Heart Beat Monitoring Device with an Optical Sensor

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Abstract: Heartbeat measurement system is an important issue to monitor the health condition of the human being. In normal resting, heart rate will be beaten between 60 to 100 beats per minute (bpm) depending on the age and physical condition. Through heart rate monitoring, several severe diseases can be discovered as preventive action of mortality; for instance, heart failure. The work within this study presents a developed heartbeat monitoring (HBM) using an optical proximity sensor to measure heart rate. It involves both the measuring on the fingertip and wrist for comparison. The proposed HBM detects the blood flow through the index finger, while the wrist measurement employs a pedometer in a smartwatch of Xiomi Mi Band 3. An HBM consists of an optical sensor with a light source and detector, a microcontroller module of NodeMCU ESP8266, and an organic light-emitting diode (OLED) display. The experimental tests measure the heartbeat with two conditions, such as no activity and after activity states; and with three different ages. The results indicate that proposed HBM is suitable for monitoring heart rate and obtained data that is possible to provide via mobile and internet applications.

1 INTRODUCTION

The new efforts for developing mobile medical devices with low production costs emerge to be a new focus in the biomedical field. Health monitoring is an important issue due to it can be discovered the diseases, physical condition, blood pressure, and heart health. The heart pulse can be monitored due to there is a change in the blood density affected by the heart pumping the blood to the whole body (Arulananth, 2017).

The most common sensor to detect the heart rate is pulse oximeter for measuring oxygen saturation in the blood. It illuminates the skin and measures the variation of the absorbed light (Jubran, 2015). It applies a near infra-red (NIR) light with a wavelength between 600 to 1000 nm; therefore the light can be penetrated the tissue (Mudeng, 2018). The designing of heart rate monitoring by implementing the different microcontrollers have been proposed for clinical trials. The combination of the proximity sensor, including a light source and detector with a signal extraction, pulse amplification, as well as display circuit, generated less time consuming and efficient cost in clinical pulse detection (Hashem, 2010). A measurement algorithm was applied in a microcontroller interfacing with analog to digital converter (ADC) and oximeter. Furthermore, this system utilized a field-programmable gate array (FPGA) to produce a control signal. With this system, the heart rate was detected in the normal state of human activity and had a low power dissipation (Keat, 2016).

A comparison of personal health monitoring devices has been conducted. A sensor with a chest strap, fitness tracker, smartwatch, and the photoplethysmography (PPG) on the smartphone feature was investigated to determine the highest accuracy for each device. The chest strap showed better accuracy due to the results were similar to the recognized medical devices. On the other hand, fitness trackers and the smartwatch had accurate results in a little physical movement. The low accuracy occurred when there were several movements, particularly on the wrist. The light intensity, in this case, will inaccuracy measure the density of blood due to the change of scattered and absorbed light through the skin. Fluctuation heart rate measurement by employing PPG occurred even in a little activity (Pessemier, 2017). The multi-measurement system, with an average of a set of data, is a proper option to be investigated for

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yielding precise results in the heartbeat sensing system.

In addition, a tiny pressure sensor but with efficient measurement and flexible shape developed to cope with comfortable and low-cost solutions in a mobile medical device (Shu, 2015). An idle heart rate, compared to the threshold heart rate, was presented to determine the heart condition using the collected data, which was stored in the database. The apparatus collected data from an analog sensor, then transfer them to the database via the internet (Farin, 2016). With new technology, the heart rate detection can be extracted by ultra-wideband (UWB) impulse radar without touching and placing the sensor around the body (Cho, 2018). The telemonitoring analyzing with heart rate sensor node was demonstrated for wireless body sensor networks (WBSNs) (Fouad, 2017), as well as continuous monitoring applied bandpass filter (BPF) based on light-dependent resistor (LDR) as a signal receiver and light-emitting diode (LED) as a light transmitter (Cohen, 2017).

In this study, we present the heartbeat monitoring (HBM) by implementing a non-invasive heart rate sensor with a wavelength of 609 nm involving an infra-red (IR) LED and a photodetector. The heart pulse, then processed by the NodeMCU ESP8266 microcontroller module. Based on the data obtained from the proposed device, we compare them with a pedometer in a smartwatch of Xiomi Mi Band 3 to verify the heartbeat in no activity and after activity conditions.

2 METHODS

2.1 Designed System

Estimating the heart condition through the placement of the sensor on the index finger is the aim of HBM. The sensor has embedded a filter and amplification circuits. Therefore, it can be interfaced directly to the microcontroller module. Also, it was provided in a sensor pair packaging composed of two primary components, namely an IR LED and a photodetector.

The low power IR LED is capable of penetrating the skin of the human body due to it has a wavelength of NIR. The NIR light penetrates inside the fingertip, hence some of the light will be scattered and absorbed. The blood pumping from the heart induces the variation in light intensity: the higher blood velocity, the higher heart bpm, and vice versa. The photodetector has to receive the light returning from inside the fingertip accurately. Figure 1 depicts the illustration of an index finger on the sensor to determine the heart rate.

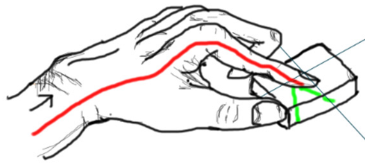

Figure 1: Illustration of HBM fingertip measurement.

The sensor counted the pulse when fingertip of the index finger touching well it. As can be seen in Figure 1, the blood pressure analog data in the artery representing by the red line will be converted to the heart rate in the embedded algorithm inside the microcontroller. This mechanism drove us to develop medical apparatus in HBM purposes. Besides, we discovered that ischaemic heart disease contributed to reducing the expectancy of men respecting women is 0.84 years (World Health Organization, 2019).

We designed the system with a pulse heart rate sensor, NodeMCU ESP8266 microcontroller module, and an organic LED (OLED) display to interpret an HBM device, as shown in Figure 2. As explained previously, the data from the sensor was transferred directly to the microcontroller, and there was an ADC processing with the counting processes of the raw data from the sensor to be a bpm. Next, the bpm and waveform displayed in OLED.

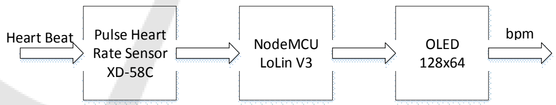

Figure 2: The proposed full system.

For detecting the heart rate, not all pins of NodeMCU was used. The sensor and OLED needed 3 volts for the power source, which was provided by two pins of NodeMCU. Additionally, only one pin in the microcontroller was necessary for connecting the signal (S) pin on the sensor to the A0 pin. SCL and SDA pins on OLED were interfaced to D0 and D1, respectively. Figure 3 shows the wiring diagram of HBM. We tried to design the measurement system with minimum electronic components for considering in the future work to provide efficient, low cost, tiny, portable, and mobile HBM instruments.

The used system can be modified in the data transmission due to NodeMCU is a microcontroller module equipped by the Wifi module. It enables to send the obtained data from the sensor to the planned database; therefore, not only the person who is worn, and this device can monitor the heart condition, but also the others.

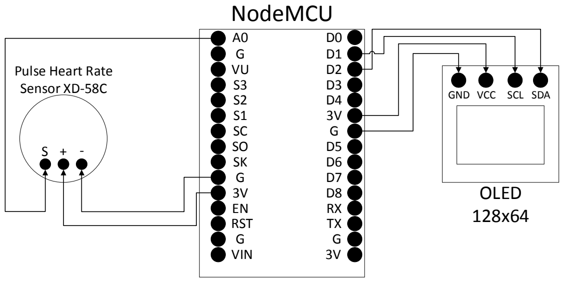

Figure 3: The schematic of HBM.

2.2 Algorithm

In this work, the software implementation was applied in the microcontroller. The flowchart for HBM is shown in Figure 4. First, analog data from

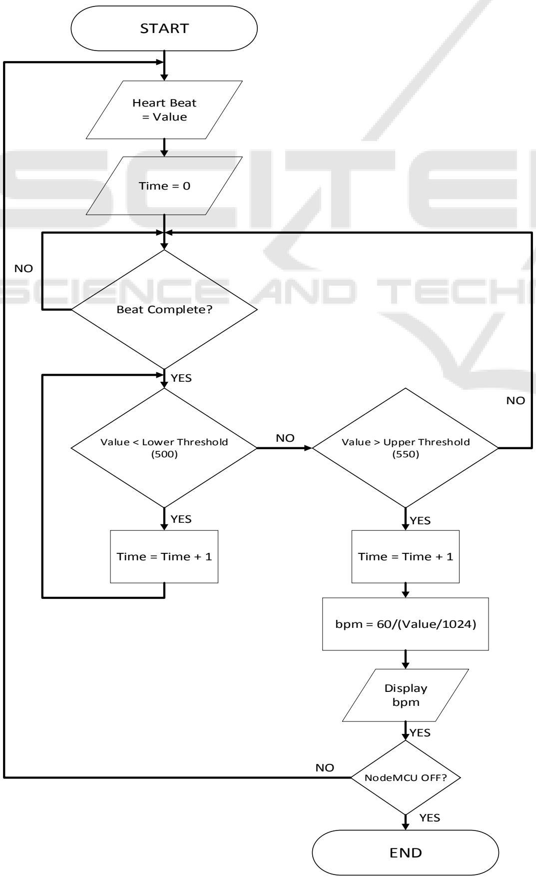

Figure 4: Flowchart for HBM.

The sensor will become the input for the microcontroller. The input indicates a heartbeat in a digital signal due to the role of ADC. We count the time was 0 for the initial condition. Then, we determined two threshold values, for instance, 500 as lower and 550 as upper thresholds, respectively. In each process, the algorithm will increase the time by one. The NodeMCU has 10 bit ADC or 1024 in decimal; hence, the digital data has to be divided by 1024. Afterward, bpm is obtained from $\frac{60}{digital\ data/1024}$. These processes are existed to measure the heart rate in our HBM.

3 RESULTS

We compared the designed measurement system with a smartwatch made by Xiomi Mi Band 3. The experimental set up conducted by no activity and after activity states. Further, we invited three volunteers to participate in the tests. An adolescent 14 years old and two adults with 20 and 49 years old were investigated using two devices simultaneously. Our HBM was placed on the fingertip of the index finger while the smartwatch was worn on the wrist. To ensure the test results, we monitored the heart beat for the right hand and left hand, alternately with three times data retrieval.

The HBM and smartwatch first put on the right hand in the no activity state. Then, we monitored the heartbeat and comparing two of a set of data from HBM and smartwatch. In the state of after activity, we restricted only in a little movement of ran on the spot for 10 seconds. Nonetheless, we allowed the resting times for 10 to 15 minutes to proceed to the next trial tests.

Figure 5 demonstrates the HBM system for measuring the heart rate. Figure 5 (a) depicts the sensing on the left hand with two devices on the no activity state. The left figure of Figure 5 (b) shows the index finger illuminated by the light source from the sensor. Moreover, the right figure in Figure 5 (b) indicating the measured heart rate is 82 bpm.

Table 1 shows the comparison between HBM and smartwatch results for 14, 20, and 49 years old with no activity and after activity condition on the right hand. The delta measurement of HBM and smartwatch maximum was 10 bpm with no activity occurred for 14 years old and 49 years old on the third data retrieval. The difference maximum measurement data was at 14 bpm for 14 years old after activity on similar data retrieval.

Table 1: Results of the right hand.

Activity	HBM			Smart Watch		
	Heart Rate 1 (bpm)	Heart Rate 2 (bpm)	Heart Rate 3 (bpm)	Heart Rate 1 (bpm)	Heart Rate 2 (bpm)	Heart Rate 3 (bpm)
None						
14 years old	71	70	69	73	70	79
20 years old	69	66	77	72	66	72
49 years old	82	64	84	88	64	74
After						
14 years old	74	86	88	74	86	74
20 years old	83	84	84	73	67	79
49 years old	94	74	87	98	64	84

Table 2: Results of the left hand.

Activity	HBM			Smart Watch		
	Heart Rate 1 (bpm)	Heart Rate 2 (bpm)	Heart Rate 3 (bpm)	Heart Rate 1 (bpm)	Heart Rate 2 (bpm)	Heart Rate 3 (bpm)
None						
14 years old	73	71	71	71	73	79
20 years old	71	68	75	73	68	74
49 years old	80	64	85	89	64	77
After						
14 years old	76	84	90	76	89	76
20 years old	85	87	86	78	69	79
49 years old	93	72	89	99	64	86

(a)

(b)

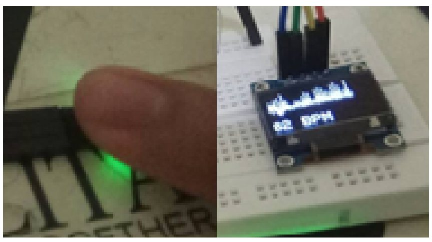

Figure 5: HBM hardware on a view of (a) left hand and (b) zooming in the index finger with showing bpm and waveform.

Table 2 shows the comparison between HBM and smartwatch on the left hand. The delta measurement of HBM and smartwatch maximum was 9 bpm with no activity occurred for 49 years old on the first data retrieval? The difference maximum measurement data was at 18 bpm for 20 years old after activity on the second data retrieval.

The considerable results were generated by the proposed HBM. The result variations were possible due to the sensitivity of photodetector. Nevertheless, it has a similar potentiality comparing with the commercial smartwatch.

4 CONCLUSIONS

In this study, a competitive HBM system has been proposed in measuring the heart rate. Farther, the future work is considered to improve the performance of proposed HBM through the packaging model, and data transmission system via mobile and internet applications wirelessly. According to the experimental results, they indicate that HBM is feasible to be a secondary wearable medical apparatus to check the data of heart rate for preventive action in the mortality caused by health problems, especially heart failure or disease. Over and under the results of HBM comparing to the smartwatch, results were occurred and could not be accurately determined; however, it remains effective for heart rate screening. Hereafter, the results can be initial progress for intensifying the development of HBM as the medical device.

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