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Acute Coronary Syndrome Disorders Classification Based on ECG Images Using Adaptive Neuro-Fuzzy Inference System (ANFIS)

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ABSTRACT
The heart is one of the most vital human organs that acts as a blood-pumping tool to supply oxygen and essential nutrients throughout the human body. Abnormalities in the heart greatly affect the work of the heart which results in the heart not being able to carry out its duties properly. Heart defect is one of the most common causes of death in many countries, including Indonesia. Electrocardiogram (ECG) is one of the most important examination models used to diagnose various abnormal heart rhythms. An ECG records the electrical activity of the heart by showing waveforms on a monitor or printing them on paper to classify cardiac abnormalities from the electrocardiogram image using image processing and artificial neural networks. The method used for the classification is the Adaptive Neuro-Fuzzy Inference System (ANFIS) and using the Chain code to take the value of the ECG feature. There were 92 ECG images to be used which were partitioned to 70 images for training data and 22 images for test data with 3 types of abnormalities, namely coronary heart disease, angina, and myocardial infarction. The test was carried out using 4 choices of ANFIS functions. The parameters used to classify coronary heart disease, angina pectoris, and myocardial infarction reached 95.23% (DR), and 29.41% (DER), using the GBell function with the number of MFs (3) and epoch (100).

Keyword: Heart abnormalities; Electrocardiogram; Image processing; Adaptive neuro-fuzzy inference system (ANFIS); Chain code

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1. INTRODUCTION

The heart is one of the most vital human organs that acts as a tool that pumps blood to supply oxygen and essential nutrients throughout the human body. Abnormalities in the heart greatly affect the work of the heart which results in the heart failing to carry out its duties.

Heart abnormality is one of the most common causes of death in many countries, including Indonesia. One of the most common heart disorders is coronary heart disease which tends to attack the elderly but does not rule out the possibility of attacking children and adolescents. (David, 1985). The factors that cause coronary heart disease include high cholesterol, diabetes, high blood pressure, and even obesity. In general, coronary heart disease is more common in men than women, one of the reasons is because many men do not adopt a healthy lifestyle, one of which is consuming cigarettes which can stimulate the atherosclerosis process because of its direct effect on artery walls.

Coronary heart disease (CHD) is the cause of disability and the highest economic loss compared to other diseases. It is estimated that the amount spent annually on CHD treatment in the United States is US$ 14 billion (about IDR 42 trillion). In Indonesia, there is no clear data, according to the Household Survey of the Ministry of Health in 1992, it was reported that CHD was the number one cause of death (Boedi Soesetyo Joewono, 2003).

Several studies related to the identification of heart abnormalities have been conducted, including identifying heart defects using the Sequence Ordered Complex Hadamard Transform and Hybrid Firefly Algorithm methods. In this study, feature extraction was performed using several models such as Auto-Regressive (AR), Magnitude Squared Coherence (MSC), and Wavelet Coherence (WTC) as well as using a standard database (MIT-BIH). The presentation of relevant feature extraction from the ECG signal was performed using Conjugate Symmetric Sequence Ordered Complex Hadamard Transform (CS-SCHT) and optimized using Hybrid Firefly and Particle Swarm (Kora & Khrisna, 2016) Another study was conducted to identify cardiac arrhythmias using the Fuzzy Cluster method. This study presented the development of a heart disease identification system by processing ECG signals using fuzzy clusters and correlation techniques by filtering ECG signals (Naveena, 2014)

Another research discussed the topic of heart abnormalities identification using an Artificial Neural Network. There are two ways to classify cardiac abnormalities, namely, QRS, where it is extracted from the noisy ECG signal using the Pan Tompkins algorithm, and the other one would involve calculating heart rate and detecting tachycardia, bradycardia, asystole as well as second degree AV block from the detected QRS peak using MATLAB (Tanoy Debnath, 2016).

A research also had been conducted to identify prenatal congenital heart abnormality of Truncus arteriosus. In this study, the system implemented a computer-aided diagnostic support system (CADSS) to diagnose congenital heart defects of Truncus arteriosus and applied ANFIS as the classifier to show clinical results of heart abnormalities. The system began to processing clinical data using the maximum probability estimation, then anatomical structures were highlighted from the previously processed information by utilizing the Fuzzy Connectedness image segmentation process. (Sridevi & Nirmala, 2016)

An electrocardiogram is a medical device used to detect heart abnormalities by measuring the electrical activity produced by heart contractions, which will be recorded by an electrocardiograph machine in the form of graphics on a visual screen or printed paper. The ECG chart cannot be directly diagnosed, so doctors need some time to read and provide diagnostic results from the electrocardiogram chart. Myocardial infarction, angina pectoris, and coronary heart disease are the indications of an acute coronary syndrome, so a system is needed to automatically classify these heart disorders (Edward, 2017).

In this study, the implementation of the Adaptive Neuro-Fuzzy Inference System (ANFIS) was proposed to classify abnormalities in the heart from Electrocardiogram (ECG) images. In Part II, the identification of the problem in this research is described. In Part III, several previous studies that have been conducted to identify abnormalities in the heart are explained. Section IV describes the proposed method. The results of the research are discussed in Section V. Section VI contains the conclusions of the study, as well as suggestions for further research.

2. RESEARCH METHOD

The proposed method to classify abnormalities in the heart consists of several stages. These stages started from acquiring ECG image data for coronary heart disease, angina pectoris, and myocardial infarction which will be used for test and training data, while the preprocessing stage was to perform resizing. to resize the image to 1000 x 150 pixels. The next stage would be segmentation to convert the image to black and white using the Thresholding method then it is followed by determining the value of the feature extraction using the chain code. The results of this process would become the input value of the classification process. The final step of this research was classification using the Adaptive Neuro-Fuzzy Inference System (ANFIS). After these stages were carried out, the classification results of heart abnormalities were obtained. The general architecture of this research can be seen in Figure 1.

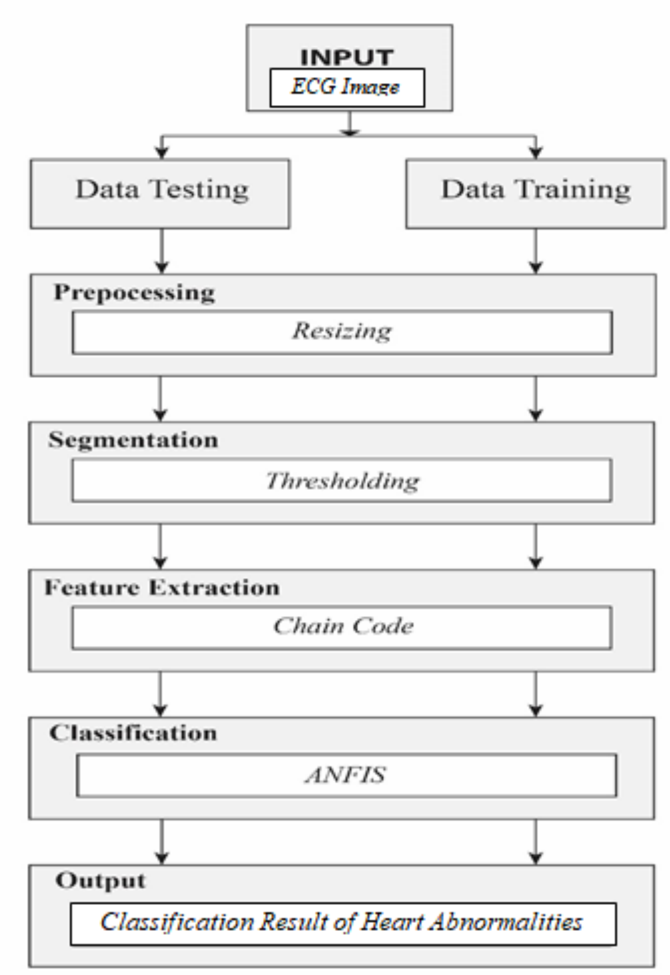

Fig 1. General architecture

A. Input

The input was divided into two parts, namely training data and test data. The research data consisted of ECG images taken from the Beecardia physiobank. An example of an ECG image used is shown in Figure 2.

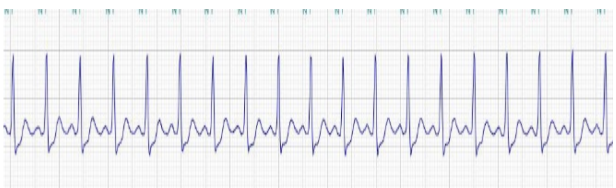

Fig 2. ECG image

B. Pre-processing

This process was performed to crop input images so all of them shared the same size. To avoid discrepancies between images for data input, be it testing data or training data.

C. Thresholding

Thresholding is a segmentation stage aiming to separate the ECG image graphs into two parts, namely, foreground and background. In the process, thresholding requires a value that is used as the perimeter value between the main object and the background, and this value is called the threshold. The results of the thresholding process can be seen in Figure 3.

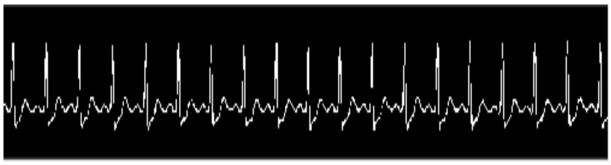

Fig 3. Thresholding image

D. Thresholding

The subsequent phase would be feature extraction to obtain the uniqueness of each image to distinguish one image from another for the classification process (Azmi, 2013). At this stage, the authors used the chain code method.

The chain code is a representation of the object method based on its boundaries, the chain code is set by determining the initial pixels and the sequence of unit vectors obtained from left, right, top, or bottom following the movement from pixel to pixel along the boundary (Nazmen, 2013). The chain code direction model can be seen in Figure 4.

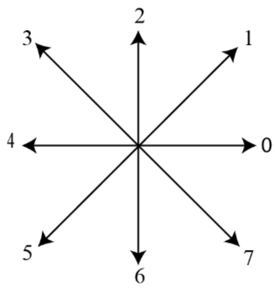

Fig 4. The 8 directions of the chain code method

The steps to get the chain code and its features are:

a. Detecting and taking the direction of image movement in accordance with the direction of the chain code.
   At x + 1, y – 1 chain code value = 7.
   At x, y- 1 chain code value = 6.
   At x – 1, y-1 chain code value = 5.
   At x – 1, y chain code value = 4
   At x – 1, y + 1 chain code value = 3
   At x, y + 1 chain code value = 2.
   At x + 1, y + 1 chain code value = 1.
   At x + 1, y chain code value = 0.
b. dx, dy was calculated by one circular displacement element of the coordinate array and transformed the scalar matrix from base to -3 and corresponds to:

$$idx = 3 * (dy + 1) + (dx + 1) = 3dy + dx + 4 \quad (1)$$

The Freeman Chain Code algorithm aims to present the contours of an object which includes pixels from the edges of an object that are interconnected and have a certain direction. The final result of the chain code-based feature extraction process is a feature vector containing information on the chain code sequence comprising the ECG image.

D. Classification

The ANFIS method is a method of combining fuzzy logic and artificial neural networks (ANN). ANFIS is an adaptive network class that is functionally equivalent to a fuzzy interface system (Gharaviri, 2008). Fuzzy logic has a logical concept that is easy to understand and has advantages in modeling qualitative aspects of human knowledge and decision-making processes by applying a rule base. Fuzzy logic has two types of value, namely between true and false. The values in fuzzy logic can be expressed in degrees of truth whose values are 0 to 1. ANFIS is widely applied because of its strong generalization ability, excellent explanation facility through fuzzy rules, and easy to combine linguistic and numerical knowledge for problem-solving. There are several implementations of ANFIS, such as forcasting water level reservoir (Valizadeh & El-shafie, 2013), predicton of human brucellosis (Babaie et all, 2021), decision support system for regional growth (Pipitone, 2021), detection of brain tumor (Kalam et all, 2021) and forecasting air quality (Al-qaness et al, 2021) . The structure of the ANFIS method can be seen in Figure 5.

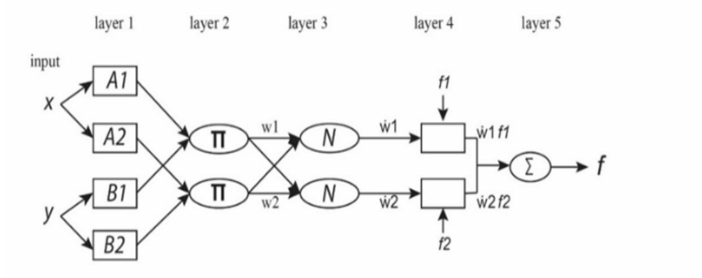

Fig 5. ANFIS structure

The following general rules for ANFIS use two fuzzy if-then rules (Takagi-Sugeno):

$$\text{Rule 1: if } x \text{ is A1 and } y \text{ is B1, then } f1 = a_1 x + b_1 y + c1, \quad (2)$$

$$\text{Rule 2: if } x \text{ is A2 and } y \text{ is B2, then } f2 = a_2 x + b_2 y + c_2, \quad (3)$$

Below is the explanation of ANFIS algorithm used for each layer (Khaled Assaleh, 2007):

a. Layer 1: all nodes in this layer are adaptive nodes where the parameters can be changed with the node function as follows:

$$O_{1,i} = \mu_{Ai}(x), i = 1{,}2 \ \ atau \ \ O_{1,i} = \mu_{B_{i-2}}(y), i = 3{,}4 \quad (4)$$

b. Layer 2: nodes in this layer are fixed (non-adaptive), nodes are labeled to indicate that in this layer, the nodes act as simple multipliers or multiply each incoming input signal, with the function of the node denotes as follows:

$$O_{2,i} = w_i = u_{Ai}(x)\mu_{Bi}(y), \ \ i = 1{,}2 \quad (5)$$

c. Layer 3: the nodes in this layer are also fixed. The N labeled nodes, in this layer, indicate the normalized firing strength function, namely the ratio of the output of the i-th node in the previous layer to all outputs of the previous layer, with the function of the node stated as follows:

$$O_{3,i} = w_i = \frac{w_i}{w_1 + w_2} \ \ i = 1{,}2 \quad (6)$$

d. Layer 4: all nodes in this layer are adaptive nodes, with node functions as follows:

$$O_{4,i} = \overline{w}_i f_i = \overline{w}_i (p_i x + q_i x + r_i) \ \ \ i = 1{,}2 \quad (7)$$

e. Layer 5: this layer only has one node labeled whose function is to add up all inputs, with the node function as follows:

$$O_{5,1} = f = \sum_i \overline{w}_i \ f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \ \ \ i = 1{,}2 \quad (8)$$

The ANFIS architecture is not unique, in which, multiple layers cannot be combined and still produce the same output. In ANFIS architecture, there are 2 adaptive layers (1 and 4), layer 1 has 3 modifiable parameters () which are the input to membership functions (premise parameters). Layer 4 also has 3 modifiable parameters () called consequent parameters (Khaled Assaleh, 2007).

3. RESULTS AND DISCUSSION

At this stage, the data and system would be tested. The data to be tested consisted of 22 images - 6 images of angina, 10 images of myocardial infarction, and 6 images of coronary heart disease.

The test was carried out using 4 ANFIS functions, namely triangle, trapezoid, Gaussian, and GBell functions. It also was conducted using a different number of membership functions (numMFs), namely numMFS (2), numMFs (3), and numMFs (4), with the epoch of each function being set to 100. To calculate the system accuracy, two parameters were used, namely detection rate (DR) and detection error rate (DER). The level of accuracy was obtained by:

$$DR = \frac{TP}{TP+FP} \times 100\% \tag{9}$$

In system testing, there were several incorrect and unidentified data. To get the level of error accuracy from the system, it can be obtained using the formula below:

$$DER = \frac{FP+FN}{TP} \times 100\% \tag{10}$$

True Positive (TP) is correctly identified data from the heart abnormalities classification. **False Positive (FP)** is incorrectly identified data from the heart abnormalities classification. **False Negative (FN)** is unidentified data from the heart abnormalities classification.

The results of system testing accuracy using triangular, trapezoidal, Gaussian, and GBell functions can be seen in Table 1

Table 1. System accuracy result

Num MFs	Accuracy Result (%)							
	Triangular		Trapezoidal		Gaussian		GBell	
	DR	DER	DR	DER	DR	DER	DR	DER
2	90	22,2	85	29,4	80,9	29,4	80,9	29,4
3	90	22,2	80	37,5	85	29,4	95,2	10
4	90	22,2	80,9	29,4	85,7	22,2	85	29,4

Based on the test result, the functions used to classify coronary heart disease, angina pectoris, and myocardial infarction reached an accuracy rate of 95.23% for DR and 29.41% for DER. The GBell function with membership functions (numMFs) (3) and epoch (100) obtained a higher accuracy compared to the triangular, trapezoidal, and Gaussian functions.

4. CONCLUSION

Based on the performed study using ANFIS in classifying abnormalities in the heart through ECG images, the accuracy rate of ANFIS reached 95.23% (DR) and 29.41% (DER) using the GBell function with the number of membership functions (numMFs) of 3 and epoch of 100. The result indicated that the GBell function performed better than the other functions because the GBell function obtained the membership function smoothly and continuously. Having more ECG data for training data would increase the accuracy of the system in classifying heart abnormalities.

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