and distance (positive and negative); thus, a total of 96 features are obtained for the entire process. In its implementation, the support vector machine method obtains the highest accuracy value of 94,762 % and 94,977 % with validation techniques, k-folds, and leave-one-out. *Significance:* This study proposes a method for extracting features from left ventricular movement.

Keywords: Echocardiography, Left ventricle, Optical flow, Feature extraction, Support vector machine.

1. Introduction

Assessment of cardiac function based on left ventricular wall movement is very important for diagnosis, follow-up, and prognostic evaluation of patients in various clinical settings. The American heart association (AHA) recommends four angles that can be assessed during the inspection process, i.e., the long axis, short axis, two-chamber, and a four-chamber section of the left ventricle [1]. The left ventricular movement is able to identify health conditions in the heart. An essential requirement is to identify a diagnosis of heart failure or cardiac dysfunction by echocardiographic examination [2]. It is recommended that each segment is analyzed individually in several views. The assessment of each hearts' segment will obtain the characteristics of the left ventricular movement. The left ventricular characteristics are normal, hypokinetic, akinetic, and dyskinetic [3]. The hypokinetic is a reduced thickening, the akinetic is an absent or negligible thickening, while the dyskinetic is the systolic thinning or stretching [3].

Assessment of cardiac function is generally carried out by calculating the ejection fraction to obtain a volume value; the ejection fraction is the percentage of blood released during the final systole process with the total final diastole volume [4]. Thus, if the heart's function is disrupted, less blood will be excreted, and the left ventricular wall will decrease. However, the ejection fraction method only calculates the volume; therefore, the information on the left ventricular wall movement's characteristics cannot be obtained. The left ventricular movement is already used to assess the heart condition based on the previous studies. However, the evaluation of left ventricular motion is still conducted visually.

Previous research conducted visualization of left ventricular movement to make it easier to diagnose heart conditions based on visual data. Sigit et al. [5] visualize the tracking of short-axis parts using a semi-automatic approach; the tracking uses contour assistance obtained from segmentation results with the active shape model method. A semi-automatic approach has also been carried out in [6]. It uses an initialization point located in the left ventricular wall to visualize tracking in a four-chamber viewpoint. Anwar et al. [7] propose a method for developing automatic heart wall cavity tracking using Lucas-Kanade optical flow. The tracking method uses a good-feature point distribution defined in the first frame using an image processing approach with a sensitivity of 90 % and an accuracy of 87.451 %.

Based on previous research that discusses tracking of the left ventricle, some of them only focus on visualizing the left ventricle's movement without extracting features to obtain information on the left ventricular motion. On the other hand, some studies employ optical flow methods to track to acquire the data to analyze. Hatimi et al. [8] use the optical-flow method to detect moving objects. The proposed method is capable of identifying the path traveled by each object. Therefore, the proposed method is deemed capable of analyzing and understanding object behavior. Another study by Shreedarshan et al. [9] uses the optical flow method to perform crowd recognition in real-time. The system can monitor unwanted crowd activity based on tracking abnormal movements result. Aziz et al. [10] conduct feature extraction to classify heart movements in the short axis perspective. The tracking process produces a feature of direction and distance movement. The obtained feature data are trained and are validated; the proposed method gets 81.82 % accuracy. Sigit et al. [11] developed a feature extraction method for constructing a classification system in short-axis views. The proposed method obtained an accuracy rate of 90.98 % - 93.23 %, which is the development of the previous study by Aziz et al. [10].

Based on the problems and the previous studies, currently, no studies have performed an extraction of features from the movement of the left ventricular wall in the four-chamber and two-chamber views. Moreover, the evaluation of left ventricular motion at Darmo hospital and Dr. Soetomo hospital in Surabaya city is still conducted visually. Therefore, this study proposes a method for feature extraction from left-ventricular tracking results at the four-chamber and two-chamber views. The obtained features are used to build a classification system for heart health conditions. The proposed method is a development of previous research, which refers to the study by Anwar et al. [7] for the stages of preprocessing, segmentation, and tracking using good-features. Good-feature movement from tracking the left ventricular wall that uses optical flow will produce features that can be analyzed to obtain information from the characteristics of the data generated.

2. Material and method

This research is developing a previous method that refers to the reference [7], which automatically traced the left ventricle. Reference [7] uses an image processing approach for tracking, ranging from preprocessing, segmentation, determination of good-features, and visualization of tracking results. Hence, this research will focus on obtaining feature values from the tracking of the left ventricular wall in the four-chamber and two-chamber viewpoints to build a system that can classify the heart's condition. The obtained features are then processed to be tested on several classification algorithms. Figure 1 shows the system diagram developed to implement the objectives of this study.

A. Preprocessing

Echocardiographic images have variable noise and varying brightness, making them difficult for doctors to identify. Therefore, it is not easy to trace the left ventricular wall parts. Echocardiographic images that have noise are caused by errors in sending data on ultrasonic devices. Therefore, doctors often face difficulty during the identification process [12]. This study only carried out the preprocessing stage in the first frame, aiming to clarify the edges of the left ventricular wall. Overall preprocessing in echocardiographic images involves several steps: converting images into grayscale, median filters, high-boost filters, and morphology operations. The initial preprocessing stage converts images into grayscale; therefore, the information obtained is only in the dark (cavity) and light (left ventricular wall). Furthermore, this study uses a median filter to remove the noise speckle. Based on references [7, 10, 13], the median filter is capable

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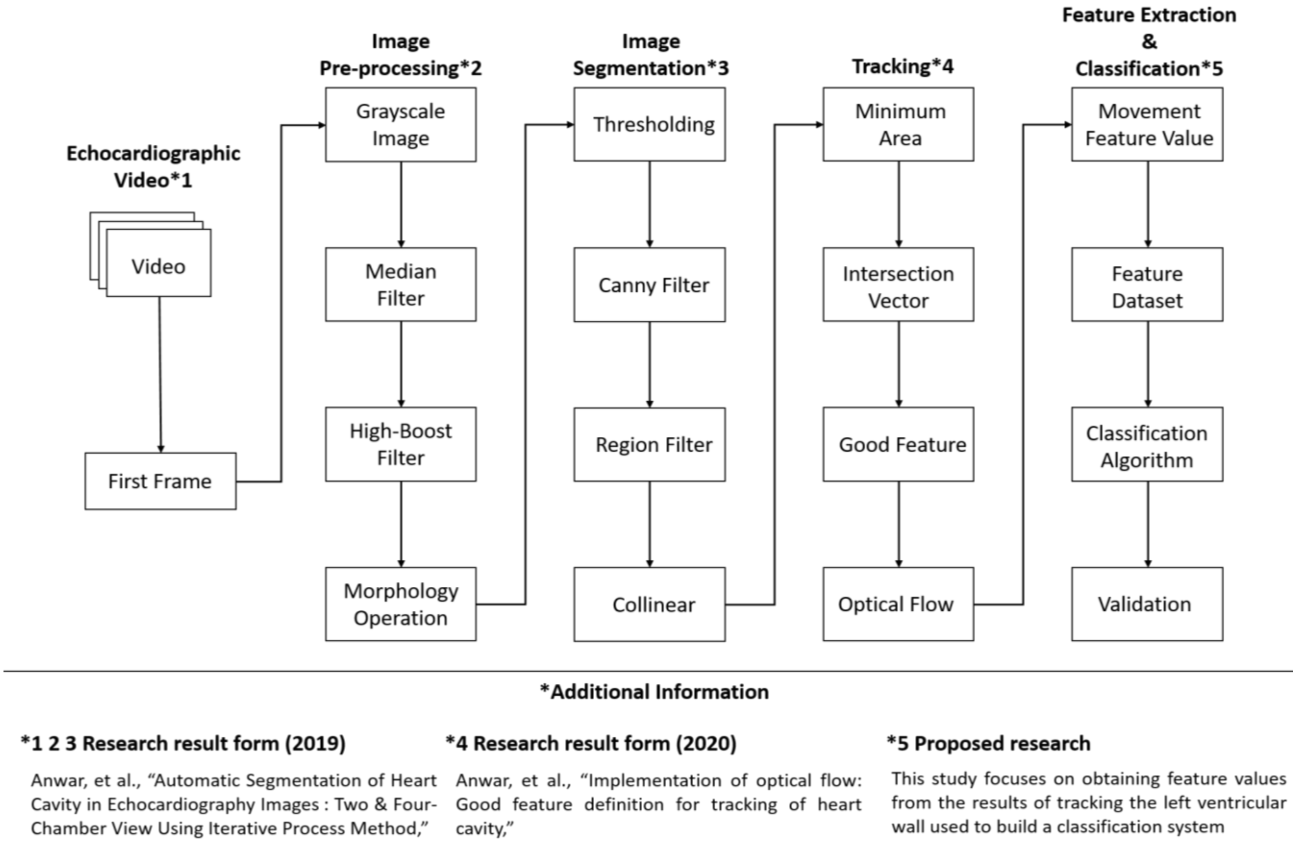


Figure. 1 System diagram

of eliminating the noise speckle. In its application, the median filter has a kernel capable of adjusting to the problem in the image. This study uses a median filter with a large number of kernels, which is 27x27.

$$I'(u,v) \leftarrow median\{I(u+i, v+j) | (i,j) \in R\} \quad (1)$$

Median filters produce images that do not have noise; however, the resulting image is blurred and has a low brightness level in the heart wall. The high-boost filter method is considered suitable for this problem, in which this method reinforces the difference between the left ventricle and the heart wall. High-boost filters are generally high-pass filters. Thus, the high-boost filter can sharpen the left ventricular wall section and obtain clearer results [14]. The high-boost filter equation can be expressed as$\boldsymbol{H}_{(x,y)}$, where A is the gain and $\boldsymbol{I}_{(x,y)}$ is the original image.

$$H_{(m,n)} = A.I_{(m,n)} - lowpass(I_{(m,n)}) \quad (2)$$

$$H_{(m,n)} = (A-1).I_{(m,n)} + [I_{(m,n)} - lowpass(I_{(m,n)})] \quad (3)$$

$$H_{(m,n)} = (A-1).I_{(m,n)} + highpass(I_{(m,n)}) \quad (4)$$

The final stage of preprocessing is implementing morphological operation to cover the exposed cavity and eliminate small noise; thus, the information contained in the image is considered good to use. This study uses a combined method between the process of morphological dilation and erosion operations to produce a combination of opening and closing morphology. The opening and closing morphological operations can be expressed in Eqs. (5-6), where I is the original image and E is the structuring element structure.

$$I \circ E = (I \oplus (-E)) \oplus E \quad (5)$$

$$I \bullet E = (I \oplus E) \oplus (-E) \quad (6)$$

B. Segmentation

Pre-processing produces echocardiographic images that clearly differentiate between the heart wall and the left ventricle. This clear distinction becomes a characteristic of separating the left ventricle from the heart wall using the segmentation method. The initial stage is to convert the preprocessing image to a binary image using the global thresholding method. The global thresholding process will produce a binary image, which is an image that has two grey level values (black and white). Global thresholding can be expressed with the following Equation:

$$p(x,y) = \begin{Bmatrix} 0, p(x,y) < th \\ 1, p(x,y) \geq th \end{Bmatrix} \quad (7)$$

Where (p) is in the coordinates (x, y) will change one (1) provided that the pixel value is higher than the predetermined threshold value, and if the pixel value is below the threshold value, the (p) will change to zero (0). Furthermore, the tracing process of the contours of the binary image uses the canny filter method for detecting the edges of the image. However, edge detection using canny-filters usually cannot obtain the desired contour, where there is a small noise contour in some parts of the left ventricle. Reference [7, 15] uses the region filter method to remove several contour lines considered noise by calculating each contour's area in echocardiographic images.

This research uses a threshold value of $T < 100$; thus, contours with an area less than the predetermined threshold value will be eliminated since it is not part of the heart wall cavity. However, there are some cases of filter regions that cannot remove large contours around the left ventricular contour lines. Reference [5, 10] proposes the collinear method to eliminate contour noise on the left ventricular contour; at this stage, the collinear process requires an initialization point located in the middle of the left ventricle. The working principle of collinear by finding the centroid of all contours is displayed in the following Equation:

$$C = \left\{ \frac{\sum_{k=1}^{n} Xk}{n}, \frac{\sum_{k=1}^{n} Yk}{n} \right\} \quad (8)$$

A collinear equation was carried out from the center of the boundary to the centroid of each contour by finding the slope and intercept [16]. Thus the collinear Equation used can be expressed with Eqs. (9)-(11).

$$y = wx + b \quad (9)$$

Where w and b can be expressed with equations:

$$w = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \quad (10)$$

and

$$b = \overline{y} - w\overline{x} \quad (11)$$

The collinear method produces contours found on the left ventricular wall; however, in some cases, the high-boost filter method A value needs to be adjusted manually depending on the brightness level of the echocardiographic image in reference [10, 16]. The reference [13] develops a high-boot filter method with automatic adjustments. Therefore, an overview of the echocardiographic image data obtained with varying brightness levels is required. The A value adjustment on the high-boost filter applies at this stage by detecting open or closed contours.

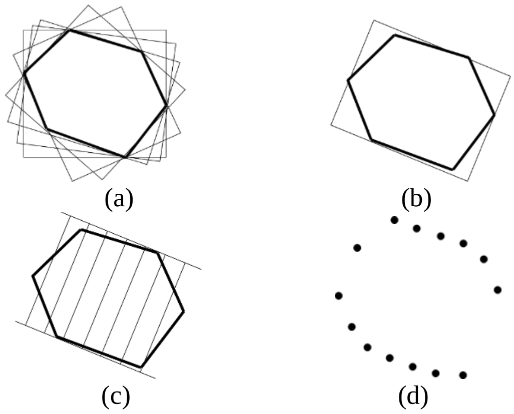


Figure. 2 Minimum area: (a) Finding minimum, (b) Minimum contour, (c) Intersection, and (d) Good feature

C. Tracking

This study traced the left ventricle using the optical flow method to track the left ventricular movement. Optical flow works on several assumptions, that the pixel intensity of an object does not improve between consecutive frames and that the adjacent pixels have the same movement. Based on previous research, the use of initialization points or good-features scattered on the left ventricular wall obtained good tracking results using the optical flow method [6, 17]. Hence, this study uses a good-feature to track the left ventricle during the diastole phase to systole. Based on reference [13], the following are good-features that will be used as points in optical flow to track heart wall movements.

Tracking on the left ventricle uses a good feature point to forward the optical flow for the next frame's tracking process. An intersection vector determines good-features on the results of the left ventricular edge detection to obtain a good feature point. In the intersection vector stage, it is necessary to find the minimum value in the square box area on the left ventricular contour. The minimum area method is an algorithm that can be used to solve optimization problems, including finding the width or diameter of a contour line [18]. The working principle of minimum-area with rotating rectangle squares at each corner is to find the minimum value, calculate area $\boldsymbol{A_1}$, update the minimum area, and save the current rectangle if $\boldsymbol{A_1 < A_{min}}$.

The intersection vector will obtain a good-feature, which is then used for the next frame image's tracking process. Reference [7] uses Lucas-Kanade's optical flow method to track the left ventricular movements using good-features. The proposed method in the research shows the results of calculations with a sensitivity of 90 % and an accuracy of 87.451 %. Thus, the Lucas-Kanade optical flow can accurately track the left ventricle's movement. In calculating optical flow and tracking moving images, the following optical flow Equations must be solved:

$$I_x u + I_y v + I_t = 0 \tag{12}$$

Where $I_{x,} I_{y,} I_t$ are a temporal-spatial image brightness derivative and u, v represents pixel displacement. Constraints on the pixels' movement in the image that occurs in the optical flow equation must be resolved. Based on reference [19], the Lucas-Kanade method divides the original image into smaller parts and assumes a constant speed. Further, the weighting and suitability of the smallest square to the constant model for $[u \quad v]^T$ is conducted in each part of Ω. The following Equation obtains the process:

$$\sum_{x \in \Omega} = b^2 \left[I_x u + I_y v + I_t \right]^2 \tag{13}$$

Where b is a window that emphasizes constraint in each middle section, the solution to the minimization problem is as follows:

$$\begin{bmatrix} \sum b^2 I_x^2 & \sum b^2 I_x I_y \\ \sum b^2 I_y I_x & \sum b^2 I_y^2 \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} = - \begin{bmatrix} \sum b^2 I_x I_t \\ \sum b^2 I_y I_t \end{bmatrix} \tag{14}$$

The Lucas-Kanade method calculates I_t using a filter [-1 1]. Based on reference [20], pixel displacement (u,v) can be completed as follows:

D. Feature extraction

In the left ventricular wall, abnormalities of movement in the left ventricular wall are usually observed in various medical conditions. Reference [21] describes the asymmetrical motion of the left ventricular wall, indicating cardiac abnormalities. Thus, the tracking process of the left ventricular wall's motions is used to obtain the value of heart movement. Therefore, the result can be used as a feature value to build a classification system for heart health. Reference [10], [22] uses the results of left ventricular tracking as a feature value used to construct a classification system in the short-axis and long-axis views. Therefore, this study proposes a method for feature extraction of left ventricular movement in the four-chamber and two-chamber

Displacement (*u*,*v*) Algorithm

1 compute I_x and I_y using kernel [-1 8 0 -8 1] / 12 and transposed form

2 compute I_t between frame 1 and frame 2 using kernel [-1 1]

3 smooth gradient components, $I_{x,} I_y$ and I_t using separable and isotopic 5-by-5 element kernel whose effective 1-D coefficients are [1 4 6 4 1] / 16

4 solve the 2-by-2 linear equations for each pixel using the following method:

5 if $A = \begin{bmatrix} a & b \\ b & c \end{bmatrix} = \begin{bmatrix} \sum b^2 I_x^2 & \sum b^2 I_x I_y \\ \sum b^2 I_y I_x & \sum b^2 I_y^2 \end{bmatrix}$

6 then eigenvalues of A are $\lambda_i = \frac{a+c}{2} \pm \frac{\sqrt{4b^2 + (a-c)^2}}{2}$

7 eigenvalues are compared to the threshold τ

if $\lambda_1 \geq \tau$ and $\lambda_2 \geq \tau$

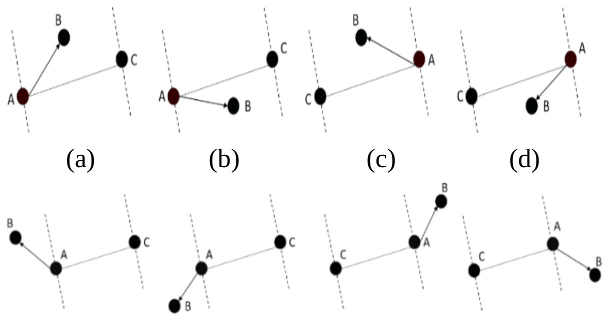
A is non-singular, solved using Cramer's rule.

else if $\lambda_1 \geq \tau$ and $\lambda_2 < \tau$

A is singular, the gradient flow is normalized to calculate u and v.

else

u and v is 0



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure. 3 Feature extraction

views. The tracking process of the left ventricle using optical flow can produce features of direction and distance of motion from the good-feature defined in the first frame. The intersection vector produces a good-feature on the left and right sides. Therefore, the results of tracking the direction have different results. Fig. 3 illustrates an algorithm for searching direction features with two outputs: the direction of the movement left ventricle in and out.

Fig. 3 shows three points: points A, B, and C. Point A is the origin, which will be a reference to determine the direction of movement at point B. Point C is the left and right good-feature connected to point A; therefore, the contour's slope will not affect the results of tracking the left ventricular direction. The explanation of each part of Figure 3 can be explained as follows:

1) Fig. 3 (a), (c) explains the displacement of point *A* moving forward towards point *B*. The resulted feature value is a positive direction since the point is inside the line threshold (0°- 180°).
2) Fig. 3 (b), (d) explains the displacement of point *A*, moving outwards towards point B. The resulting feature value is negative since the point is outside the line threshold (181°- 360°).
3) Fig. 3 (e), (g) explains the displacement of point *A*, moving forward down towards point *B*. The resulted feature value is a positive direction since the point is inside the line threshold (0°- 180°).
4) Fig. 3 (f), (h) explains the displacement of point *A*, moving out downwards towards point B. The resulted feature value is a negative direction since the point is outside the line threshold (181°- 360°).

Left ventricular wall tracking using the optical flow method can produce direction and distance movement features of the good-features that have been determined in the first frame. Several parameters are acquired using cosine rules and Euclidean distance equations in 2-dimensional space. Therefore, the value of the direction and distance features of the good-feature movement during the tracking process is gained. The cosine and Euclidean rules in 2-dimensional space are expressed in the following Equation:

$$\cos A = \frac{b^2+c^2-a^2}{2bc} \tag{15}$$

$$d_{(i,j)} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{16}$$

Fig. 4 illustrates the direction and distance features of the good-feature tracking results on the left ventricular wall. Based on the explanation in Fig. 3 (a), the direction and distance of displacement in Fig. 4 are considered positive, considering the tracking results that move inside.

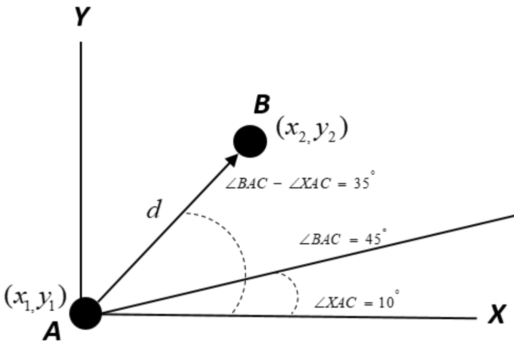


Figure. 4 Feature value

E. Classification & validation

This study uses the obtained features from the results of left ventricular tracking to be tested on several classification algorithms. This test is conducted to see the accuracy generated by the classification algorithm, and high accuracy values indicate the method proposed in this study has useful dataset information. Performance evaluation of the classification algorithm applies a validation technique that aims to obtain the error rate of the algorithm model and conduct an assessment. The classification algorithm uses several validation techniques to get the model's error rate. Validation techniques used are k-fold cross-validation and leave-one-out cross-validation.

3. Result & discussion

This study is a development of a previous method based on references that developed the segmentation method [13] and automatic left ventricular tracking [7]. Thus, this research focused on expanding a method for extracting features from left-ventricular tracking results at the four-chamber and two-chamber views. A tracking process employing the optical flow method produces direction and distance displacement features. The obtained features were tested on several classification algorithms. The direction and distance displacement features are used to build a system that can classify heart conditions in four-chamber and two-chamber views. The following are the results of discussions of the proposed research using an image processing approach that involves preprocessing, segmentation, tracking, feature extraction, classification, and validation.

A. Preprocessing result

Preprocessing in echocardiographic images eliminates speckle noise and improves the image. This research uses preprocessing, which involves several stages: median filter, high-boost filter, and morphology operation. Thus, it obtained echocardiographic images with a clear difference between the heart wall and the left ventricular cavity and reduced noise in the image. Fig. 5 shows some of the results of preprocessing in the left ventricle.

This study uses a median filter with a considerable kernel value. The use of a large kernel intends to reduce speckle noise which interferes with visual vision and still maintains the left ventricular wall; however, the image obtained becomes blurry. Thus, the high-boost filter method is used to strengthen the difference between the left ventricle and the heart wall, where the dark areas will become darker, and the white areas will be brighter. Therefore, the

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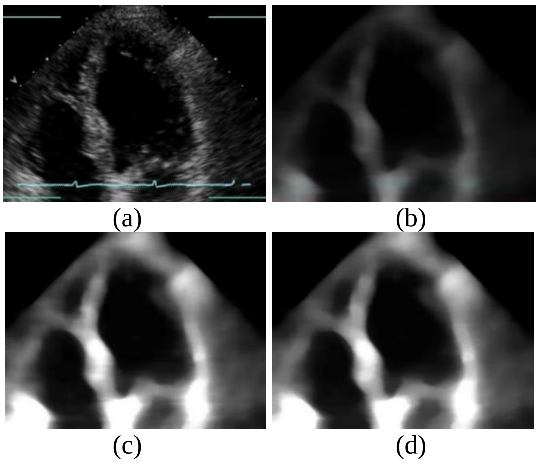

Figure. 5 Pre-processing result: (a) original image, (b) median filter, (c) high-boost, and (d) morphology operation

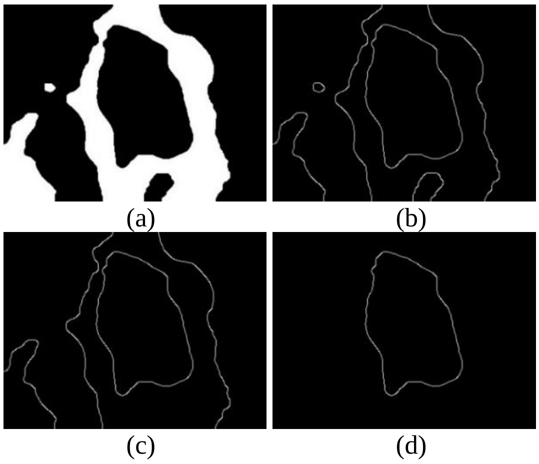

Figure. 6 Segmentation result: (a) global thresholding, (b) canny edge detection, (c) region filter, and (d) collinear

difference between the left ventricle and the heart wall will be visible. Furthermore, morphological operations are used to improve the image caused by noise. The image improvement aims to cover the left ventricular wall that is open; thus, the information in the image can be used.

B. Segmentation result

Segmentation in echocardiographic images is used to separate the left ventricular cavity from the heart wall, therefore obtaining the contour of the left ventricular wall. Overall, the segmentation process involves global thresholding, canny filter, region filter, and collinear methods. This stage of the segmentation process aims to obtain the left ventricular contour's clean results from the noise in the echocardiographic image. Based on reference [13], the segmentation method used in this study has an accuracy rate of 89.409 % in tracing left ventricular contours. Figure 6 shows the stages of image segmentation results to obtain the left ventricular section.

This research uses a global thresholding method with the threshold value given to the image is $T > 150$. Thus, the grayscale image of the preprocessing results will be converted to binary images, where the image has only two levels: black and white. The pixel in the coordinates (x, y) will turn to white (1) provided that the pixel value is higher than the predetermined threshold value and will turn to black (0) if it is below the threshold value. Furthermore, a canny filter is applied to obtain the contour of the edge of the wall; however, the results of the canny-filter image still need to be improved, considering there are small contours that are considered noise around the left ventricular cavity. This study uses a region filter to remove small contours by calculating the area of each contour line in the image, whereas the collinear method for eliminating large contour portions that are beyond the reach of the left ventricular wall. The collinear method produces contours that are in the left ventricular wall. However, there are constraints in the segmentation process, where echocardiographic images have varying brightness levels, affecting the results obtained. Based on reference [13], these constraints can be solved by adjusting A's value in the high-boost filter method. The proposed method performs an iteration process until the contours of the left ventricular wall are closed.

C. Tracking result

The contour of the left ventricle obtained from the collinear method is used as a point distribution. However, not all contour lines are used for tracking; therefore, this study proposed a method for finding the distribution of points or good-features in the left ventricular wall.

The initial stage is to use the minimum area method to obtain the slope of the contour. The value

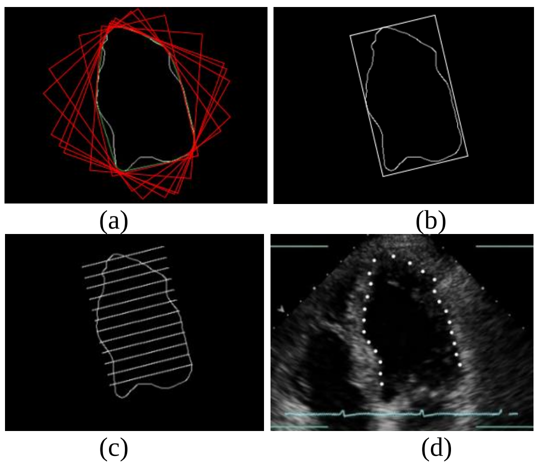

Figure. 7 Good feature result: (a) find minimum area, (b) minimum area, (c) intersection vector, and (d) good feature

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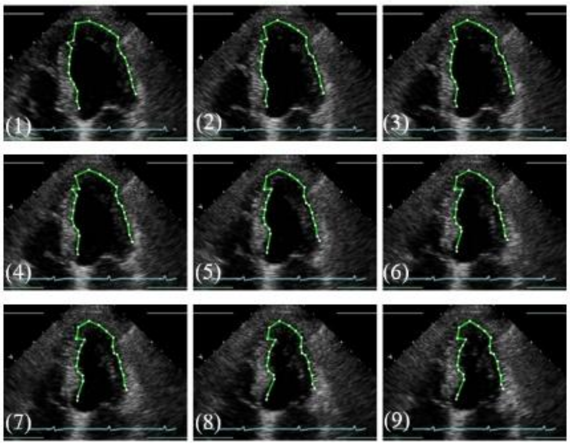

Figure. 8 Tracking optical flow normal data

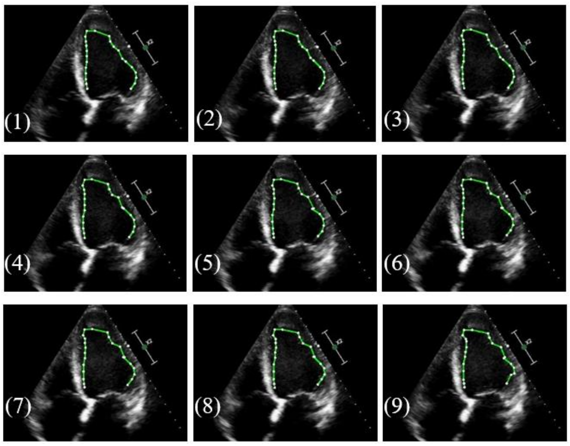

Figure. 9 Tracking optical flow abnormal data

of the slope of a contour line plays an essential role in the process of taking good-features; therefore, it has a significant role in the results of feature extraction. Good-features are obtained from the intersection of the left and right-sided lines between the left ventricular contours, as in Fig. 7 section (c). This line intersection is called an intersection vector; thus, the process obtains good-features spread on the left ventricular wall, as shown in Fig. 7 section (d). In this research, the good-features are only defined in the first frame. The obtained good-features are further processed using the Lucas-Kanade optical flow method to track the entire frame video during the diastole phase to the systole. Based on reference [7], the tracking method used in this study obtained an accuracy value of 87.451 % in tracking the left ventricular wall. Figs. 8 and 9 show the results of the tracking process on normal and abnormal heart data, where good-features are capable of tracking well on the moving left ventricle.

D. Feature extraction result

The *good-feature* determination uses the minimum area method to detect the slope of a contour and takes left and right sides to intersect a vector of 12 lines. Therefore, it produces 24 *good-features*, which are used for tracking the left ventricular movements. Information on the data in this study can be seen in Table 1. During the systole phase to diastole, the process obtains the direction and distance displacement features of the tracking results on the left ventricle. The direction and distance features are divided into two types of values, positive and negative. A positive value is the displacement of good-features from tracking the left ventricular wall moving in and toward the center. In contrast, the negative value is the displacement of the good-feature from tracking the left ventricular wall moving outward or opposite from the center. The following process obtains the mean value of each tracing direction and distance features resulting from the diastole phase to the systole. Thus, the percentage of left ventricular movement is obtained. Based on the explanation above, each good-feature that tracks the left ventricle during the diastole phase to the systole produces four features namely, direction (negative and positive) and distance (negative and positive). Thus, the total features obtained are 96.

E. Classification result

The obtained features from the results of left ventricular tracking are then tested on several classification algorithms. This study tests several algorithms that are available in the Scikit-Learn library with the Python programming language using classification algorithms support vector machine (SVM), neural network (NN), K-nearest neighbor (KNN), naïve bayes (NB), logistic regression (LR), random forest (RF), decision tree (DT). The classification algorithm assessment uses k-fold and leave-one-out validation techniques. Based on the data in Table 2, the results of the experiment with the k-fold validation technique showed that the classification algorithm using the SVM method obtained the best validation results with an accuracy

Tabel 1. Data information

Good Feature	Number of Features				Amount of Class Data		Data Type Feature
	Direction		Distance		Normal	Abnormal	
	Positive	Negative	Positive	Negative			
24	24	24	24	24	283	153	Numerical
Total	96				436		

Table 2. Performance measurement

Classification Algorithm	K-Folds cross validation				Leave-one-out cross validation			
	Accuracy	Precision	Recall	F1-Score	Accuracy	Precision	Recall	F1-Score
SVM	94.762%	95.051%	93.599%	94.311%	94.977%	93.870%	95.026%	94.445%
NN	93.636%	93.382%	92.712%	93.041%	94.520%	93.670%	94.222%	93.945%
KNN	92.468%	93.691%	90.119%	91.849%	92.694%	90.450%	93.482%	91.941%
NB	92.716%	92.311%	91.862%	92.080%	92.237%	91.462%	91.462%	91.462%
LR	94.090%	94.027%	93.076%	93.542%	94.748%	93.845%	94.545%	94.194%
RF	94.075%	94.830%	92.501%	93.631%	94.063%	92.411%	94.497%	93.442%
DT	88.144%	87.685%	87.093%	87.371%	89.497%	88.145%	88.627%	88.386%

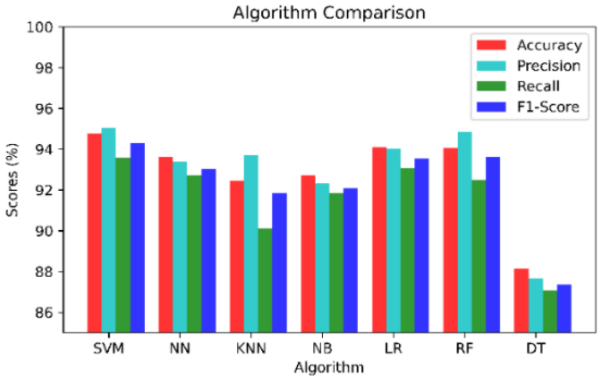

Figure. 11 K-folds cross validation

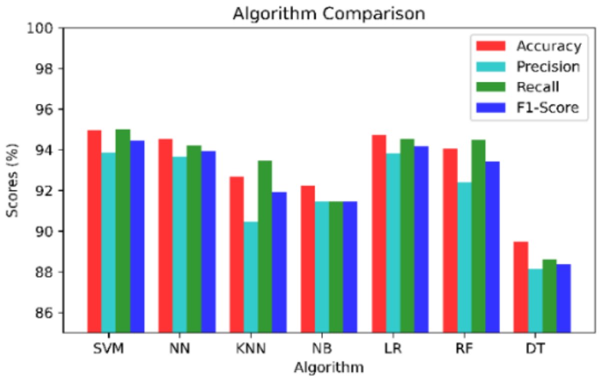

Figure. 12 Leave-one-out cross validation

Table 3. Comparison with other study

No	Reference	Automatic Segmentation	Automatic Tracking	Accuracy
1	**Proposed**	✓	✓	**94.97%**
2	Refer [11]	✓	✓	93.23%
3	Refer [10]	✓	✓	81.82%
4	Refer [7]	✓	✓	-
5	Refer [6]	X	X	90.00%
6	Refer [5]	✓	✓	-
7	Refer [16]	✓	✓	-
8	Refer [22]	X	X	80.0%

value of 94.762 %, a precision of 95.051 %, a recall of 93.599 %, and f1-score of 94.311 %. In the meantime, for the experiments with leave-one-out validation techniques, the SVM method's classification algorithm obtained the best validation results with an accuracy value of 94.977 %, a precision of 93.870 %, and a recall 95.026 %, and an f1-score of 94.445 %.

Based on the experiments that have been done, the method proposed in this study can automatically classify the results of feature extraction in the four-chamber and two-chamber views of the heart cavity in the left ventricle. The proposed research has the highest level of accuracy compared to previous research. Table 3 a comparison of our segmentation accuracy result against several other methods.

4. Conclusion

The method proposed in this study can automatically classify feature extraction results in the four-chamber and two-chamber views of the heart cavity in the left ventricle. This research involves several stages of procedures: image processing, image segmentation, tracking, feature extraction, classification, and validation. This research develops the previous method that automatically produced the left ventricular segmentation and tracking method. Thus, this study proposes to acquire feature values and classify the heart's condition from the movement of the left ventricular wall. The obtained features from the results of left ventricular tracking are then tested on several classification algorithms. This test is conducted to see the level of accuracy generated by the classification algorithm. The classification algorithm assessment uses k-fold and leave-one-out validation techniques. Based on the experiments conducted, the SVM classification algorithm produces the best accuracy compared to other classification algorithms.

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