Implementation of Heart Beat Detector and Analyzer Based on Arduino Microcontroller

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Abstract— **This paper proposes to implement the heart beat detector and analyzer based on Arduino microcontroller. Heart beat rate or pulse rate can be influence by many things including age, weight, physical activity, stress, illness, injury and medications the person are taking. The objectives of this work are to design a simple and easy heartbeat detector using optical sensors compared to ECG electrode and can be analysed the heart rate. For this project, pulse sensor is used as the sensor to detect the heart beat by put on the fingertip, earlobe or any capillary tissue on the body part, and the heart beat is processed by Arduino Microcontroller. It displayed the heartbeat waveform by the Pulse Sensor Amped Visualizer using processing software then analyzed for overweight and body posture categories person. The function to analyse these categories is to make sure that this heartbeat detector suitable to be used for medication device. The picture of heart beat waveform from visualizer will be send to the webpage using Ethernet Shield for monitoring. This detector produced the heart rate data of waveform, interbeat interval and beat per minute on visualizer for various person category that can be monitored on the web using Ethernet shield. The function to monitor on web is to help both the doctor and patient for medication procedure which the patient that need regular check-up for heart beat does not need to go to hospital and just send their heartbeat data to the web for monitoring by the doctor. This method cannot been achieved by using the ECG electrode procedure since the ECG device only used on the hospital and conducted by expertise.**

Keywords-Pulse Sensor, Arduino Microcontroller, Liquid crystal display (LCD), Ethernet Shield, Interbeat Interval (IBI), Beat per minute (BPM).

I. INTRODUCTION

Heart beats can be measured by the Electrocardiogram (ECG) that is usually being used today, but it requires the expertise to test on the patient where it must be supervised by a medical doctor and sometime involving the ECG technicians. It is because the ECG is a diagnostic tool that used to access the electrical and muscular functions of the heart. It used the electrodes that will be attached to the selected locations of the skin like arms, legs and chest. Areas that the electrodes will be placed such as the chest may need to be shaved [1]. Although the test does not takes long time to perform after the skin is cleared, the steps before the test is quite troublesome. So, the device system with simple and easy is required plus the data that detect heart beat can be monitored on the web by the doctor at the hospital.

There are a few work has been reported in designing heartbeat detector. One of the design is using Fingertip sensor[2]. The sensor design based on infrared LED as a transmitter and infrared photodiode as a detector which is placed side by side. Besides that, there are several microcontroller that can be used for designing the device such as PIC16F876. This microcontroller is used to collect and process data and then stores it in a serial EEPROM. The ECG signal is fed to the A/D converter within the PIC16F876 [3]. The latest technology used to detect heartbeat is using Piezoelectric Polyvinylidene Fluoride (PVDF) Polymer-based sensor patch. It based on the piezoelectric sensing mechanism to detect the pulsatile vibrations during heartbeat and also periodical deformations on the chest wall of human body during respirations [6]. Instead of using Fingertip sensor, Pulse sensor is used in this project due to more accurate than the fingertip sensor because pulse sensor is well-design plug and play heart rate compared to fingertip sensor and it also compatible with Arduino microcontroller.

The heart beat can be affected by many things including age, weight, physical activity, body position, stress, illness, injury and medications person are taking. At rest, heart rate is at its lowest. The muscle in the body is relaxed and function normally with less effort. The supine position have lower heart rate than the upright position[4]. When the body move from lying down to sit up, muscle are engaged to hold the body in an upright position and gravity is affecting blood flow. These will increase the heart rate. When the body is move from sitting to stand, the lower body engaged and it takes effort to pump the blood through the body and the heart beat increases again [5].

The objective of this project is to design and implement the device that detect the pulse of heart beat and analyse the heart beat rate. Besides that, to monitor the heartbeat from the web using Ethernet shield. The significant of this study is to analysis the heart beat rate by using the data that obtained from the designing of heart beat detector. It used the simple device which the sensor that been used is quite small so that it can be placed on the finger tip or ear lobe and also portable. Moreover, this device will help the doctor to monitor the

heartbeat condition from the hospital through web for the patient at the their house. Sometime the patient cannot go to the hospital for regular check up due to a few circumstances. This paper will concentrate to analyse heart beat that affected by body position and weight. The design of the heartbeat detector using Arduino microcontroller is presented and processing the data on the visualiser then monitored through web using Ethernet shield.

II. THE HEART'S ELECTRICAL SYSTEMS

The heart is the most important part in human system. Heart rate happened by electrical activity of the heart. The heart can be divided into two chambers which is upper and lower chambers. It has its own natural pacemaker which is called the Sinoatrial (SA) node. The electrical impulse begins in the upper chambers of the heart at the SA node located in the right atrium that set the rate and rhythm of the heartbeat. The electrical activity spreads through the walls of the atria and causes them to contract. In Atrioventricular (AV) node which located between the atria and ventricles, the electrical signal is delayed before it enters the ventricles. Electrical signal continue onwards to a network of specializes fibers, called the His-Purkinje system, to all parts of the ventricles. This contraction forces blood out of the heart to the lungs and body [7]. The SA node trigger another impulse and the cycle begins again.

III. HEART BEAT ANALYSIS

In heart beat, rate refers to how fast the heart beats. Normally, the Sinoatrial (SA) node generates an electrical impulse 60-100 times per minute. For the abnormal hearts beats, it called arrhythmias. There are several types of arrhythmias but most common types which is Bradycardia and Tachycardia. Bradycardia describes a heart rate less than 60 beats per minute while Tachycardia describes a heart rate faster than 100 beats per minute[8].

Rhythm refers to the type of heartbeat. The examples of heart rhythms include Normal Sinus Rhythm, Sinus Tachycardia, Sinus Bradycardia, Atrial Fibrillation, Atrial Flutter, Ventricular Tachycardia and Ventricular Fibrillation [9]. The figures below show the examples of Normal Sinus Rhythm, Tachycardia and Bradycardia output waveform.

Figure 1. Normal Heart Rhythm (Normal sinus rhythm)

Figure 2. Tachycardia

Figure 3. Bradycardia

The electrical activity of the heart are recorded by the ECG where it displayed as a series of electrical waves characterized by peaks and valleys. This ECG have two types of information. The first one is the duration of the electrical wave crossing the heart which decides whether the electrical activity is normal or slow or irregular and the second is the amount of electrical activity passing through the heart muscle which enables to find whether the parts of the heart are too large or overworked[10].

The ECG signal waveform is characterized by five peaks and valleys labeled by the letters P, Q, R, S, T as shown in the Figure 4 below. In some cases, another peak called U also included. The ECG analyzing system performance depends on the accurate and reliable detection of the QRS complex, as well as T and P waves. The P-wave represents the activation of the atria which is the upper chambers of the heart, while the QRS complex and T-wave represent the excitation of the ventricles or the lower chamber of the heart. The detection of the QRS complex is the most important task in automatic ECG signal analysis. Once the QRS complex has been identified a more detailed examination of ECG signal including the heart rate calculation, abnormality detection and signal calculating ECG intervals & self diagnosis can be performed[10].

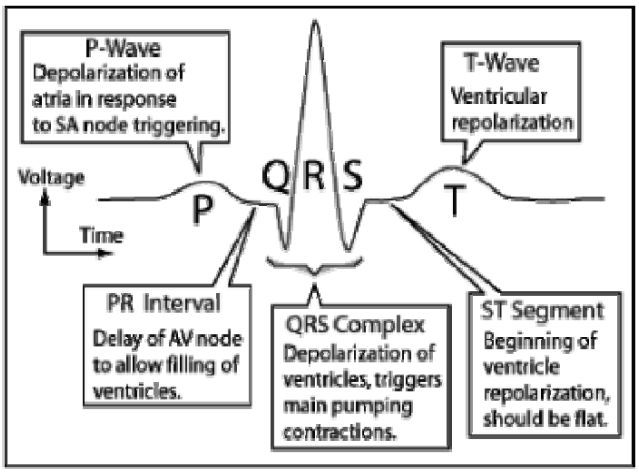

Figure 4. The normal ECG waveform

IV. SYSTEM OVERVIEW

A. Block Diagram

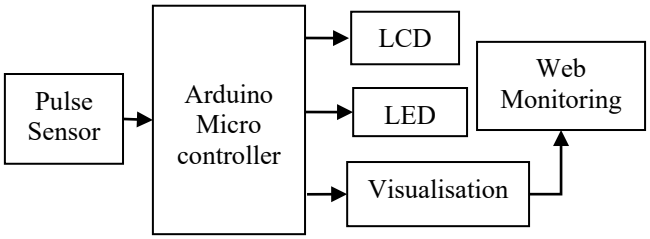

Figure 5. Block Diagram

Pulse sensor is used as the input to the arduino microcontroller. This sensor is in analog input. The output of the arduino microcontroller are LCD display, LED and Visualisation. LCD will display the number of beat per minute (BPM) and interbeat interval (IBI) while each of heart beat will synchronized with the LED. Every heart beat will turn on the LED. The data from arduino are sent to visualize by using Processing 2.0b8 software. The IBI in processing visualiser defined as Inter Beat Interval where the time taken for one beat to another beat and it is operating by interrupting to Timer2 with a 500Hz. The processing software visualised the heart beat waveform, IBI and BPM. This displayed visualiser can be saved as a picture. Then, it will be copied to the SD card and inserted into ethernet shield and the picture will be monitored on the web.

B. Pulse Sensor Amped

Figure 6. Pulse sensor

Pulse Sensor Amped is advanced from the normal pulse sensor for the Arduino microcontroller. This sensor adds amplification and noise cancellation circuitry to normal pulse sensor hardware. It is faster and easier to get reliable pulse reading. Besides that, it works with either a 3V or 5V arduino. This is the side that makes contact with the skin. This pulse sensor works based on the signal of an LED. On the front has a small round hole, which is where the LED shines through from the back, and there is also a little square just under the LED. The square is an ambient light sensor. The LED shines light into the fingertip or earlobe, or other capillary tissue, and sensor reads the light that bounces back. The back of the sensor is where the rest of the parts are mounted. The LED used is a reverse mount LED.

C. Arduino Visualiser

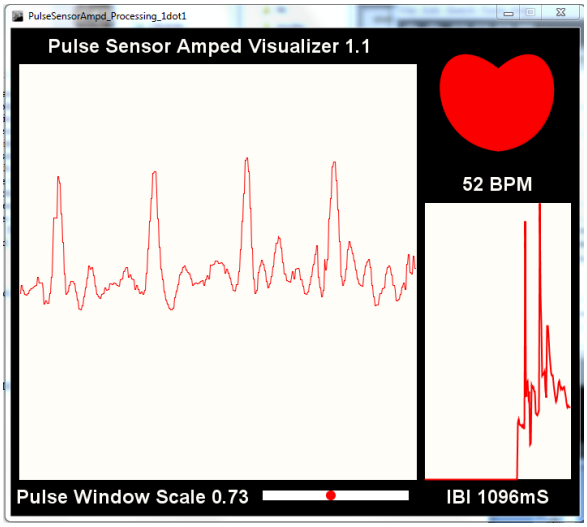

Figure 7. Pulse sensor Amped Visualizer

Pulse Sensor Amped Visualiser programmed by using Processing 2.0b8 software. The processing software executed the programming of heartbeat from the Arduino serial ports and the data from Arduino are transferred into processing for visualisation as shown in Figure 7. The visualizer show heart beat waveform, BPM and IBI value. The graphic of heart will beat once a pulse is detected and show the beats per minute rate below. The visualiser are limited to 200 BPM because logically there is no other person will surpassed that value. IBI defined as inter beat interval and it is operating by interrupting to Timer2 with a 500Hz sampling rate frequency.

D. Ethernet Shield

Figure 8. Arduino Ethernet Shield

The Arduino Ethernet shield are used by mount it on top of Arduino Uno board function as connecting the Arduino to the internet. The cable to connect to the network on this ethernet shield is RJ45 cable or known as Local Area Network (LAN) cable. This Ethernet Shield based on the Wiznet W5100 ethernet chip which provides a network (IP) stack capable of both Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). There is an onboard micro-SD card slot used to store files serving over the network. In this project, ethernet shield used to monitor the heart beat waveform picture on the webpage that been copy manually into SD card memory from the computer.

V. METHODOLOGY

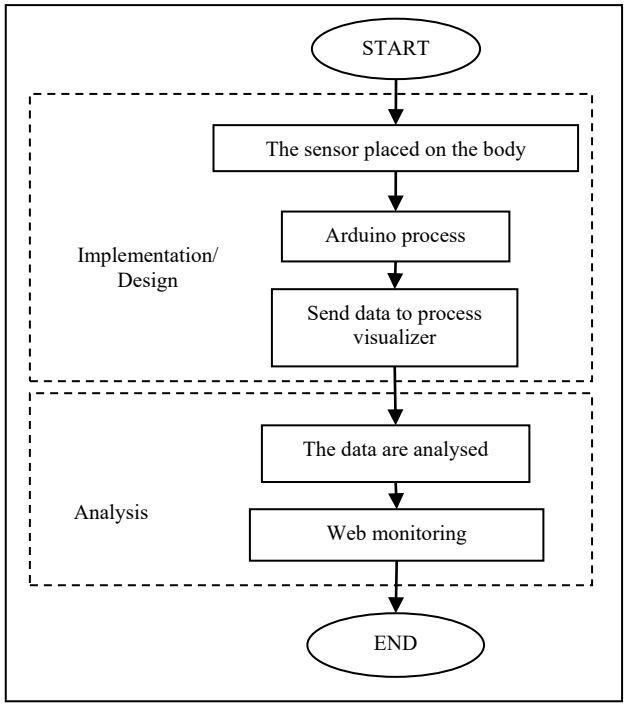

Figure 9. Flowchart of methodology

At first, the sensor are placed on the human body such as finger tip or ear lobe due to its small size and can be clipped. Then, the coding are made for the sensor to detect the heart beat rate using Arduino microcontroller. The data of heart beat such as Interbeat Interval (IBI), pulse with heartbeat waveform and beat per minute are visualised using Processor Software and show in the computer. Then, the waveform can be capture by pressing 's' on the keyboard to save the current waveform picture in jpeg file type. The picture will be copied to the SD card and inserted to the ethernet shield for web monitoring. Before insert the SD card into ethernet shield, the picture file of heartbeat waveform are renamed because the name saved from the processing is random number. In the webpage source code, the name for picture of heartbeat waveform are set as Heart, so the picture that been saved will be renamed as Heart. In the browser, IP address for ethernet shield had been set which is 192.168.0.101. So, the user will enter the IP address to access the page to show the heartbeat waveform picture that been copied into ethernet shield. Then, user will be requested to enter the ID number before get access to the heartbeat picture.

There are several category of sample person heartbeat that will be analysed which is weight and body posture to see the different heartbeat rate between these persons.

The IBI in this heartbeat are used to get the BPM value as shown in equation (1). IBI is known as the time taken for one beat to another beat in millisecond unit, so to get the BPM values, it will time by 60 for a minute.

$$BPM = \frac{1\,beat}{IBI(ms)} \times \frac{60s}{1\,min} \quad (1)$$

Theoretically, the equation (1) shows that the higher IBI, the lower BPM values.

For analyzing method, the weight analysis use BMI which is stand for Body Mass Index are included. This BMI used to see the weight of the person whether that person is overweight or not. The equation of BMI are shown as below and the categories for different BMI are shown in Table 1.

$$\text{BMI} = \text{Weight(kg)} / [\text{Height(m)} \times \text{Height(m)}] \quad (2)$$

TABLE 1. BODY MASS INDEX (BMI) CATEGORIES

BMI	Description
Less than18.5	Underweight
18.5 to less than 25	Ideal
25 to less than 30	Overweight
30 or more	Obese

The method for taking the data recorded on the samples or persons by place the sensor on their finger which is known as among the sensitive part on the body. The processing visualisation show the current heartbeat to monitor the waveform whether in good signal or not. Several picture are captured in visualisation after make sure that the waveform is in good signal and then only the best result is recorded as shown in Table 2.

As for the second assignment to analyze position of body, two person are used for the samples that having BMI value 20 and 25. The samples need to lying down first and the heartbeat detector recorded the BPM. After the BPM value is steady that shown on the heartbeat detector display, the data are recorded. Then the samples are told to sit and the BPM value are taken. Lastly, the samples need to stand from sitting position and his BPM are taken. All the data are recorded as shown in Table 3.

VI. RESULT AND DISCUSSION

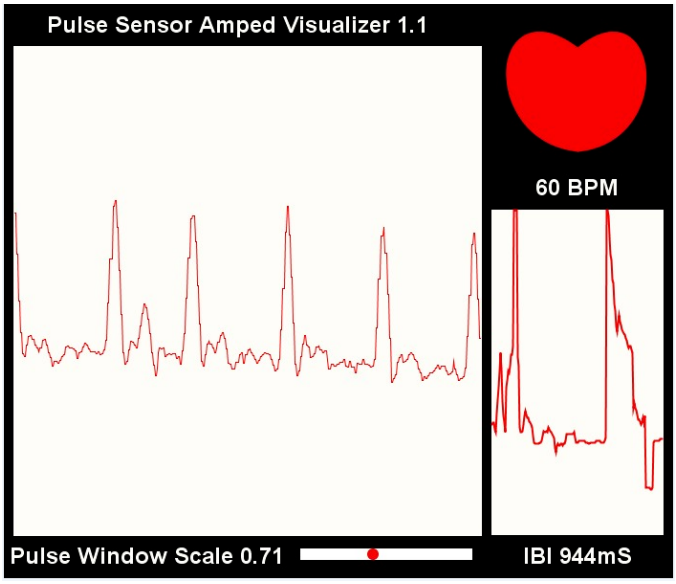

Figure 10. Pulse Sensor for normal person

Figure 11 shows the waveform from the normal person that display from visualisation process. The sensor is put on the fingertip of the person. The result show that his heart rate is low which is 60 BPM. This is because his heart beat is not need much activity due to rest condition. As can be seen in the

Figure 11, the peak is known as QRS complex in ECG waveform show the time when heart is trigger or beating. The heart beat waveform show some distortion because the sensor is too sensitive. Even on the slight move it will give much distortion on the waveform. For the IBI, it take 944 millisecond for his heart beat to another beat.

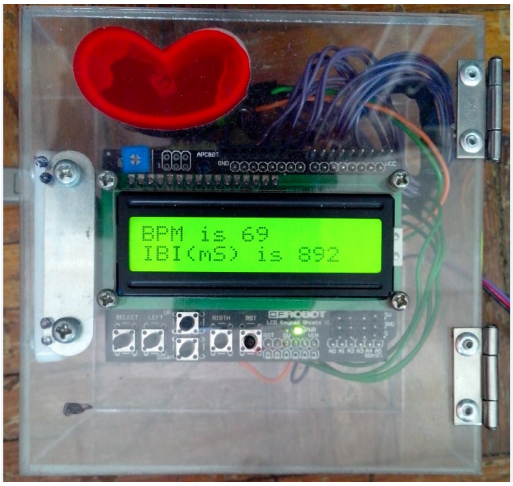

Figure 12. LCD Display on heartbeat detector

LCD will show the value of BPM and IBI and updated every beat of heart. As shown in Figure 12, the sample of normal person are taken and show that his BPM is 69 and his IBI is 892 ms. The value will change if there have a movement of the sample because the pulse sensor is quite sensitive. The value on LCD display for both BPM and IBI are same with the value in visualizer processing.

As for adults person, normal heartbeats are about 60 to 100 times per minute. In this result, the normal person for different weight had been focused to analyse their heart beat using Heartbeat detector. Eight person had been test for the sample during rest condition and the data are shown as Table 2 below.

TABLE 2. DATA FOR OVERWEIGHT CATEGORIES

Person	BMI	IBI(s)	BPM
A	25	508m	83
B	22	788m	71
C	27	714m	94
D	20	944m	60
E	24	596m	86
F	21	802m	78
G	20	794m	77
H	20	660m	82
I	21	812m	74
J	24	562m	78
K	22	836m	75
L	26	518m	86
M	22	822m	72
N	21	783m	77
O	20	819m	64

From fifteen person that been test as samples for this heartbeat detector, there are three persons that categorizes as overweight which is above 25 BMI. The data shows that the overweight person have a higher heart beat and for the less weight person vice versa. This is because the overweight people heart will work harder to provide energy required to function in body system compared to less weight person. However, Adam got quite higher BPM though he is not including in overweight person. This is because his BMI are almost in overweight group due to this person have huge body size.

Since there are no specific range of heartbeat for normal adult person from 60 to 100 BPM, we assumed that the heart beat above than 80 is higher and below that is lower. From the Table 2, only E and H samples from 15 samples have higher heart beat even they are not overweight person. So, they are categorized as the Error Sample. The calculation of the accuracy for this heart beat detector are show as below.

$$Accuracy\ Device\ \% = \frac{Total\ Sample - Error\ Sample}{Total\ Sample} \times 100 \quad (3)$$

$$= \frac{15 - 2}{15} \times 100$$

$$= 86.66\%$$

Accuracy of this device in this overweight categories analysis is 86.66%.

TABLE 3. DATA FOR DIFFERENT BODY POSTURE

Person	BMI	Lying (BPM)	Sitting (BPM)	Standing (BPM)
1	20	55	64	72
2	25	64	72	89

The second data for different position of the body is shown in Table 3. The sample is the normal adult person. The lying position recorded for the first person with 20 BMI shows the lowest heartbeat which is 55 BPM due to relaxing position and the heart use less energy to pump the blood through the body. Heartbeat increasing when body move from lying to sit as shown in the Table 3 which is 64 BPM. This is because the heart need more energy to function because of the movement and the same goes to the change position from sitting to stand up which is 72 BPM. The second person with 25 BMI also show the same increasing heartbeat as the first person from lying down with 64 BPM to sit with 72 BPM then stand up with 89 BPM. This data shown that heart need to pump the blood for energy when the body move from relaxing state as lying down to sit and same goes for standing from sitting.

VII. CONCLUSION AND RECOMMENDATION

In this paper, the implementation of heartbeat detector achieve the objectives. The pulse sensor will be detect the heart beat rate on the selected area. So, the device design are perfectly worked on the real sample. The heart beat rate are processed by arduino microcontroller and visualised on the computer. The picture of current heartbeat can be saved and send to the web for monitoring for the user or doctor. So, the data will be monitored on the web using Ethernet shield. The heartbeat rate for person of more weight is faster because the heart will have to work harder to provide the energy that the body require to function. For the body position analysis, the heart beat is increased when the body is move from laying down to sit up and increase again when the body move from sitting to stand. However, this pulse sensor have some

limitation where for the patients that have thin skin tissues give more precise data compared to person that have thick skin tissues. This is because the light emitted from the pulse sensor cannot effectively penetrate to the thick skin tissues.

For the recommendation, this project can be upgraded by make the live monitoring system from the web. Since this project is not live monitoring system, so this idea will help the doctor make the regular check-up for his patient more efficiently. Besides that, the IP address that been using for ethernet shield is can only be seen by the local web browser which mean this IP address cannot been access from other network besides the home router network. So, port forward is the best way to overcome this problem and need to be registered so that the IP address can be accessed by other network user.

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