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Design of Robust Heart Abnormality Detection System based on Wavelet Denoising Algorithm

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Abstract. The technology that continues to be developed by many researchers today is an automatic heart attack detection system based on an Electrocardiogram (ECG) signal. Several other studies have been carried out to build an Internet of Things (IoT) based heart abnormality detection system. Based on the analysis of related studies that have been carried out previously, several researchers have developed an ECG signal-based heart abnormality detection system using clean ECG signal data. While the reality of the concept of an IoT-based detection system, the process of recording ECG signal data on the sensor, the process of sending data to the server, and the process of retrieving data from the server are vulnerable to noise exposure. ECG signal containing noise will greatly affect the accuracy of system detection. This paper proposes the development of a noise-resistant heart condition detection system using a wavelet denoising algorithm. The process of denoising ECG signals using the Wavelet algorithm is generally able to improve the accuracy of detecting noisy ECG signals. The most significant increase in accuracy is seen in the low SNR value. The Daubechies 4 (db4) denoising algorithm is the best-performing algorithm. The ECG signal classification method uses the Artificial Neural Network (ANN) algorithm. Detection system hardware is also designed in this research using the concept based on the Internet of Things.

1. Introduction

Heart attack disease is one of the deadliest diseases in the world. Not a few cases of heart disease sufferers become increasingly severe because of the delay in detecting the disease. More than threequarters of these deaths occur in low- and middle-income countries [1]. A large number of patients with heart disease has become a priority for many researchers in various fields to continue to develop technology that can help detect symptoms of heart disease. One technology that continues to be developed by many researchers is an automatic heart abnormality detection system based on an Electrocardiogram (ECG) signal. The ECG signal represents the electrical activity of the four chambers of the heart, which can be analyzed from a series of P waves, QRS complexes, and T waves [2]. Several other studies have been conducted to build an Internet of Things-based heart abnormality detection system. Rangappa, et al [3] conducted a study by designing an ECG signal classification algorithm for cardiac abnormalities. Researchers used 3 steps in the ECG signal detection process. The system is used to recognize normal and abnormal conditions of the human heart based on the characteristics of the ECG signal obtained through the MIT/BIH database. The researcher also compared the classification methods of KNN, Naïve Bayes, Random Forest, Neural Network, and Support Vector Machine (SVM) with the same test data. The results show that the KNN method

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produces the best accuracy compared to the others. Khan, et al [4] conducted a study on the recognition of heart disease based on ECG signals using the Deep Neural Network. Researchers focused on the system algorithm used to detect abnormalities in the human heart based on ECG signal images generated from electrodes attached to 12 points of the human body. The detection results using the proposed algorithm are quite capable of distinguishing 4 heart conditions that have been previously labeled when testing the detection system. Liu, et al [5] conducted a study on the classification of ECG signals to detect human heart abnormalities using the Wavelet Scattering Transform algorithm. Researchers also focused on detection system algorithms to classify 4 human heart conditions, namely non-ectopic (N), supraventricular ectopic (S), ventricular ectopic (V), and fusion (F). The results showed that the highest accuracy was achieved by the KNN algorithm with a constant value of k=4 with a 10-fold Cross-Validation validation test.

Based on the exposure to related research that has been done previously, several researchers have developed an ECG signal-based heart abnormality detection system. Several studies have been carried out using the concept of the Internet of Things in the detection system for heart abnormalities, but the data used is only limited to the clean ECG signal. While, the process of recording ECG signal data on the sensor, the process of sending data to the server, and the process of retrieving data from the server is vulnerable to noise exposure. ECG signal that contains noise will greatly affect the accuracy of system detection. This paper proposes the development of a robust heart abnormality detection system using the ANN algorithm and wavelet-based denoising. Several other studies have used wavelet algorithms in the process of denoising speech signals [6], [7]. Besides being used in the sound signal denoising process, the wavelet algorithm has also been used in the image denoising process [8], [9]. In this paper, a wavelet algorithm is proposed to be implemented in the ECG signal denoising process. The wavelet algorithm will be combined with the ANN detection algorithm. Several parameters of the wavelet algorithm and ANN will be analyzed to produce the best performance. Furthermore, the development algorithm will be designed in a detection system based on the Internet of Things.

2. Methodology

The development of a heart abnormality detection system is designed in several stages. The first process is the initial processing which aims to standardize the ECG signal data. The ECG signal data used is obtained from the PTB Diagnostic ECG Database dataset which has two conditions, namely normal and abnormal (myocardial infarction). The ECG signal data is further divided into 11641 training data and 2911 test data. Noise is mixed with the test data in some SNR values. The addition of noise to the test data aims to test the development system using the wavelet transform algorithm. The next step is denoising the ECG signal using a wavelet algorithm. Three types of wavelet algorithms used in this study are daubechies 4 (db4), daubechies 5 (db5), and symlet 8 (sym8). After the denoising process, the next process is the detection of the ECG signal using the Artificial Neural Network (ANN) algorithm. The method of developing a human heart abnormality detection system is shown in Figure 1. The wavelet transform algorithm is quite widely used in the image and video denoising process. In this study, several types of wavelet algorithms will be used for the signal denoising process. The denoising process using the wavelet algorithm is shown in Figure 1, starting from calculating the DWT value, thresholding in the wavelet domain, then calculating the inverse wavelet transform.



Figure 1. Proposed robust heart disease detection process

Several parameters need to be set in the denoising process. The level of decomposition, the type of wavelet algorithm, and the thresholding method are important parameters that need to be analyzed. Two types of thresholding processes are soft and hard thresholding operations [5]. The soft or hard thresholding is applied to the coefficient yielded from the wavelet decomposition process [6]. The respective mathematical formula of hard and soft thresholding can be seen in Equations (1) and (2),

$$y_{hard}(t) = \begin{cases} x(t), & |x(t)| > \delta \\ 0, & |x(t)| < \delta \end{cases}$$
(1)

$$y_{\text{soft}}(t) = \begin{cases} sgn(x(t)). (|x(t) - \delta|), & |x(t)| > \delta \\ 0, & |x(t)| < \delta \end{cases}$$
(2)

with x represents the noise coefficient, δ is the threshold, and y is the estimated output.

After the denoising process, the next process is the detection of the ECG signal using the Artificial Neural Network (ANN) algorithm. An overview of the ANN algorithm used as a signal pattern detection method is shown in Figure 2. In the ANN algorithm, neurons are arranged in several layers. The number of layers used can be adjusted to the needs of the system. The test data results from the denoising process using the wavelet algorithm and then the detection process is carried out using the ANN algorithm. Several important parameters have been determined in the ANN algorithm for the training process and prediction of ECG signal data.

 Table 1. ANN parameter setting

Parameter	Detail
Number of hidden neurons	20
Activation function	Leaky ReLu
Learning rate	0.001
Number of Epoch	50

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Figure 2. Artificial Neural Network Diagram

The heart abnormality detection system is also designed in the form of internet of things (IoT)based hardware. The hardware design of an IoT-based heart abnormality detection system is shown in Figure 3. The sensor used to read the ECG signal is AD8232, then as a controller and sender of ECG data to the server using an ESP32 microcontroller. Monitoring and detection system using a laptop with python programming. Web application-based monitoring system using the Flask web framework. The output of the heart abnormality detection process is in the form of a PDF report file containing the patient's identity, the identity, and notes of the medical staff, the display of the patient's ECG signal, the results of monitoring the patient's heart rate, as well as the results of system detection in the form of normal or abnormal heart conditions (myocardial infarction).



Figure 3. Hardware detection system-based Internet of Things

3. Results & Discussions

The heart abnormality detection system based on the ECG signal that is designed has several stages, starting from recording the ECG signal, preprocessing, and the detection process using the ANN algorithm. In addition, the denoising process using the Wavelet Transform is added to this system. The use of the Wavelet algorithm is carried out to eliminate noise that can interfere with the detection

system. In this research, noise is added manually to test the algorithm performance of the development system. The ECG signal-based heart abnormality recognition system using the ANN algorithm has produced high accuracy. System accuracy will decrease if the ECG signal gets noise interference. Some noise with varying SNR intensities is added to the ECG signal. The effect of noise on the ECG signal on the conventional recognition system using the ANN algorithm is shown in Table 2.

 Tabel 2. Comparison of Recognition Accuracy on Clean and Noisy ECG signals

 ECG signal

 SNR
 Recognition Accuracy (%)

ECG signal	SNR	Recognition Accuracy (%)	
Clean signal	-	97,05	
	15	80,50	
	10	78,98	
Noisy signal	8	77,84	
noisy signai	5	76,40	
	3	73,65	
	2	70,94	

Table 2 above shows that the heart abnormality recognition system using the ANN algorithm has produced a high accuracy of 97.05%. The detection system does have high accuracy on clean ECG signals, but on noisy ECG signals it turns out that the detection accuracy has decreased significantly. A noisy ECG signal with a value of SNR = 15 resulted in a decrease in accuracy of 16.55% from the detection system that uses a clean ECG signal. Meanwhile, the lower the SNR value, the accuracy of the detection system also decreases.

The ECG signal denoising system is designed using a Wavelet transform algorithm. Three types of wavelet algorithms tested in this study are Daubechies 4 (db4), Daubechies 5 (db5), and Symlet 8 (sym8). Each wavelet algorithm is used for the ECG signal denoising process, then a comparison is made to determine the best type of wavelet algorithm in this study. The results of the comparison of the three wavelet algorithms in the ECG signal denoising process are shown in Table 3.

No	SNR —	Recognition Accuracy (%)		
		db4	db5	sym8
1	15	82,27	83,89	81,76
2	10	81,72	79,49	81,38
3	8	79,66	75,30	78,53
4	5	76,92	76,78	74,30
5	3	76,61	73,24	74,58
6	2	76,23	70,18	72,55

Table 3. Comparison of the performance of the three Wavelet algorithms in the ECG signal denoising process

Table 3 shows the comparison of the three wavelet algorithms in the ECG signal denoising process. The results showed that the greater the SNR value of the ECG signal, the greater the accuracy of the detection system in the three wavelet algorithms. The db4 wavelet algorithm has the best performance in almost all SNR values (2, 3, 5, 8, & 10). At the SNR value of 15, the db5 algorithm produces the best performance, with an accuracy of 83.89%. Figure 4 shows the comparison of the accuracy of the conventional detection system with the development of a robust detection system using the three wavelet denoising algorithms (db4, db5, & sym7).



Figure 4. Comparison of recognition accuracy of all methods

Based on the comparison of the accuracy of several methods shown in Figure 4, the denoising process of ECG signals using the Wavelet algorithm is generally able to increase the detection accuracy of noisy ECG signals compared to conventional detection methods. The most significant increase in accuracy is seen at low SNR values. The denoising Daubechies 4 (db4) algorithm is the algorithm that produces the best increase in accuracy at SNR 2 to SNR 10. While at the SNR 15 value, Daubechies 5 (db5) produces the highest accuracy compared to other algorithms. Based on the experimental results, the Daubechies 4 algorithm was chosen as the best algorithm in the ECG signal denoising process. The heart abnormality detection system is then designed using the ANN development algorithm and the db4 wavelet. The detection system development algorithm is then implemented on the internet of things-based system hardware. The AD8232 sensor is used to pick up the patient's ECG signal. The ECG signal data will then be sent by the ESP32 microcontroller to the webserver. The detection system is embedded in a computer at the location of the medical officer. When the ECG signal data has been sent to the webserver, the medical officer's computer will retrieve the ECG signal data and then carry out the detection process on the detection system algorithm that has been developed previously.



Figure 5. Display of data input and monitoring system.

Figure 6. Display of file report.

4. Conclusion

The development of a human heart abnormality detection system is carried out by designing a system that is resistant to noise. The denoising algorithm using wavelet has been successfully implemented in the detection system. The process of denoising ECG signals using the Wavelet algorithm is generally able to improve the detection accuracy of noisy ECG signals. The most significant increase in accuracy is seen at low SNR values. The denoising Daubechies 4 (db4) algorithm is the best performing algorithm that can overcome noise at SNR 2, 3, 5, 8 & 10.

The system development algorithm has been implemented on the internet of things-based system hardware. The AD8232 sensor is used to pick up the patient's ECG signal. The ECG signal data is then sent by the ESP32 microcontroller and stored on the webserver. The detection system is embedded in computers at the location of medical personnel. The results of the detection process for the patient's ECG signal are in the form of a pdf report file with information about the patient's identity, the identity and notes of the medical staff, the display of the patient's ECG signal, the results of monitoring the patient's heart rate, as well as the results of system detection in the form of normal or abnormal heart conditions (myocardial infarction).

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