Heart Condition Classification using Deep Learning as A Diagnosing Helper

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Abstract. Heart is one of the most vital organ. One of its roles is to pump blood so that the blood can circulate through the body and then receive it after the blood passed the lungs for cleaning. Unfortunately, heart disease is one of the most deadly disease in the world. One of many tools to support heart disease examination is echocardiography. Echocardiography shows the heart's left ventricular movement so that doctors can see whether the patient is experiencing ischemia or infarction. Sadly, the examination results depend on the doctors' experience and accuracy. Hence, in this study, a system with the ability to classify human heart conditions based on left ventricle movement are developed. The methods used in the system include optical flow Lucas-Kanade to track heart cavity movement. The features that will be extracted from the process are distance and direction. Distance feature will be calculated using Euclidean distance formula and direction feature will be calculated according to the points' angle using cosine triangle formula. And at final, after all the feature obtained, the classification will be done using deep learning method. The tracking and feature extraction process is done succesfully. The classification process obtained 71,43% accuracy.

Keywords: Heart disease; deep learning; tracking; optical flow; classification

1 Introduction

Heart is one of the most vital organ in the body which has a function as a human blood pumping organ [1]. Unfortunately, nowadays heart abnormality is the most affecting problem to human body condition [2]. Doctors use echocardiography to examine a patient's heart condition. Echocardiography will show information about the heart cavity's movement. Those information can only be read by experts, in this case, doctors. Hence the examination result relies on the doctor's correctness and their experience [1]. Therefore, in this study, echocardiographic video will be processed to be able to classify heart condition into normal and abnormal conditions. This particular study will continue the processing of segmented echocardiographic image. In a previous study done by K. R. Ummah et al. [3] regarding tracking multidimensional echocardiographic image, the process after segmentation is to find good features points that later will be used to track the heart cavity movement. This study compares the usage of optical flow Farneback and Lucas-Kanade method. And the result

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shows that optical flow Lucas-Kanade had higher accuracy in range 87,88% until 93,56% in different views. Tracking will detect the heart movement in each frame. This process will result in the calculation of distance between two points in the respective position in a sequential frame using Euclidean distance, and also the flow direction of each point. Research [4] used a method for obtaining the flow direction. The angle of the between line of the earlier point of good features to the later one and the line of the earlier good features and center of heart cavity will be calculated using cosine formula. The distance and flow direction are the features that will be used to detect heart abnormality. From research [5] tracking features for echocardiographic image done using two points initialization which will form a line and used to detect the heart cavity. However, the result is not always good. In this study, the features used will be around the heart's cavity so that we can detect the entire movement. This heart movement can detect whether the condition is normal or abnormal. According to [6] Catherine M. Otto, cardiac abnormality can be indicated by the movement of the endocardium and pericardium tissues. The movement of the heart and the size of the walls of the heart when under contraction and relaxation can have indications of abnormalities in the heart. Heart wall abnormality has several types of qualitative assessment. A normal heart will have inward endocardial movement and normal wall thickness during systole. Meanwhile, abnormal condition can be divided into three types, hypokinetic will have inward endocardial movement and slow wall thickening during systole; akinetic will have no endocardial movement inside or thickening of the wall during systole; and dyskinetic will have outward endocardial movement (segment moving in the opposite direction) during the systole. This theory will be used in deciding how the good features tracking indicate whether the heart is normal or abnormal.

2 Methodology

This study uses good feature points for marking the heart cavity edges, optical flow Lucas-Kanade as the method for tracking the heart movement, euclidean distance and cosine formula for calculating the distance between two points in sequential frame and the flow direction. Deep learning is used to classify heart condition. The input used is segmented image of multi view echocardiographic image. The complete block diagram of the system as seen in Fig.1 below.

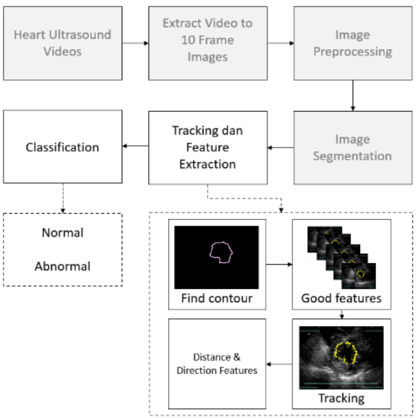
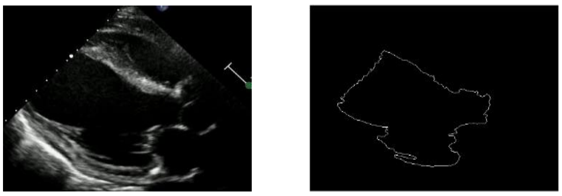


Fig. 1 System’s block diagram

2.1 Image input

The system starts with loading input image. The loaded image is a segmented contour of the left ventricular cavity. Fig. 2 (a) shows the original ultrasound image before processing is performed. Whereas Fig. 2 (b) images that have already been processed up to segmentation, which will be used as input. On the segmentation results a thresholding process is also performed to convert into binary form.



(a) (b)

Fig. 2 (a) Original image and (b) Segmentation image

The image used here is the first image out of ten image sequences. These images are extracted from a systole to diastole process video. The number of images can be various based on how many frames are there between the systole-diastole process. The images are already preprocessed until the segmentation step in a separate part of research, here we directly use the result of segmentation.

2.2 Find contour

The find contour process is performed to find contours from bitmap image. The reason why it needed to do is because bitmap image cannot be processed directly in the process. It is needed to find the contour coordinates to process the image further. The comparison between input image and after the contour was found can be seen as in Fig. 3.

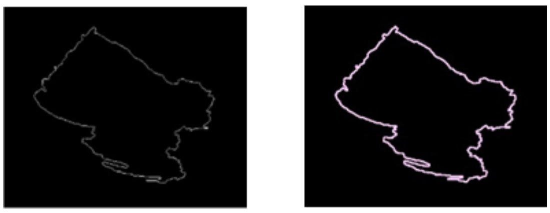
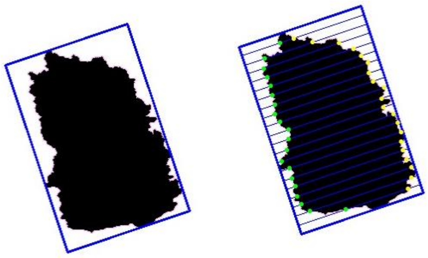


Fig 3. Contour obtained from segmentation image

2.3 Good features

This process aimed to find initial points along the contour. Initial points are the points that will be used as a reference in the later tracking process. The good features must be placed accordingly to the left ventricle segment’s edge. To find the good features points for long axis, two-chamber, and four chamber views, the minimum area rectangle and intersection vector methods are used.

The minimum area rectangle method is used to find a rectangle bounding the contour. This rectangle will be used as the reference for intersecting the area to several lines. The intersection lines then used for determining where the good features located. Fig. 4 shows the image of both methods.



(a) (b)

Fig. 4 (a) Minimum area rectangle (b) Intersection vectors and the good features points

A different approach is used for the short axis view, to find the good features here, we can divide the total contour coordinate points obtained from find contour process by the number of good features to be made. In this study, will be using 14, 40, and 24 points of good features respectively for long axis, 2-chamber and 4-chamber, and also short axis. The number of points is decided if it is not too cramped and not too loose in covering the contour line. The difference in number for each view is because of the difference in area size.

2.4 Optical flow tracking

Tracking is performed to find out the position of each good features on each frame in sequences. Using the optical flow method, point tracking is performed based on the feature similarity between two sequential frames, assuming the intensity of the pixels is the same.

There are several types of optical flow algorithms. One of these will be used in this study, the Lucas-Kanade optical flow. This method is a member of the sparse optical flow variant, which only tracks a few pixels desired. According to research [7], by combining information loaded by several adjacent pixels, the Lucas-Kanade method eliminates the ambiguity in the optical flow equation.

Lucas-Kanade's pyramid algorithm can be described as follows as presented by Bouguet [8]. The two sequential 2-dimensional grayscale images are I and J. Then I(x, y) and J(x, y) are the grayscale values of both images at the location x = (x, y), where x and y are the two pixel coordinates of the generic image point x. Consider an image point to be u = (ux, uy) on image I. The purpose of the LK pyramid is to find the location v = u + d = (ux+dx, uy+dy) in the image J depending on the similar I(u) and J(v). Vector d = (dx, dy) is the optical flow at point u.

2.5 Feature extraction

To obtain quantitatively the values of the direction and distance of displacement, it is possible to use formula calculations. Equation (1) for the distance feature and (2) for direction feature.

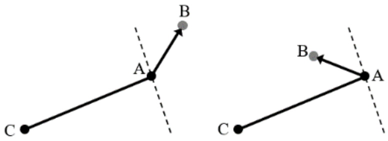
(1)

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

Equation (1) shows the euclidean distance equation. It calculates the distance between two points (xi, yi) and (xj, yj). The implementation on the system is to find the distance from good features point ki to point ki+1 in frame j and frame j+1.

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

Equation (2) shows the triangle cosine formula used to find cos A from a triangle ABC. For the implementation on the system, the triangle will consists of the points of the contour center (C), good feature point ki in frame j (A), and good feature ki+1 in frame j+1 (B). The direction feature will be split to positive and negative direction.



(a) (b)

Fig. 5 (a) Negative direction (b) Positive direction

The type of direction is decided according to the angle in point A. As seen in Fig. 5 (a), direction is negative because the displacement of point A to B is outside the dashed line (T line) which also means the angle of A to the T line is between 181°−360°. Direction is positive in Fig. 5 (b) because the displacement is inside the T line which has the angle of A between 0°−180°.

2.6 Classification

Deep learning is an artificial intelligence function that mimics the workings of the human brain in processing data and creating patterns used for decision making. One method in deep learning is the multilayer perceptron method, that is the simplest form of feed-forward network. Multilayer perceptron will be used in this system. The algorithm of the classification process is shown in Figure 6.

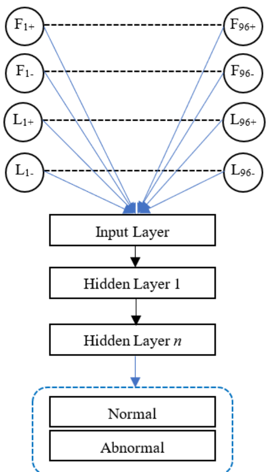


Fig. 6 Classification algorithm

The input used is a tabular data of distance and direction features that have been obtained in the precious process.

3 Result and Discussion

This study purpose is to build a classification system of heart condition, to obtain the data for classification training need several processes. The result data are the distance and direction, which are split to positive and negative, from the movement tracking using optical flow. The features obtained then arranged to a tabular data to be tested using the classification algorithm. The testing using multilayer perceptron is available in Scikit-Learn library using Python programming language.

3.1 Find contour result

The find contour process is performed to find contours from bitmap image by using the findContour() function available on the OpenCV library. The contour is successfully found if we have 2 as the contours size which means the contour is detected as a whole and is not broken. Fig. 7 shows the result of this process.

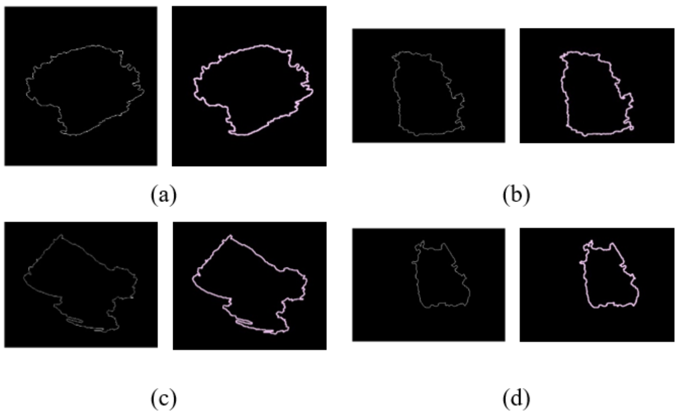


Fig. 7 Contour successfully found in (a) short axis (b) two-chamber (c) long axis (d) four-chamber view.

It was found that if find contour was directly performed on the input image, many unimportant contours would be obtained outside the detected contour of the heart cavity. Then it needs to be done the thresholding process first to detect only the contour lines of the cardiac cavity only. After trials, the threshold value used in the process is 120. Because for this dataset, the 120 value produce clean line following the white contour line from the input image. After this process we will have the coordinates along the contour. This way, the heart cavity contour can be processed further.

3.2 Good features result

Defining good features is using several points marked in the edge of the left ventricle contour. There are 24 good features in the short axis good features definition that will be used to track the movement using optical flow. Fig. 8 shows the example of the good features result in multiple short axis inputs. The process is initially done to the first frame.

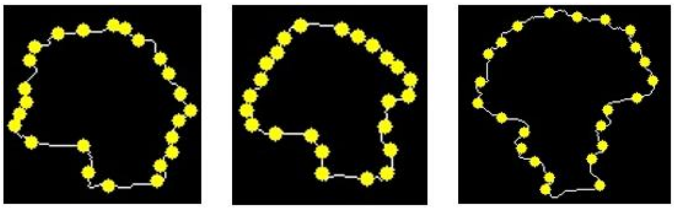


Fig. 8 Good features process' result example

To track good features in other frames will be using the tracking process.

3.3 Tracking result

Good features point that have been defined in the first frame then will be tracked to find the good features in the next frames. Fig. 9 shows the result of tracking from the diastole to systole of the heart images consecutively from left to right, frame 1 until frame 9.

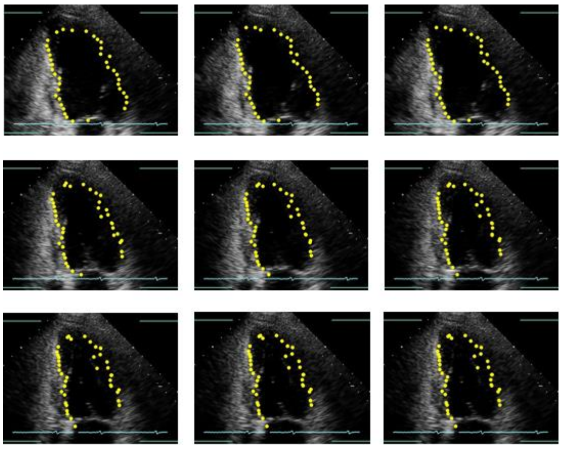


Fig. 9 Tracking result

3.4 Feature extraction result

This stage aims to obtain features of distance and direction of displacement on the image. The features obtained are four types of features at each point of good features. There are 24 points in each short axis contour. So that will be 96 features for one input. The obtained features need to be normalized before used as an input for deep learning process. Table 1 shows the sample of data of features.

Table 1. Feature extraction result.

No	Feature	Type	Value
1	F1	Positive Direction	0.333333
2	F2	Negative Direction	0.666667
3	F3	Positive Distance	11.095745
4	F4	Negative Distance	19.943640
…	…	…	…
93	F93	Positive Direction	0.666667
94	F94	Negative Direction	0.333333
95	F95	Positive Distance	31.703417
96	F96	Negative Distance	5.213029

3.5 Classification result

This is the final process to this study, the purpose is to decide whether an input is a normal or abnormal image of heart. This process is done using MLP deep learning model to train and test the data using scikit-learn library in python programming language. Table 2 shows the result of prediction process from the testing data.

Table 2. Classification test result.

Test Data	Prediction Result	Result	Accuracy
Abnormal	Abnormal	True	71,43%
Normal	Normal	True	
Abnormal	Abnormal	True	
Normal	Abnormal	True	
Normal	Normal	False	
Normal	Normal	True	
Normal	Normal	True	
Normal	Abnormal	False	

There are some causes that affected this low accuracy result. First, the data used are too few. In the early step, the dataset in the form of extracted echocardiograph image sequences were needed to be manually copied to the project folder. This takes a lot more time, so that the used data are much fewer than the total data we have. The solution is to make the initial input process automated, this could be done if this research was merged with the first part of the research (the grey blocks shown in Figure 1). That way, will be more data used finally. Second, the tuning process of the classification process is not maximum. To fix this the hyperparameter tuning can be tried in later development.

4 Conclusions

To automate the examination od heart condition, this study proposes the method to classify heart condition. Images from ultrasound. The images extracted from an ultrasound video is processed before classified. The first frame of the extracted video is processed to reduce noise and smoothen, then the segmented contour is found. The segmentation image then need to be marked with good features points. Then tracking process is done to mark the movement using the good features in every frame. Each points have four features extracted using Euclidean distance to find displacement distance and cosine equation to find direction.

The result of this study is succeed conducting tracking and extracting feature. The classification result is able to classify with 71,43% accuracy. But the classification is not perfect. It needs more input data and better deep learning algorithm to do a better performance.

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