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Design of an Arrhythmia Detection System Using Wearable PPG Sensor

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***Abstract*—Any abnormality in the heart rhythm from the normal range is called arrhythmia. It may be due to lower or faster heart rate and the reason of other severe phenomena like Atrial and Ventricular fibrillation which are the most severe arrhythmias. Most of the cardiovascular deaths occurs due to arrhythmogenesis. Therefore, continuous heart rate monitoring is critical for patients who are in the high risk of cardiac events like the patients who have previous heart attacks. ECG based devices are commonly used for this type of monitoring. However, ECG recording needs placement of ECG electrodes and needs at least two limbs for recording. Chest leads ECG are sometimes uncomfortable for continuous monitoring. Therefor. PPG sensors are getting popularity for measuring heart rate as it can easily recorded from only fingertip or earlobe and does not require any adhesive gels. Considering the situations, we proposed a design of a heart rate measuring system using a low-cost available PPG sensor for the patients who need to monitor their heart rate at home especially at rural areas where clinical facilities are not much available. This system will continuously monitor the heart rate and in case of any abnormality of heart rhythm, the system will inform the concerned person immediately through the GSM module as well as an alarm will ring automatically. In the proposed system the MAX30102 pulse oximetry biosensor is used. Moreover, to check the reliability of the heart rate detection, we have used the KardiaMobile data to compare the PPG sensor based reading, which is an FDA approved clinical grade single-lead ECG monitoring device. Promising results were found which indicate that the low-cost PPG biosensor can be used as portable Arrhythmia detection device.**

Keywords— Arrhythmia, PPG, KardiaMobile, MAX30102

I. Introduction

The heart generates electrical impulse, which travels through the chambers of the heart and generates contraction and relaxation of the chambers. This causes the blood to flow to all the body parts and generates heart rate which is measured in BPM. But in case of any abnormality in the heart rate, the supply of blood flow is affected, and different cardiovascular disease (CVD) arises. This abnormality in the heart rate is called arrhythmia. Arrhythmia is the root cause and the first vital sign of other CVDs like heart attack, heart failure and different life threating fibrillation like Atrial and Ventricular fibrillation. Sustained atrial fibrillation which is analyzed by abnormal heart rate pattern is the cause of having stroke. Most of the Sudden Cardiac Death occurs due to arrhythmias (sudden cardiac arrest). The person who has faced a heart attack previously has a 75% possibility of cardiac arrest and SCD. The risk is higher during the first six months of a heart attack. A person who has hypertension, a family history of heart disease, high cholesterol, and smokes, has a higher possibility of suffering from coronary artery disease and this disease causes the 80% risk of sudden cardiac arrest, hence sudden cardiac death [1]. Someone having any of these symptoms needs to check his/her heart rate on a regular basis using a reliable heart rate detector. So that he/she can take proper action in the due time and avoid SCD.

To monitor or detect arrhythmia, mainly ECG based monitoring is used which need Electrode placement at proper positions and most of them are in clinical settings. Several other techniques are reported in literature which are based on PPG such as detection of atrial fibrillation using a wrist-worn device [2], respiratory rate estimation using respiratory sinus arrhythmia from photoplethysmography [3], conventional photoplethysmography (PPG) [4], pulseoximetry [5], spectrophotometry [6], photo-acoustic, nearinfrared spectroscopy (NIR), diffuse reflectance spectroscopy [7], laser Doppler anemometry, sphygmomanometry [8], and echocardiography (ECG) [9]. PPG sensors does not use any adhesive gels and only single sensor can be used to monitor heart rate and the oxygen level in the blood. Although different methods are offered for detecting arrhythmia, however, these methods are not very suitable for home use. Therefore, in this work our goal is to propose a reliable cheaper portable device for detecting arrhythmia frm short length data recording which can be used for patients who are in home after release from the hospital after having some history of CVDs.

II. Proposed System Architecture

The main objective of this project is to design a system that will measure heart rate as well as it will detect arrhythmia and alarm the user or the caregiver about any possible abnormality. The system consists of a microcontroller development board, a pulse oximetry biosensor MAX30102,

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a GSM module, an LCD display, and a buzzer. Figure 1 shows the block diagram of the proposed design.

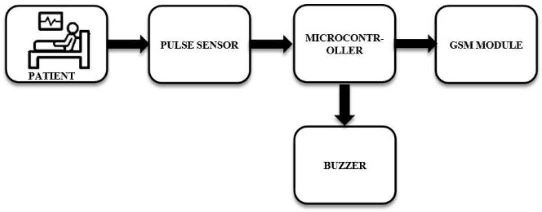

Fig. 1. Block diagram of the proposed system architecture

A flow chart below explains the working principle of arrhythmia detection and the steps a system maintains to function itself properly. The system is designed following some steps to regulate it properly.

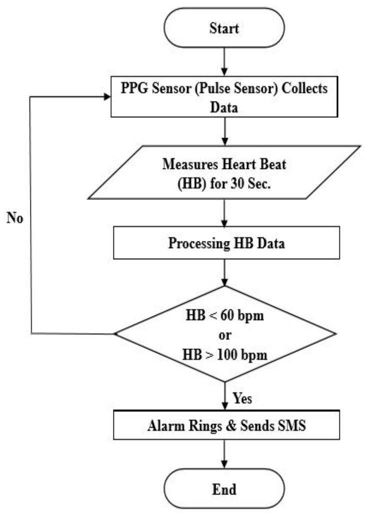

Fig. 2. System flowchart

A. Pulse Sensor: MAX30102

From some available PPG sensors in the market, MAX30102 is chosen for this project which is an integrated pulse oximetry sensor and heart-rate monitor biosensor module which contains internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection. The module operates on a single 3.3V power supply. It communicates through a standard I^2C-compatible interface [10].

B. Arduino Uno Rev3

The Arduino UNO Rev3 is a microcontroller development board. It is based on ATmega328 single-chip microcontroller. The Arduino UNO Rev3 has 14 digital input/output pins. Among them, 6 can be used as PWM (pulse width modulation) outputs. All those PWM pins are marked with a symbol, looks like this (~). There are 6 analog input pins available on the Arduino UNO board. These analog pins are able to read the analog signals from the sensors as well as covert analog signals into digital signals. On the power section one 5V, one 3.3V and three ground pins are available. Arduino UNO Rev3 development board also contains a few LEDs. These LEDs blink according to the different operations. One reset button and one DC power barrel jack are also available on the board. The reset button is used for restarting the code which is loaded to the board and the DC power barrel jack is used for powering up the board [11]. The Arduino integrated development environment (IDE) cross-platform application is used for the coding purpose of the board.

C. GSM Module: SIM800L

GSM (Global System for Mobile Communications) module is used for the purpose of communication between a mobile phone and a GSM system. The GSM module that used in the design is SIM800L. It's a low cost and small cellular module. This cellular module allows for making a voice call, receiving a voice call, sending an SMS, receiving an SMS and GPRS transmission. It has 13 pins but only 6 pins are used in this project for just sending SMS.

The module contains an LED status indicator. If the LED blinks every one second, it implies that the module is running but hasn't connected to the cellular network. If the LED blinks after every two seconds, it implies that the requested data connection is active and in the third case, if the LED blinks after every three seconds, it implies that the module is connected with the cellular network [12].

III. METHODOLOGY

The pulse sensor MAX30102 is made based on the reflective mode of Photoplethysmography (PPG). It is a light-based technology where the high precision light sensor is used to detect the volume of blood flow to understand the fluctuation in heart rate.

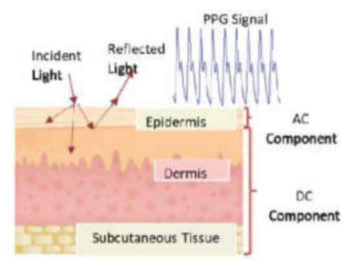

Fig. 3. The schematic of reflective PPG sensor [13]

To validate the reading of heart rate as found in the MAX30102 pulse sensor, we compared the heart rate readings of the subjects with KardiaMobile single lead portable ECG device simultaneously. KardiaMobile is a clinically validated device approved by FDA (Food and Drug Administration) [14]. The readings were taken simultaneously from both of the devices. Each reading was taken for 30 seconds duration. During the process of taking readings from the MAX30102 pulse sensor and KardiaMobile device for each subjects' ring, middle and index fingers were used. Both of the hands' ring and middle fingers were placed on the KardiaMobile device's sensor to take the readings from it. At the same time, the left hand's index finger was used to get the readings from the MAX30102 pulse sensor as shown in figure 4. Then data collected from both devices were compared the check reliability of the PPG sensor data. This is critical as incorrect heart rate readings form the PPG sensor will generate false alarms.

Fig. 4. Data recording technique

IV. RESULT

We collected data from 6 young adult university students after their consent to participate in this study. The Department of EEE of the university approved the study protocol following the ethical guidelines. The readings collected from our designed system were compared to the readings collected from KardiaMobile. We used KardiaMobile as our reference because this device is clinically validated and FDA approved.

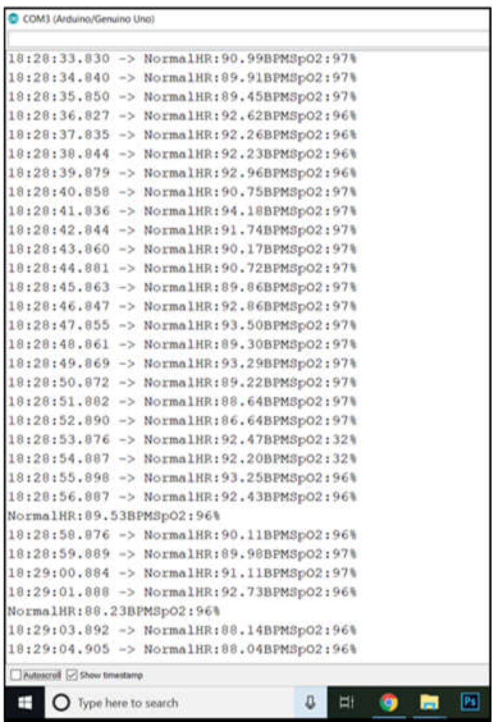

Fig. 5. Data from Arduino's serial monitor.

Figure 5 shows continuous heart rate and SPO_2 data are collected from MAX30102 PPG sensor using Arduino's serial monitor.

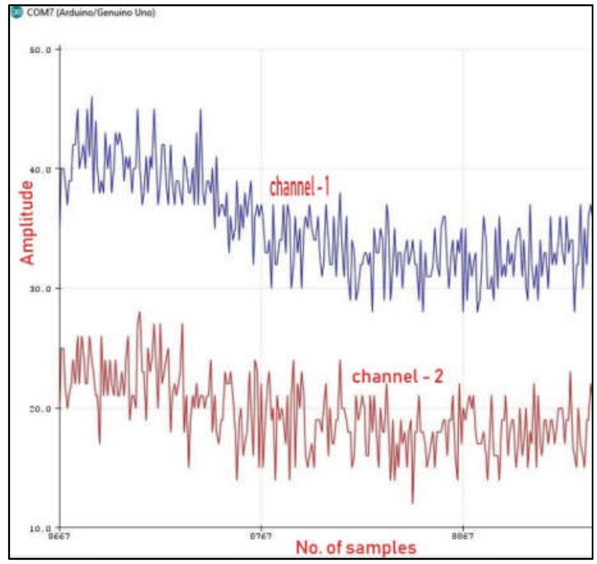

Fig. 6. Graph from the MAX30102 before placing the finger

The above graph (figure 6) is achieved from Arduino IDE's built in serial plotter before placing the finger on the MAX30102 PPG sensor and the figure 7 below is showing the graph, when the finger is placed on the MAX30102 PPG sensor. These graphs are generated using the raw data of MAX30102.

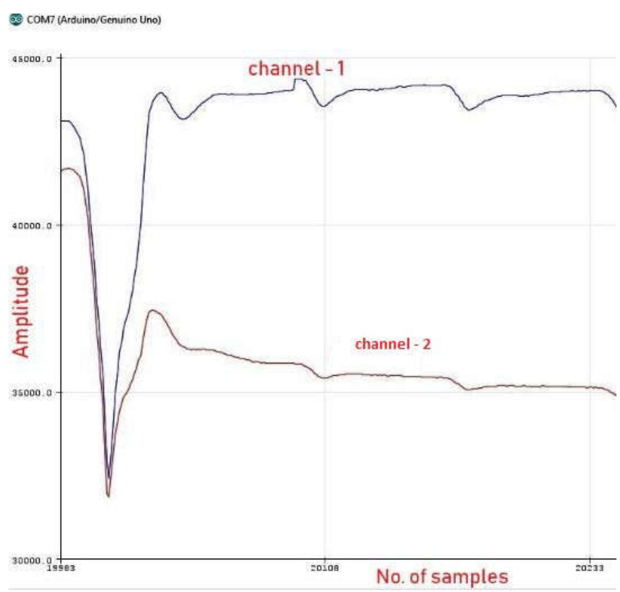

Fig. 7. Graph from the MAX30102 after placing the finger

In the following table, the data from both of the devices and error rates in our designed system is provided. The error rates were calculated using the following formula:

$$\% \; of \; Error = \frac{|Avg.Value \; from \; KardiaMobile - Avg.Value \; from \; MAX30102|}{Avg.Value \; from \; KardiaMobile} \; X \; 100\%$$

Table 1: Heart rate Data comparison between MAX30102 and KardiaMobile

Subject	Avg. Data from MAX30102 (BPM)	Avg. Data from KardiaMobile (BPM)	% of Error
1	78	79	1.266
2	93.34	94	0.702
3	104.69	105	0.295
4	102.81	103	0.184
5	103.27	102	1.245
6	85.75	84	2.083

From the data table it can be concluded that the results which are achieved from the proposed system is very close to the reference device KardiaMobile.

In the figure 8 below, it is shown that when any abnormality is detected the proposed system sends SMS to the concern using the GSM module.

Fig. 8. SMS received from the GSM module

V. CONCLUSION

Heart is the powerhouse of a body. Abnormal heart rate variation (i.e. Arrhythmia) is the root cause of other cardiovascular diseases (CVD) and is the detection of arrhythmia is the first sign of CVD. Therefore, easy to use low cost continuous and reliable monitoring of heart rate is required for healthy lifestyle. There are many devices available in the market to monitor the heart rate using PPG sensors, but some are not much reliable. PPG devices used in hospitals are expensive and not much suitable for personal use. Considering these matters, the proposed system is designed which is cheap and gives reliable heart rate reading as validated by a clinical grade portable ECG recorder(i.e. AliveCor KardiaMobile). Considering the data accuracy rate, this system might be used as a reliable device for heartbeat rate monitoring and arrhythmia detection.

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