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IoT-based health information system using MitApp for abnormal electrocardiogram signal monitoring

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ABSTRACT

Information systems are currently developing very rapidly, and this is inseparable from the role of internet of things (IoT) technology, especially in the world of telemedicine. MitApp is an open-source application that can be used to monitor electrocardiogram (ECG) signals in real-time. The aim of this study is to develop an IoT-based ECG signal monitoring system that utilizes the MitApp application to detect abnormal ECG signals that are characterized by symptoms of cardiac arrhythmias. To process ECG signal data obtained from lead electrode results, the research method utilizes Arduino Uno as a microcontroller. The result is then displayed on the thin film transistor (TFT) layer using the Nextion module. The ESP32 module is used as a Wi-Fi module to send data to the MitApp app on a smartphone. The results showed that the results of the comparison test of ECG signal module data with ECG simulator tools with beats per minute values of 60, 80, 100, 120, and 140 obtained an error rate of <0.05. Based on these results, there is potential to develop this feature and integrate the system with the patient management system to improve the effectiveness of remote monitoring.

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1. INTRODUCTION

One of the uses of electrocardiograph (ECG) signals is important, especially when monitoring in real-time using a remote monitoring system model [1]. The elektrokardiogram (EKG) signal is a graphical representation of the electrical activity generated by the heart. A normal EKG shows regular cycles of cardiac depolarisation and repolarisation. The purpose of this monitoring system is to detect abnormalities in heart rhythm and heart muscle [2]. The heart cycle works through a mechanism repeatedly and continuously, otherwise called a heartbeat [3]. Cyclically, the heart performs a systolic period, a period when the heart contracts and empties its contents (blood), and a diastole period, a period of relaxation that fills the heart with blood. The two atria relax and contract simultaneously, and the two ventricles also relax and contract simultaneously to perform this mechanism.

Under normal conditions, the heart signal (ECG) has a certain shape so that it can be used as a reference to determine the condition of the human heart. The ECG signal is owned around 60 beat per minute (BPM), and in Figure 1 you can see a pattern consisting of several main components, including P waves: which represent the depolarization of the atria as they contract. QRS complex: represents the depolarisation of the ventricles (chamber spaces) as they contract. Usually, the QRS complex is larger and more complex than the P wave. T wave: which represents the repolarization of the ventricles as they recover from contraction. As long as the heart is beating at approximately 60 ppm, the interval between the P wave, QRS complex, and T wave will be relatively constant [4]. This indicates a regular heart rhythm in Figure 1, the cardiac signal forms a PQRST wave pattern, where the P wave indicates atrial depolarization triggered by the SA node, the PR segment indicates the cessation of impulses at the AV node, the QRS wave indicates ventricular depolarisation, the ST wave indicates the absence of impulses due to the refractory period and the TCardial period. According to Patil *et al.* [5], normal ECG waves have characteristics as shown in Table 1.

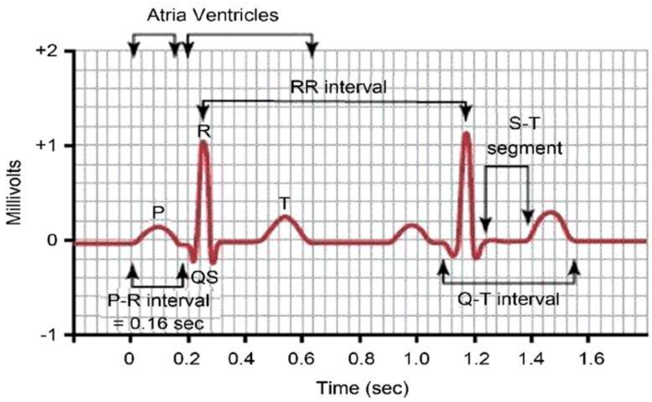

Figure 1. Normal ECG waves

Table 1. Electrocardiogram parameters

Wave electrocardiogram	Amplitude	Electrocardiogram interval	Duration (sec)
P	<0.3	P-R	0.12–0.20
Q	1.6–3 mV	Q-T	0.35–0.44
R	25% from R	S-T	0.05–0.15
T	0.1–0.5 mV	Q-R-S	0.06–0.10

In general, the calculation of the heart rate (BPM) value starts from the interval between R and R, which indicates the period of heartbeat that can be converted into heart rate (H): H=6000/(R-R) (bpm), where R-R is the interval between peak signal R and peak signal R measured in milliseconds. The R-R interval is relatively constant from beat to beat, so the conversion of ECG signals can determine the BPM value [6]. The use of smartphone-based applications is very possible for patients and health workers to access heart health through the patient's ECG signal in real-time, such as it-based applications [7]. The development of the internet of things (IoT) is increasing day by day, especially in the field of remote monitoring systems. Previous research has been conducted on remote monitoring system methods, such as monitoring vital sign parameters Spo2 and heart rate using finger sensors with the Things Speaks application as an IoT service and monitoring Oximetry and heart rate using an IoT-based smart band with the smartphone-based MitApp application [8] can show good parameter reading performance, but has not given expectations by the desired standards, especially BPM parameters. Similar research has also been conducted by Durani *et al.* [9] regarding the development of it with the help of the NodeMCU ESP8266 device in developing smart homes for automatic needs such as turning on/off household devices using the Blynk app, then by Kamble and Birajdar [10] regarding the ECG monitoring system by utilizing E_cloud on an IoT platform equipped with data storage on an SD card displayed on a thin film transistor liquid crystal display (TFT LCD) for health services. Meanwhile, Pal *et al.* [11] further analyzed and empirically tested the theoretical framework to determine the core factors that can influence user acceptance of smart home services for IoT-based elderly healthcare. This is because service user adoption is very low, so a more comprehensive approach is needed for healthcare management [11]. The impact of the IoT on the progress of the healthcare industry is enormous, especially in the 4.0 era, where the development of healthcare applications has been carried out using both software and hardware. In principle, the IoT base can be connected to all medical equipment [3], [12], especially ECG equipment, which is usually used conventionally because its use requires high costs, both equipment and usage time. Therefore, the development of it makes it easier, to access it and perform image analysis [13]. The purpose of this research is to design an IoT-based ECG signal processing equipped with an SD card to store data displayed on the Nextian TFT screen and processed using MATLAB to obtain the BPM value, using the AD8232 sensor module and ESP32 as Wi-Fi connected to the MitApp smartphone app [14], [15].

Although IoT technology has been widely applied, the use of vital signs in the medical field requires calibration tests to ensure accuracy. The application of it in medical institutions offers many benefits. For example, mobile phones equipped with radio-frequency identification (RFID) sensors can serve as a medical platform to monitor health and manage drug supply. This technology allows patients to easily track their health status and ensure adherence to medications, improving their overall healthcare experience. A technology that includes a communication system between the sensing node and the processor and, the processing algorithm in generating output from the data collected by the sensor needs to be tested output value, especially system error (%). Likewise, in this study, the results have been tested using an ECG simulator and ECG recording tests that produce error values of <0.005, as well as machine learning methods used to classify ECG signals to detect sleep and wake conditions [16]. The contribution of this study can be summarized as:

a. This paper presents the implementation of an IoT based health system using the MitApp application for real-time monitoring of ECG signals. This demonstrates the application of IoT technology in the healthcare sector.
b. This study focused on the detection of abnormal ECG signals, specifically cardiac arrhythmias. By using the MitApp application and the Arduino Uno microcontroller, the system can monitor and analyze ECG signal data to identify abnormal patterns associated with cardiac arrhythmias.
c. The research method employs Arduino Uno as a microcontroller to process ECG signal data acquired through the electrodes. The data afterward seems to the TFT screen using the Nextion module, providing a user-friendly interface for visualizing ECG signals.
d. Integration of Wi-Fi module for data transmission: The ESP32 module is utilized as a Wi-Fi module to enable the transmission of ECG signal data to the MitApp application on smartphones. This enables remote monitoring of ECG signals, enhancing accessibility and convenience for healthcare professionals and patients.
e. Accurate BPM measurement: the study contributed to obtaining accurate beats per minute (BPM) values by comparison of ECG signal data with the ECG simulator measured at different BPM values (60, 80, 100, 120, and 140). The achieved error rate of <0.05 indicates the system's effectiveness in accurately measuring BPM values, which is crucial for reliable health monitoring.

In brief, this study contributes to the application of IoT-based health systems for real-time monitoring of ECG signals, focusing on detecting abnormal patterns associated with cardiac arrhythmias. This paper presents practical solutions using Arduino Uno, Nextion module, and ESP32 module, while also highlighting the system's accuracy in measuring BPM values. These findings show the potential for further development to improve remote monitoring and patient management in healthcare.

2. METHOD

2.1. Design system and instrumentation data

This study aims to develop an IoT-based health service system that can track patients' arrhythmia-related conditions. The system is powered by the MitApp app, which is a free tool used by doctors and paramedics to cheque a patient's heart health. The proposed system is easy to install and can be used remotely. The three electrode leads of the ECG data recording can be connected to an Arduino Uno and used for signal processing. The data collected by the device can be saved on an SD card. A PC can then process the data using MATLAB [17]. ESP32 is used as a Wi-Fi module that is sent to the MitApp application in the form of a BPM value [18]. The system can be improved in the future by adding more sensors, which can be used to measure various other vital signs such as heart rate and blood pressure. Creating a cloud-based database would be beneficial in maintaining the patient's medical record, but doctors would still be able to access the data whenever an EKG reading is taken analyzed [19]. Doctors can also send counseling reports to patients Figure 2. The equipment used in this design includes an Arduino Uno microprocessor, AD8232 sensor, TFT LCD, and ESP32 MCU node. The AD8232 sensor is a signal conditioning block capable of extracting, filtering, and amplifying the body's highly noisy biopotential signals. The sensor gets this biopotential signal input through electrodes placed on certain body parts based on Einthoven's triangle bipolar lead theory [20]. The sensor gets this biopotential signal input through electrodes placed on certain body parts based on Einthoven's triangle bipolar lead theory [20]. The sensor is based on the 3-lead ECG technique, which uses a yellow electrode with a positive pole, a red electrode with a negative pole, and a green electrode as ground with an analog signal reading output.

The electrodes get bioelectric signals based on the principle of contact between metal ions and a suitable metal to generate an electric potential called electrode potential. The electrode potential is generated due to a reduction in the rate of ion transfer within. The ESP32 MCU node is a complex device. In this microcontroller, there is already a Wi-Fi module in the chip so it is very supportive to create an IoT application system because programming this device can be done in the Arduino IDE software using USB to serial communication [21], [22]. Further testing and data analysis using error deviation by comparing BPM values 60-140 with Cortec MS 400 ECG simulator.

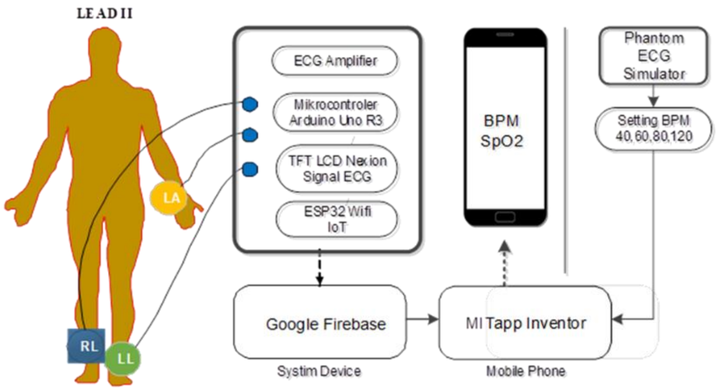

Figure 2. ECG signal data processing and monitoring using the MitApp application

2.2. Data testing and validation

This research starts with assembling tools, testing or measuring tools, and validating and calibrating tools [23], [24]. In the device design, test, and calibration with ECG simulator, heart rate measurement in respondents was carried out under normal conditions or when they did not perform the activity Figure 3(a). This heart rate measurement is carried out in conjunction with a device test assisted by medical personnel Figure 3(a). This measurement is repeated three times. The data obtained is recorded on a data collection sheet which will then be analyzed to conclude all the data that has been collected.

In Figure 3(a), the ECG module is tested using 3 electrode leads. After, programming on the Arduino Uno, the ECG signal appears on the TFT display screen. The results of the ECG signal data stored in the SD Card data are processed using the Teraterm application, which is then processed in the MitApp application, which is then processed in the MitApp application which is displayed on a smartphone in the form of BPM parameters [25]. Validation of BPM data is carried out using ECG simulator comparison data Figure 3(b) [24].

(a) (b)

Figure 3. Data validation process using ECG instruments and calibration simulator; (a) ECG signal data acquisition process and (b) comparison test process with ECG simulator

3. RESULTS AND DISCUSSION

3.1. ECG signal testing

In identifying the ECG signal in the module, an ECG Simulator tool is required to test the accuracy of the data obtained from the AD8266 lead sensor (ECG module). ECG module testing uses values of 60, 80, 100, 120, and 140 BPM [26]. The results can be seen in Table 2 and graph Figure 4. A one-sample t-test analysis is required to determine the extent of differences in some BPM value parameters. Furthermore, it can be seen in Table 3.

Table 2. Comparative test measurement results using ECG simulator

Number	BPM	X1	X2	X3	X4	X5	Mean	Error (%)
1	60	59	60	61	59	61	60	0.000
2	80	80	78	79	81	80	79.6	-0.667
3	100	99	100	99	101	100	99.8	-0.333
4	120	121	119	120	120	122	120.4	0.667
5	140	140	139	140	140	141	140	0.000

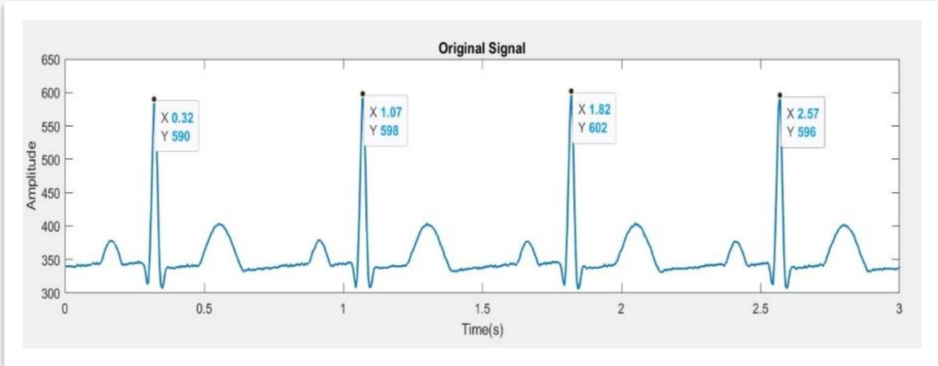

Figure 4. Heart signal condition on BPM-60 measuring instrument

Table 3 using the T-one sample test shows that the BPM-60 experiment obtained at-count value=0.000 with a p-value=1.000 (0.05), with a confidence interval value ranging from -0.938 ± 0.938 [27]. So, the results of reading the BPM value for 5 samples are by expectations below 5%. The results of each experiment are as follows for experiments using BPM-80 obtained t-count value=0.971 with p-value=0.381 (0.05), experiments using BPM-100 obtained t-count value=-1.000 with p-value=0.363 (0.05), experiments using BPM-120 obtained t-count value=0.791 with p-value=0.465 (0.05), experiments using BPM-140 obtained t-count value=0.000 with p-value=1.000 (0.05) so that the overall test uses one sample test on BPM reading parameters by measurement standards.

Table 3. One-sample T-test analysis parameter BPM

Parameter	T-Stat	Sig. (2-tailed)	Mean difference	95% Confidence interval of the difference		Test value
				Lower	Upper	
BPM-60	0.000	1.000	0.000	-0.938	0.938	= 60
BPM-80	-0.961	0.381	-0.400	-1.470	0.670	= 80
BPM-100	-1.000	0.363	-0.333	-1.190	0.523	= 100
BPM-120	0.791	0.465	0.333	-0.750	1.417	= 120
BPM-140	0.000	1.000	0.000	-0.663	0.663	= 140
Level of confidence 0.05%						

3.2. ECG signal overview

EKG signals provide a picture of the electrical activity of the heart. This is a graphical representation of the heart's electrical impulses recorded over some time. The EKG signal is obtained by placing electrodes on the body, which detect the electrical changes produced by the contractions of the heart. The EKG signal consists of a series of waves and intervals that correspond to the different phases of the cardiac cycle. The main components of the EKG signal include the P wave, QRS complex, and T wave. The P wave represents atrial depolarization, the QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization [28]. To identify the ECG signal image, an ECG electrode lead is needed, which is then processed through the Arduino Uno microcontroller and displayed on the nection TFT display screen. Furthermore, the ECG data is processed for data analysis to determine the accuracy of the calculated BPM value from the R to R peak. An overview of the processed and analyzed ECG signal data using the MATLAB application. From the data, it can be seen that the distance between the first peak to the second peak is 1.49 seconds. It can be concluded that at the 60th second, the peak point is 40, so the ppm value is 40 beats per minute [29], [30]. From the data, the distance between the first peak to the second peak is 1 second. It can be concluded that at the 60th second, the peak point is 60, so the ppm value is 60 beats per minute [29]–[31].

Figure 4 is a picture of the condition of the heart rate under normal conditions, in the BPM-60 measurement the count from the first peak point to the next peak point shows a value of 1 second (60 minutes). Likewise, Figure 5 is a picture of the condition of the heart rate under normal conditions. In the BPM-80 measurement the count from the first peak point to the next peak point shows a value of 1 second (60 minutes).

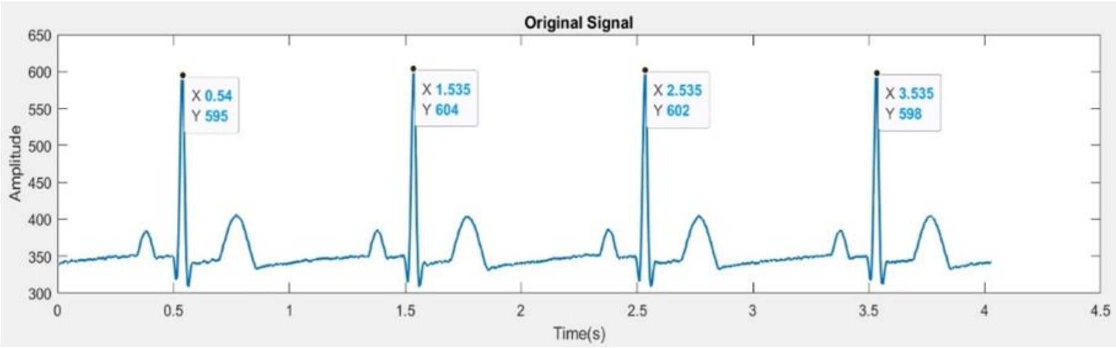

Figure 5. Heart signal condition on BPM-80 measuring instrument

In Figure 6 the distance between the first peak to the second peak is 0.75 seconds and so on is 0.66, 0.33, 0.35, and at the last peak is 0.35 (seconds). It can be concluded that in seconds-to-seconds experience irregularities. While in Figures 5 and 6 from the peak point to the next peak of 1 minute (60 seconds), which is under normal heart rate conditions [29]-[31].

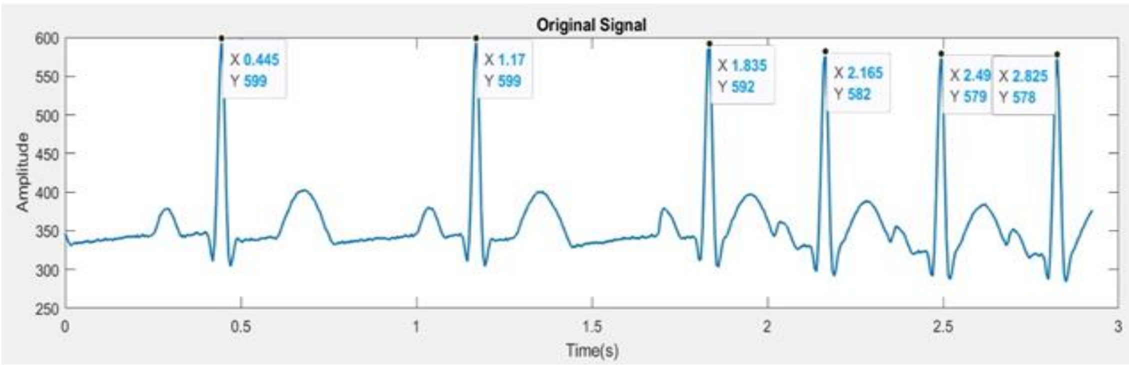

Figure 6. Abnormal heart signal condition on BPM-120 measurement

4. CONCLUSION

In this research, we successfully developed an IoT-based health system application, using MitApp for the monitoring of abnormal ECG signals. The findings demonstrate that the application is capable of accurately detecting and monitoring ECG signals, with an error rate below 0.05, as indicated by comparative testing with a 40-120 BPM simulator. These results highlight the potential of the developed application to effectively assist in the early detection and monitoring of cardiovascular abnormalities. One of the accuracy of data in an application greatly determines the reliability of equipment, especially supported by calibration tests that can be shown with high accuracy values below 5%. A requirement for tools used for monitoring vital signs in the future must be equipped with calibration data on the tool, to determine the convenience in determining each parameter used.

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