Internet of Things based Heart Rate Monitoring and Alert System

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Abstract— Heart rate analysis provides vital information of the present condition of the human body and become one of the important indicators of health. Manual monitoring method no longer efficient since requires physical access from the medical staff. Thus, a system that provides a real-time monitoring and alert is needed. In this paper, we develop a heart rate alert system that is usable for medical officer and patients. The system measures the variation of the tissue blood flow rate by means of a photo transmitter and detector through fingertip known as photoplethysmography (PPG). The detected signal is passed through active low pass filter and then amplified by a two stages high gain amplifier. The amplified signal is feed into the microcontroller to process the heart rate. Then, the heart rate reading is transferred to a running web server for dashboard views for monitoring. For alerting medical officer, the system able to trigger and send a notification message through Telegram platform in the occurrences of abnormal heart rate reading. Mean of reading differences and response time testing were carried out for the performance testing of the system. Overall, the system is capable in providing an alternative method for the medical staff to monitor and get alert about the heart rate of the patients. This system can be deployed in hospitals or used by heart disease patients to monitor their heart rate condition from time to time.

Index Terms— Heart monitoring, microcontroller, alert, Internet of Things

I. Introduction

THE presence of Internet of Things (IoT) has become one of the enablers of real-time monitoring. For example, such monitoring is in [1] that aims to monitor elderly people, monitors home air quality [2] and health monitoring [3]. Health monitoring that is based on IoT has greatly catch an attention among researchers. There are quite a few related works in the literature as presented in the paper.

Health monitoring is important since the increasingly growing number of people with the chronic diseases due to a busy lifestyle that leads to an unhealthy diet, lack of exercises and rest, stress etc. [1]. A monitoring system is needed to continuously monitor and detect any occurrence of illness symptom of a patient for quick medical assistance. It is one of the most important steps to prevent the disease from becoming more serious and getting worsen. The heart rate is one of the important indicators of health in the human body. It measures the number of times the hearts beat per minute (bpm). This paper focuses on the heart rate monitoring and alert.

The speed of the heartbeat is depending on the physical activity, emotions and the heart conditions itself. Article in Medical News Today [5] provide the list of a normal resting heart rate reading published by the United States National Institute of Health (NIH). The normal resting heartbeat for kids aged over 10 years to elder adult is similar ranging from 60-100 bpm. However, the heart rate value is depending on an individual. Active individual tends to have lower heart rate which is commonly below than 60 bpm during the resting state. Elderly who are exceeding 60 years old would have a target zone between 80 to 136 bpm. There are many factors that can affect heart rate which are age, medication, fitness level, stress, body size and body position. However, the heart rate does not change drastically due to those factors.

The paper is organized as follows. Section 2 presents the methodology used in developing the system. Section 3 analyzes the result and discusses them accordingly. Section 4 concludes the paper with an outline of contribution and the future work.

II. Related work

Manual monitoring method using fingertips to check the pulse and stethoscope to listen to the patient heart rate. These data are normally kept in paper which is hardly to be accessed later by the medical staff. It is also inconvenient because it requires the staff to be physically available to access patient data. Due to these scenarios, it is hard for the medical staff to continuously monitor the patient's condition.

Early work proposed by Kumar and Rajasekaran [3] use a stand-alone system that stores health data such as temperature, heart rate and respiration rate in the connected devices such as patients' phone and local server. Koshti and Ganorkar [6] enable transferring patient's data wirelessly to the remote server. The data can be monitored by the medical staff whenever they want.

Parihar, Tonge and Ganorkar [7] proposed a monitoring system for heartbeat and temperature that display the reading on the LCD screen. Similarly, in [8] and [11], they also display the

heartbeat to the LCD display for monitoring purposes. In addition, the display can also passively alert medical staff through monitoring the pattern of heartbeat.

Inspired by cloud technology, researchers in [9] and [10] use a cloud server as an online monitoring platform for patients' data. Data that is kept in the cloud server can be access for real-time monitoring. But there is no real-time alert if any abnormal heart rate reading occurs.

Research by Chaithra, Amrutha and Rajesh [12] also proposed an online monitoring system with email for alerting purposes. This work introducing additional platform for alerting the medical staffs instead of having the LCD display. Table 1 summarizes the related works that shows the pattern in each research that moving from storing data in a physical server to cloud. Also, from the literature, researchers are interested in providing instant alerts to the medical staff in case of abnormal reading in the patients' data. It highlights the need of a system that provides online monitoring and instant alert to the medical staff for quick medication action.

TABLE 1
SUMMARY OF RELATED WORKS

Related Work	Description
2016 [3]	Developing a stand-alone system.
2016 [6]	Patients' data is wirelessly monitored from a server
2017 [7] 2018 [11]	Display heart rate reading in LCD.
2017 [8]	Displaying data on LCD display.
2017 [9]	Real time monitoring system implemented using cloud server.
2018 [10]	Viewing heart rate through the cloud server.
2019 [12]	Online monitoring and send alert using wifi module to email (Arduino)

Thus, this paper is extending the idea of using external platform for alerting purposes while having online monitoring as well. Initial idea from [12] sending alert using email is not efficient since checking email is not an instant action. The email receiver needs to check their inbox, and this could lead to late response. Instead of using email, we are embedding a social media platform that is telegram for the same purpose.

III. Development and System Design

Heart Rate Monitoring System is a project focused in providing a system to monitor heart rate reading continuously. The development of the system adopts the Waterfall model that involves requirement analysis, system design, implementation, testing and maintenance.

Phase 1 – Requirement Analysis

This phase involves determining all requirements including analyzing existing and related works, identifying hardware and software. Literature review for the related works also studied to identify gaps and requirements for the system. In this project, we explore the Arm Mbed microcontroller that has WiFi module. Previous research had used either Raspberry Pi or Arduino. The pulse/ heart rate sensor is for measuring patient's heart rate.

Phase 2 – System Design

System design aims to properly design the system including physical, logical and interface design and the flow design of the system. These designs are incorporated with the identified hardware from the previous phase. Fig. 1 shows the logical design of how the system works. The sensor is connected to the controller where there are three pins for positive, negative, and signal. The positive pin (black wire) is wired to +5V port located at the microcontroller board, the negative (red wire) wired to GND port and signal (purple wire) to A0 port. The microcontroller is connected that has the WiFi module send the patients' data to the cloud storage. The medical staffs can view the patient's data through a simple dashboard and notification is sent via telegram.

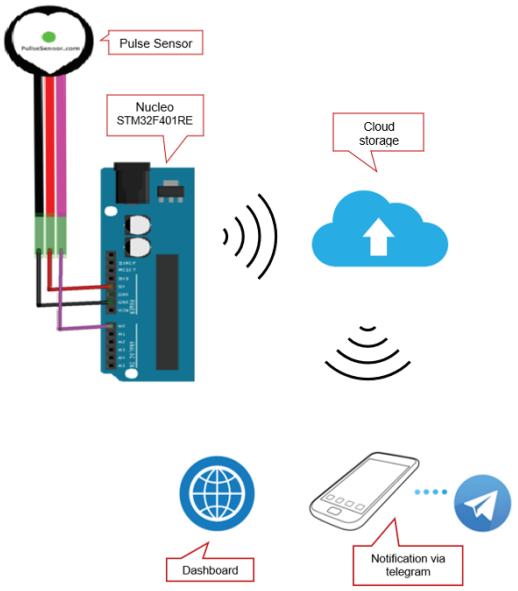

Fig. 1. Design of the Proposed System

Fig. 2 shows an example of the interface design for each patient in the dashboard. The reading for each patient is kept in the system, thus if there are any abnormal reading, the system can detect. For first time patient, the medical staff needs to key in the information such as name, the normal heart reading for the patient with minimum and maximum value. The plotted graph in the figure shows the live heart reading value captured from the sensor.

Fig. 3 shows the flow design for the alert notification module. The sensor starts reading the pulse rate when activated. If there is no bpm detected, the sensor retries. If yes, then the bpm is sent to the cloud server. If the reading is abnormal, then the alert is sent to the medical staff via telegram and the reading continues.

Phase 3 – Implementation

The product prototype is developed based on user requirements, and then tested based on the functionality using

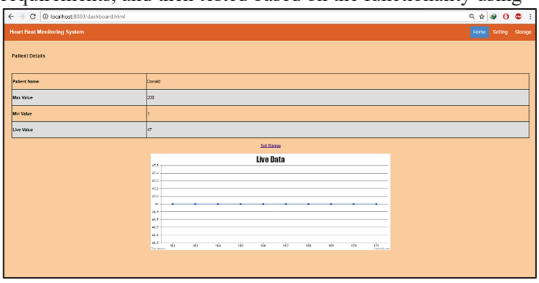

Fig. 2. Example of an Interface Design

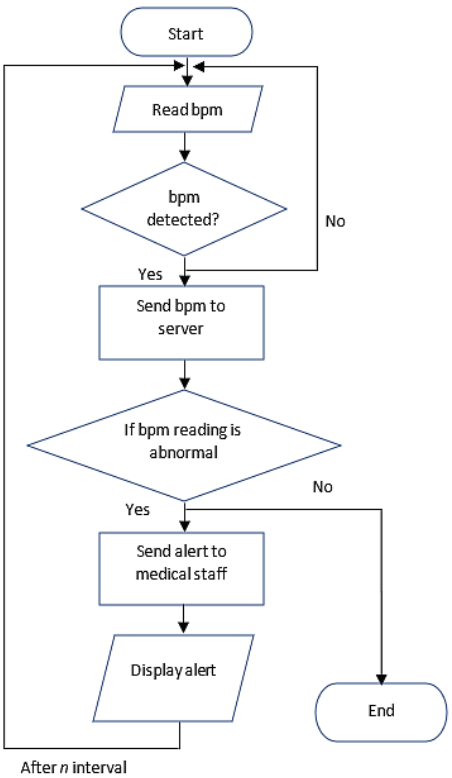

Fig. 3. The Flow Design of the System for Alert Module

the unit testing method. As the main objective is to detect human heartbeat, therefore the product needs to achieve the objective as it initial goal.

Phase 4 – Testing

In this phase, the product prototype that has been developed is tested using several methods of testing; functional, differences and response testing. The functional testing is to determine whether it can detect and record the reading of pulse of a user. The differences of reading and the response time to receive alerts are also tested. Differences of reading is expected since the most accurate of reading is the manual method [14]. Thus, the differences of reading are recorded to ensure the reading produce by the sensor is reliable. The formulae used for differences of reading as below:

$$\text{Mean of Differences (bpm)} = \sum_{n=1}^{m} \frac{(HRM-C)}{m} \quad (1)$$

C is referred to the compared methods that are Now 2 and Manual.

Phase 5 – Maintenance

Maintenance process is the last stage in the methodology which is needed if there is any failure detected to the prototype product. It is a recurring phase that is activated when needed.

IV. RESULTS AND DISCUSSION

This section presents the results from the testing phase. Fig. 4 shows the captured reading that is recorded in the cloud server. This testing is one of the functional testing being done. The inconsistent reading is purposely created to see if the plotted graph successfully captured the data.

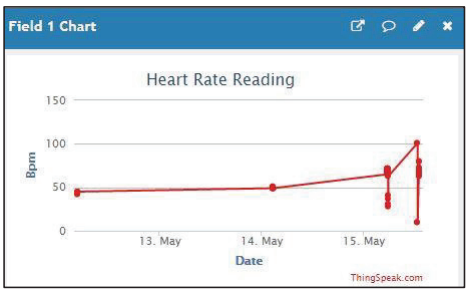

Fig. 4. Example of Real-time Monitoring at the Cloud Server

The second testing is the accuracy testing that aims to see if the Heat Beat Monitoring (HRM) able to provide consistent and reliable reading. A comparison is made between readings recorded manually and Weloop Now 2 Smartwatch. The manual reading is collected by placing finger at wrist and counting detected heartbeat in one minute. Weloop Now 2 Smartwatch is an example of available product in the market used by users to consistently track their fitness condition such as heartbeat reading. The heart rate sensor that is embedded in the smartwatch is not specified by the manufacturer, thus we cannot compare the specification.

Fig. 4 shows the reading comparison between Weloop Now 2 Smartwatch and manual method. There are five users involved in the testing phase. The average of reading shows that the differences from the comparison with Now 2 is between 1.6 – 3.9 bpm. On the other hand, the comparison with the manual method is between 0.0 – 1.9 bpm. These values are acceptable which based on an article from Live Science in [13]. The article mentions about the comparison of different product of fitness tracker to the electrocardiogram (EKG), which physician uses for diagnostic purposes. It reported that the Apple Watch and the Mio Fuse did the best in their study where most of their measurements fell within a range of 29 beats per minute (BPM) which is far difference compared to HRM differences with manual method. The differences of Now 2 to the manual method also bigger than HRM which is between 1.7 – 3.7 bpm.

TABLE 2
READING COMPARISON OF HRM, NOW 2 AND MANUAL METHOD

Reading No.	User 1			User 2			User 3			User 4			User 5		
Format of Tool Used	HRM	Now 2	Manual	HRM	Now 2	Manual	HRM	Now 2	Manual	HRM	Now 2	Manual	HRM	Now 2	Manual
1	55	54	54	76	74	74	81	83	80	85	83	85	68	79	68
2	57	55	58	72	74	70	79	77	79	84	82	84	67	63	67
3	59	57	56	77	75	75	82	80	82	83	85	83	67	68	67
4	58	57	59	72	73	74	83	81	83	83	81	83	67	65	67
5	59	58	59	73	72	76	83	85	83	84	84	84	67	64	67
6	60	63	58	75	77	76	83	81	83	85	82	85	66	62	66
7	61	59	60	75	72	76	83	82	83	85	80	85	65	61	65
8	54	51	55	74	72	77	84	84	84	86	90	86	66	65	66
9	56	54	58	74	73	74	85	84	85	85	83	85	66	64	66
10	60	58	58	74	76	77	85	83	85	86	89	86	68	61	66
Mean of Differences (bpm)		1.9	1.4		1.8	1.9		1.6	0.1		2.5	0.0		3.9	0.2

Moreover, this prototype is not aimed to replace the EKG but only to give an early signal if the reading is abnormal.

The third test is the time of the occurrence of abnormal reading until the alert is received in Telegram application software. The alert is triggered when the user's heartbeat exceeds or is lower that the pre-determined normal value for the user. Time taken for a notification message received by the user is recorded in Table 3.

Based on Table 3, the time taken is considered low, only 2 seconds is needed for a message to be received by the receiver. The test successfully notified the medical staff about the patient that has an abnormal reading via telegram

TABLE 3
TIME TAKEN FOR ALERT TRIGGERED IN TELEGRAM

Trial No.	Time Taken (second)
Trial 1	1
Trial 2	0.6
Trial 3	0.8
Trial 4	1.5
Trial 5	2

The developed system is able to detect heart rate using STM32F401RE microcontroller, that provide a monitoring system that give alert and save data in cloud storage platform.

Heart rate monitoring system consist of two major component which is heart rate detection device and client-server communication to broadcast the monitoring system and control the notification. The detection device is connected to a computer while a node.js server is running on the computer to retrieve the heart rate data from the detection device through serial port. Then, the server broadcast a web dashboard to display the live data and set the maximum and minimum value of the heart rate. the maximum and minimum value is set on the client side. Once the value has been set, the medical staff can receive a notification message through telegram application on their smartphones. Furthermore, user also able to download the saved heart rate data in the Thingspeak as a link is provided on the webpage. All of these features ease the targeted user which is a heart disease patient who need fulltime treatment with the doctor able to monitor the heart rate continuously and alert if there is abnormal reading detected.

V. Conclusion

A Heart Rate Monitoring (HRM) System has successfully been developed. This system can be used by a medical staff in monitoring and alerting of abnormal reading of a patient's heart rate. From the research this system is considered as a good solution to ease medical staff having fast alert in emergency case, since only two seconds or less is required to receive the alert. Furthermore, the reading of patient's heartbeat is nearly accurate that is differ only between 0.0 – 1.9 bpm to the manual method. This could give an early signal if any abnormal reading detected. HRM is seen to be a promising system to provide a real-time monitoring and alerting the medical staff instantly.

For future research, this system can be deployed in hospitals or used by heart disease patients to monitor their heart rate as it provides real-time monitoring to user and it is a usable, reliable and effective system.

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