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Implementation of Internet of Things Using Electrocardiogram Sensors to Identify Atrial Fibrillation Heart Disease

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ABSTRACT

Atrial Fibrillation (AF) is one of the most common heart diseases and increases the risk of stroke and heart failure up to five times. The symptoms of AF are very diverse and often asymptomatic, so an immediate examination is needed to detect it. Given the dangers of AF that could lead to heart failure or death, a diagnosis that can record daily heart rhythms is urgently needed. Research trends show increased use of the Internet of Things (IoT) due to its efficiency and real-time monitoring capabilities. The purpose of this study is to utilize the IoT concept by designing a prototype AF detection device called Atrial Fibrillation Detector (AFD) using a ESP8266 microcontroller device and an AD8266 Electrocardiogram (ECG) sensor. The results of the study show that AFD can identify AF through 4 main stages, including the process of recording ECG data, the process of sending data from the AFD device to the server, the process of processing data to identify the appearance of AF and the process of sending notifications if there is an indication of the appearance of AF. To further test AFD, two experimental scenarios were applied; blackbox testing and comparison of the suitability of AF detection results. In the first experiment, AFD managed to pass the total number of scenarios that existed at 16 scenarios. In the second experiment, AFD only managed to identify exactly 9 out of 15 scenarios.

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1. INTRODUCTION

The heart is one of the organs that has an important role in human survival. This muscular hollow organ rhythmically contracts like a pump to regulate blood flow activity to the pulmonary capillaries for the circulation process of blood reoxygenation, in the human cardiovascular system (Laitupa & Amin, 2019; Mesotten et al., 1998). Because it is one of the main organs in the body, therefore a healthy lifestyle is very important to note in order to avoid the appearance of symptoms of heart disease in humans. Behavioral factors with the greatest risk of heart disease are unhealthy diet, lack of physical activity, tobacco use and harmful alcohol consumption.

Heart or cardiovascular disease is a disease of impaired function of the heart and blood vessels. As many as 36 million people die (63% of all deaths) each year due to Non-Communicable Diseases (NCDs), where globally NCDs are the number one cause of death caused by cardiovascular diseases which is as many as 17.9 million people annually or about 31% of all deaths worldwide (Chrisanto *et al*., 2019). In the United States, one person dies every 37 seconds and as many as 647,000 people die each year from cardiovascular disease (Benjamin *et al*., 2019). In Indonesia, the disease is the leading cause of morbidity and mortality, and is responsible for one-third of all deaths in Indonesia (Maharani *et al*., 2019).

One of the main causes of sufferers in cases of cardiovascular disease is Arrhythmia (Zareba *et al*., 1994). Arrhythmias occur when there is abnormal electrical activity in the heart, where the heart beats too fast or too slow, and may be regular or irregular (Ravi & Singh, 2013). One type of arrhythmia heart disease that is most often encountered and treated in daily practice is Atrial Fibrillation (Darby & DiMarco, 2012). Atrial Fibrillation or Atrial Fibrillation is an arrhythmia that has the characteristics of rapid, irregular and chaotic atrial activity resulting in decreased mechanical function of the heart atria (Khoo & Lip, 2009). The risk of stroke and heart failure also increases almost five times greater in patients with atrial fibrillation, and about 20% of stroke sufferers are caused by this disease (Sethi *et al*., 2018; Wolf *et al*., 1991).

In 2017, out of a total of 166,793 deaths, 26,077 cases came from patients with atrial fibrillation heart disease. While in Indonesia, based on the results of a study by the Multinational Monitoring of Trend and Determinant in Cardiovascular Disease (MONICA) explained that cases of atrial fibrillation heart disease in Jakarta City were 0.2% with a ratio of men to women 3: 2. Based on information from the Harapan Kita Heart and Blood Vessel Hospital, data on the number of inpatient atrial fibrillation patients always increases every year, namely 7.1% in 2010, 9.0% in 2011, 9.3% in 2012, and 9.8% in 2013 (Yuniadi, 2017).

Atrial fibrillation has a reciprocal relationship with age. The prevalence and incidence of atrial fibrillation in individuals increases sharply after age 65, and more than 10% of patients who are at least 85 years of age suffer from clinical atrial fibrillation (Andrade *et al*.,2014; Boriani *et al*., 2016). It is estimated that between 2.7 million and 6.1 million people in the United States suffer from atrial fibrillation, and as the population ages, the number of people with this disease is estimated to increase (Go *et al*., 2001; Miyasaka *et al*., 2006).

Atrial fibrillation heart disease has very diverse and generally nonspecific symptom characteristics (Streur, 2019). Sometimes people with this disease have no symptoms at all, and some people experience very severe conditions such as fainting when attacked by atrial fibrillation, so to detect it can only be through direct physical examination. Because the danger of atrial fibrillation can risk heart failure and even death, it is necessary to have a diagnosis process that can record heart rhythm or by using a heart monitor that is used for days.

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In terms of detection of atrial fibrillation, there have been several studies to prevent delays in handling atrial fibrillation patients, such as making an electrocardiogram handheld device by utilizing the Random Forest Classifier method to detect 3 classes of atrial fibrillation rhythms: normal and sinus rhythms, other rhythms, and rhythms that are too noisy to be analyzed. The algorithm used in the study managed to get the best results in the PhysioNet/CinC competition in 2017 with an overall score of 83%. Then the use of another method has also been described by Faust *et al* (2018) by inserting data partitions every 100 heartbeats into a deep Recurrent Neural Network (RNN) using Long Short-Term Memory (LSTM). The study, which claims to be the first researcher to detect atrial fibrillation using this deep learning method, validated and tested the data using the Atrial Fibrillation database from the Massachusetts Institute of Technology - Beth Israel Hospital (MIT-BIH).

2. METHODS

The data used in this study was obtained from 2 main sources, namely the MIT-BIH ECG recording database on the PhysioBank ATM data bank webpage along with ECG sensor recording data obtained from the AFD tool.

2.1. MIT-BIH ECG Data Collection

The first source of data comes from the PhysioBank ATM web page. The PhysioBank ATM web page has a complete ECG dataset both Normal Sinus Rhythm Database (nsrdb) data which is ECG recording data from non-AF patients, and Atrial Fibrillation Database (afdb) data which is ECG recording data from patients with AF disease. This data can be obtained from the following link: https://archive.physionet.org/cgi-bin/atm/ATM. The distribution of the data obtained and the criteria for the data format used in this study can be seen in **Table 1** and **Table 2**.

Table 1. ECG MIT-BIH data sharing.

Data Name	Data Classification	Sum (data file)
Normal Sinus Rhythm Database (nsrdb)	Normal	16
Atrial Fibrillation Database (afdb)	AF indicated	4

Table 2. Division of ECG MIT-BIH data format criteria

Format Data	Applied Data Parameters
Standard	ECG data timing
RAW ADC units	ECG wave value

2.2. ECG Sensor Record Data Collection

This ECG recording data was taken on July 31, 2020 from 5 respondents who were known to have no previous history of AF disease. During the data recording process, an AFD device is attached to each respondent to take ECG wave value data along with the ECG data time for 10 seconds. From the ECG recording process for 10 seconds using this AFD tool, the amount of data in the range of 512-514 rows of data for each respondent was obtained.

One example of ECG sensor recording data can be seen in **Table 3** with examples of ECG recording data from respondents can be seen in **Table 4**. While the graph of the results of plotting ECG recording data from related respondents can be seen in **Figure 1**.

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Table 3. Responding data.

Identify	Data
Name	Brahma
Age	24 years 3 months
Gender	Man
History of heart defects	None

Table 4. Example of ECG record data from respondent 1.

No	ECG wave value – Time
1	888-82924
2	627-82944
3	505-82963
4	494-82983
5	493-83002
6	498-83022
7	502-83041
8	511-83060
9	525-83080
10	530-83099
…	…

Figure 1. Graph of the results of plotting ECG data from respondent 1.

3. RESULTS AND DISCUSSION

Broadly speaking, the process flow that occurs in the AFD tool is divided into 4 main stages starting from recording ECG data, sending ECG data to the server, processing and analyzing ECG data to identify AF indications, to conveying detection results in the form of notifications via social media, which can be seen in **Figure 2**.

As seen in Figure 2 AFD devices connected to the internet via Wi-Fi will forward the ECG recording data from the device to the server, on this server the signal processing process is carried out to get positive results or not the patient is identified AF. The results themselves will be formed into a message that will be sent via social media API in this case Telegram, to ultimately be forwarded to the child / family of the patient.

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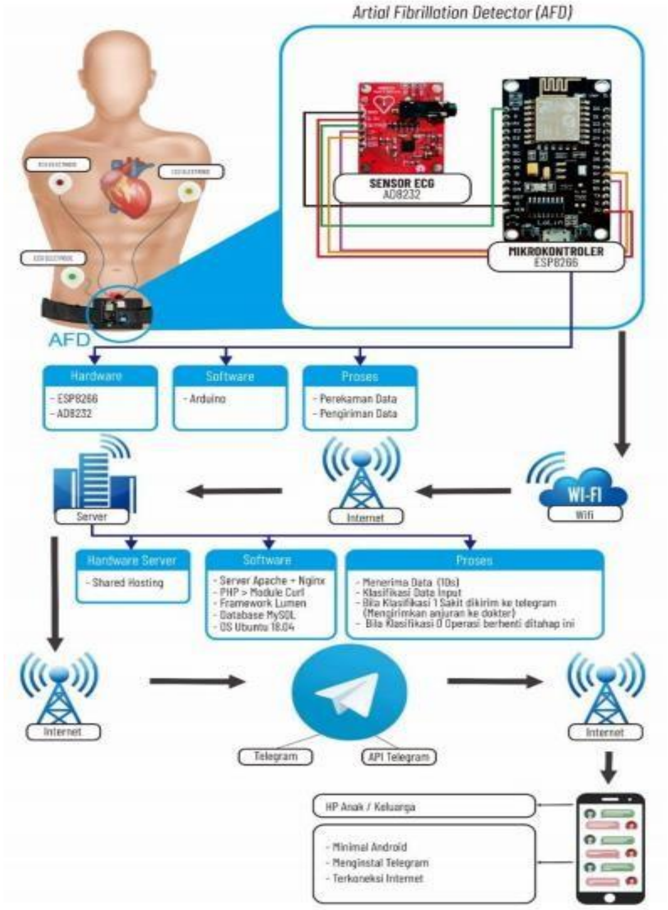

Figure 2. Process flow illustration from an AFD device.

In order for an AFD device to run properly, it must go through the following series of configurations:

(i) C1H340G driver installation for microcontroller ESP8266
(ii) Importing package ESP8266 (which is available online at http://arduino.esp8266.com/stable/package_esp8266com_ index.json) on the Arduino IDE
(iii) Installing a board manager for microcontrollers ESP8266 and selecting the board "NodeMCU 1.0 (ESP-12E Module)
(iv) Configure the upload speed in the settings at speed '115200'.
(v) The microcontroller assembly ESP8266 with a ECG8232 sensor as illustrated in **Figure 3** with the following details.
  - ground pin on microcontroller to ground on sensor,
  - pin 3v on microcontroller to 3.3V on sensor,
  - pin A0 on the microcontroller to the output on the sensor,
  - pin D8 on the microcontroller to the LO- on the sensor, and
  - pin D7 on the microcontroller to LO+ on the sensor.

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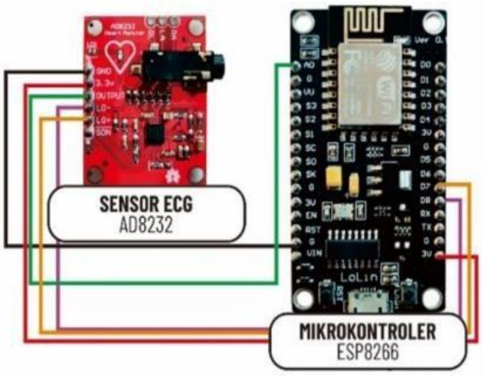

Figure 3. Illustration of ESP8266 assembly with ECG8232 sensor.

To test the reliability of the prototype that has been built during the research, data from 2 main sources were used, namely the MIT-BIH ECG recording database on the PhysioBank ATM data bank webpage along with ECG sensor recording data obtained from the AFD device itself.

3.1. Results and Analysis of Blackbox Experiments on AFD Tool Functions

In this blackbox experiment, testing was carried out on the main functions of the AFD tool. A recapitulation of the results of this experiment can be seen further in **Table 5**. The test scenario applied to this experiment is divided into two, namely "If true" which indicates the suitability of the function according to expectations, and "If it fails" which indicates the function of the AFD tool that does not work as expected.

Table 5. Result of blackbox experiments on the main functions of the AFD tool.

Identity	Test Scenarios	Expected results	Test Results
Turn on AFD	If true	ESP light on	appropriate
	If fail	ESP lamp does not light up	appropriate
Turn on WiFi	If true	Console shows message: "Successfully connected"	appropriate
	If fail	Console shows message: "Waiting for connection"	appropriate
Attaching the electrodes of the ECD sensor	If true	The light on the ECG sensor lights up	appropriate
	If fail	The light on the ECG sensor does not light up	appropriate
ECG data recording	If true	The value and time at which the data was retrieved will appear in the *console*	appropriate
	If fail	The value and time at which the data was retrieved do not appear in the *console*	appropriate

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Table 5. (continue) Result of blackbox experiments on the main functions of the AFD tool.

Identity	Test Scenarios	Expected results	Test Results
10-second ECG data merge ready for processing	If true	The merged data will appear in the *console*	appropriate
	If fail	Data that has been merged does not appear in the console	appropriate
Sending ECG data to the server	If true	The console shows the message: "Data successfully sent to server"	appropriate
	If fail	The console shows the message: "Data failed to be sent to server"	appropriate
Data processing on the server	If AF is detected	Send message notifications to Telegram	appropriate
	If AF is not detected	Not notifying messages to Telegram	appropriate

It can be seen in **Table 5** that there are 7 points of need that represent the functions of the AFD tool, including: turning on the AFD, turning on WiFi, attaching ECG sensor electrodes, recording ECG data, combining ECG data for 10 seconds that are ready to be processed, sending ECG data to the server, and processing data on the server. From all the points tested, the results of this test show that all functions of the AFD tool developed run as expected.

3.2. Results and Analysis of AF Detection Results Conformity Experiment

In the AF detection result suitability experiment, a comparison of AF detection results has been carried out between the original dataset and the detection results carried out by the AF tool. A recapitulation of the results of this experiment can be seen in **Table 6**. The data sources used in this experiment came from 2 sources, namely ECG data from the MIT-BIH ECG database consisting of 8 normal data (nsrdb) and AF disease data (afdb). While the second source came from recording ECG data obtained using an ECG tool on 5 respondents who were known to have no previous history of AF disease.

Table 6. The experimental results conform the AFD identification results to the actual.

Data Sources	Name	Indication	Program Experiments	Conformity
MIT-BIH	Normal 1	Normal	Normal	Appropriate
MIT-BIH	Normal 2	Normal	AF indicated	Not compliant
MIT-BIH	Normal 3	Normal	AF indicated	Appropriate
MIT-BIH	Normal 4	Normal	AF indicated	Not compliant
MIT-BIH	Normal 5	Normal	AF indicated	Not compliant
MIT-BIH	Normal 6	Normal	Normal	Appropriate
MIT-BIH	Normal 7	Normal	AF indicated	Not compliant
MIT-BIH	Normal 8	Normal	Normal	Appropriate
MIT-BIH	AF 1	AF indicated	AF indicated	Not compliant
MIT-BIH	AF 2	AF indicated	Normal	Not compliant
Tool AFD	Brahma	Normal	Normal	Appropriate

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Table 6. (continue) The experimental results conform the AFD identification results to the actual.

Data Sources	Name	Indication	Program Experiments	Conformity
Tool AFD	Farista	Normal	Normal	Appropriate
Tool AFD	Irsyad	Normal	AF indicated	Appropriate
Tool AFD	Ramdan	Normal	Normal	Appropriate
Tool AFD	Rooseno	Normal	AF indicated	Appropriate

Based on the experimental results shown in **Table 6**, it is known that from a total of 15 test data, there are 9 test data that have the suitability of test detection results, including 4 normal data from the MIT-BIH ECG database, and all ECG data derived from recording using AFD tools. While the other 7 test data are known to be inconsistent with the actual detection results, including 4 normal data and 2 AF data from the MIT-BIH ECG database

4. CONCLUSION

The design of IoT-based AFD tools to detect Atrial Fibrillation heart disease using ECG sensors has been developed through 4 main stages, including the process of recording ECG data, the process of sending data from the AFD device to the server, the process of processing ECG data to detect the appearance of AF, and the process of sending notifications if indications of AF appearance are found.

The implementation of IoT technology using ECG sensors in detecting AF heart disease has been carried out through several stages of the process, including the configuration of microcontrollers and sensors and their assembly, the implementation of microcontroller programming, the implementation of AF heart disease detection programming, along with the configuration of preparation for the notification process through third-party applications.

The experimental process carried out in the development of AFD tools to detect AF heart disease in this study was divided into 2 test scenarios, including blackbox testing to determine the suitability of the function of the AFD tool and testing the suitability of the original dataset detection results with detection using the AFD tool. The overall blackbox test showed the suitability of all AFD device functions, while the AF detection test showed 9 corresponding results from a total of 15 data tested.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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