# Heart Rate Monitoring and Alert System Using Smartphone

By

Mohamad Syarmie Faizlin bin Anuar
16166

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronic)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____________________
(Dr Nasreen Badruddin)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2016

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMAD SYARMIE FAIZLIN BIN ANUAR

## ABSTRACT

Heart disease like arrhythmia need continual long-term monitoring. For example, in emergency at home, where the patient is unable help themselves or seek help, there is a need for long distance health monitoring for early and faster assessment for treatment. This project presents a remote monitoring system for monitoring the irregularity in heart rate, which enables real-time monitoring for the cardiovascular diseases (CVDs) patient. The system utilizes Photoplethysmography (PPG) sensor to obtain the pulse reading. The sensor is non-invasive where pulse reading is taken from the finger. The microcontroller is used to receive and process the signal. When irregularity in heart rate is detected, the microcontroller will send data to a smartphone using Bluetooth. A mobile application is developed to receive the data and to send out an alert in the form of a text message to another mobile phone. The alert is successfully sent to the specified recipient such as medical doctors or next of kin in the emergency which contain the details such as heart rate information and GPS coordinate. Evaluation on the functionality of the device shows that the developed device can reach accuracy of 97.50%, precision of 96.55%, sensitivity of 99.29% and specificity of 91.67%.

## ACKNOWLEDGEMENT

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**TABLE OF CONTENTS**

**LIST OF FIGURES**

**LIST OF TABLES**

# CHAPTER 1
# INTRODUCTION

## 1.1 Background Study

Cardiovascular diseases (CVDs) are the cause of fatality to approximately 17.5 million people in 2012 globally which represents 31% of global deaths [1]. CVDs are the main causes of death [2], more people die annually from CVDs compared to other causes. 7.6 million deaths are due to coronary diseases and one of the common causes of death are due to arrhythmia. In addition, most patients are from the older people, constituting half of the CVD patient population [3]. The main factor is due to increased size of aged population. In a research [4], the incidence of CVD is three times higher in older person compared to younger patients.

Arrhythmia is one of the CVDs, a condition where the heart beats is irregular. Type arrhythmia rhythm are tachycardia, a condition where the rhythm of the heart is too fast and Bradycardia where heart rhythm is too slow. If tachycardia or bradycardia continuous for long period of time, it can cause the heart to pump less blood to the whole body, which can result in damaging vital organ like brain, heart, lung et cetera. An example of fatal form of arrhythmia is ventricular tachycardia [5], if it is not treated immediately, the victim might expose to injury and even death. Heart rate is the important parameter in classifying whether the heart beat is irregular or normal.

Heart rate is the number of heart contracting in a period of time, defined in beats per minute (bpm). The measurement of heart rate is important in the human cardiovascular system. The rate of heartbeat depends on several factors, which include age, body size, body movement, heart condition medication and even temperature. The resting heart rate for a normal person is 60 to 100 bpm for adults and 70 to 100 bpm for children. However, a person who is fit like an athlete can have a low resting heart of 40 bpm.

## 1.2 Problem Statement

Some disease and disorder such as heart disease require constant monitoring to enable fast response if incident occurs. For instance, ventricular tachycardia is one of the type of arrhythmia that needs continual long-term monitoring. In emergency at home for example, where the patients could not help themselves or seek help, there is a need for long distance health monitoring for early and faster response for treatment.

## 1.3 Objective and Scope of the Work

### 1.3.1 Objectives

The main objective of this project is to design, implement and testing a real-time heart rate monitoring device using Photoplethysmography (PPG) sensor to detect irregularities in the heart rate. When irregular heartbeat is detected, the system will automatically send out an alert in the form of text message using mobile GSM network.

The sub-objective of this project includes:

1) To develop an android-based mobile application to receive data from the sensor and transmit data or alerts using the mobile network.
2) To determine the location information of the patient and include it in the alert.
3) To validate the output data of the designed system.

### 1.3.2 Scope of the Project

The scope of the project will

1. Detect arrhythmic pulse using PPG to be used as wearable device for CVD patient.
2. This project does not include designing PPG sensor; hence, PPG sensor available in market is used.
3. The designed device will detect ventricular tachycardia and categorized the detected signal as irregular heart rate.
4. The pulse signal acquired from the sensor is analyzed, which encapsulate the decision-making in determining whether the recorded heart rate is normal or irregular.
5. This project will establish communication between the sensor and the mobile phone.

## 1.4 Feasibility of the Project

The project requires the student to design, implement and test a real-time heart rate monitoring device within the two-semesters of Final Year Project 1 and Final Year Project 2. Based on the Gantt chart, the project is achievable during the period of the two semester. The resources needed to complete the project is sufficient because the information needed can be obtained online. Besides that, the components needed for hardware implementation and testing can be easily acquired online or can be accessed in university's facility. The most important part to ensure the project is feasible is the ability of the author in term of knowledge and skills needed to accomplish the project requirements. Since the project mainly deals with programming, programming knowledge and skills are vital for a successful project implementation. Thus, the project can be achieved within the scheduled time.

# CHAPTER 2
# LITERATURE REVIEW AND THEORY

## 2.1 Arrhythmia

Arrhythmia is a condition of abnormality of the heart's rhythm. The heart rhythm is irregular, faster or slower than the normal heart rate. Two main type of arrhythmia is atrial arrhythmia and ventricular arrhythmia. Example of atrial arrhythmia is atrial fibrillation and atrial flutter while ventricular arrhythmia includes ventricular tachycardia, ventricular fibrillation and premature ventricle contraction.

Among the types of the arrhythmias, ventricular tachycardia (VT) and ventricular fibrillation (VF) are considered as a fatal form of arrhythmia which cause most of most of the sudden cardiac arrest in USA [6]. VT refers to heart beating for more than 100bpm (mostly from 110-250bpm) with at least 3 irregular HR in row. VT is characterized as a fast, regular beating of ventricles that can last for only few second or much longer. VT often does not cause harm, however episodes of VT which last for more than 30 second [7] can turn into more serious arrhythmia that is ventricular fibrillation (VF). VF is rapid, uncontrolled and irregular contraction of ventricles. In VF, ventricles merely quiver and does not contract as normal. Thus, heart will not pump enough blood to the body and this condition can immediately cause cardiac arrest. ECG waveform of VT and VF is as shown in Figure 2.1 and 2.2 respectively.

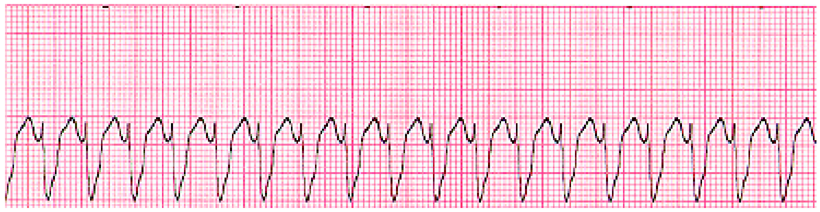

Figure 2.1 ECG waveform for Ventricular Tachycardia

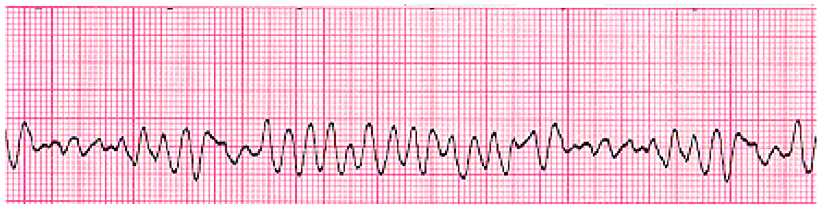

Figure 2.1 ECG waveform for Ventricular fibrillation

## 2.2 Recording techniques

Various research is conducted to monitor the wellbeing of CVDs patient. Heart rate monitor generally monitor the vital parameter of CVDs patient that is heart rate (HR). There is wide variety of heart rate monitor that has various functionality. In general, heart rate can be monitor by Electrocardiogram (ECG) and Photoplethysmography (PPG).

### 2.2.1 Electrocardiogram (ECG)

ECG is a test by placing electrodes on body to detect any electrical activity of heart. ECG signal consists of three complex patterns that is P-wave, QRS complex, and T-wave as shown in Figure 2.3 [8]. The heart pumping action is controlled by the electrical impulse where the electrical activity inside the heart can be translated into the P-wave, QRS complex, and T-wave. P-wave represents the atrial depolarization and the ventricular depolarization are represented by QRS complex. The rapid repolarization of ventricles reflects the T-wave.

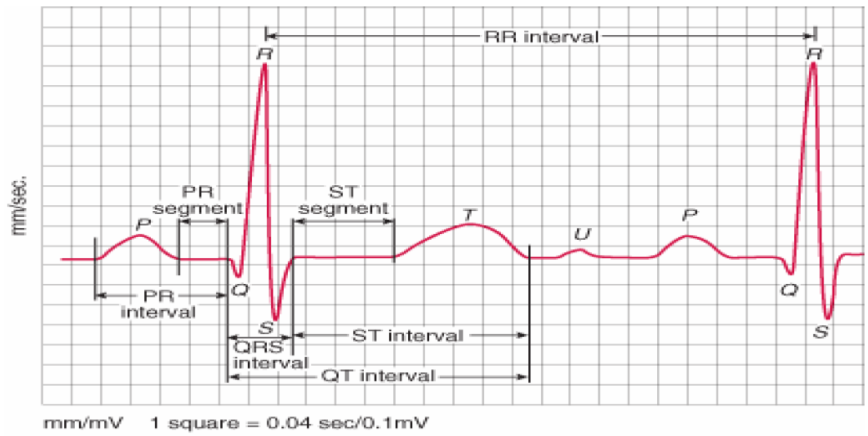

Figure 2.2 P-wave, QRS complex and T-wave wavelet

ECG helps in the medical field because it provides a unique and periodic signal to identify the activity in the heart. Various research has been conducted to analyse the signal generated in the heart and uses the signal to detect any abnormal activity in the heart. The work done in [5] uses Pan Tompkins Algorithm to determine the QRS complex to find heart rate for arrhythmic pattern caused by disorder in heart's electrical impulse.

Other work presented by [9] acquired the ECG waveform using Matlab's LabVIEW for analysis and arrhythmia detection. Rashed et al. in their work [6] used Fast Fourier Transform (FFT) to extract information from the ECG signal for detection of myocardial infarction which is also known as heart attack.

The implementation of ECG requires the use of electrodes, which necessitates the use of gel, sticky pads or paste. Therefore, many researches has been done to remove the necessity of using "wet" ECG sensor. In work done by Chulsung et al. [10] a sensing device from Quarsar which does not require skin preparation. In other work by Meiran et al. [11] uses conductive fabric to build electrode for ECG recording. The work presented in [12] introduced equipment to monitor abnormal rate of heartbeat. Their design employs electrocardiogram (ECG) chest belt to receive electrical impulses from heart and transmit the signal to receiver and the data captured are processed and analysed.

### 2.2.2 Photoplethysmography (PPG)

The change of blood volume in blood vessel are called photoplethysmography (PPG) [13]. Blood flows to capillary vessel and the flowing action is the major constituent of change of volume. Typically, pulse oximeter is used to measure the change of blood volume in the body tissue. Pulse oximeter has a light-emitting diode (LED) to illuminates the skin and a photodiode (PD) will detect the reflected light, which represents the change of volume in blood. The irradiated light from the LED, usually green light, (wavelength: 400-500nm) is absorbed by the oxygenated haemoglobin and the reflected light is received by PD as shown in Figure 2.4.

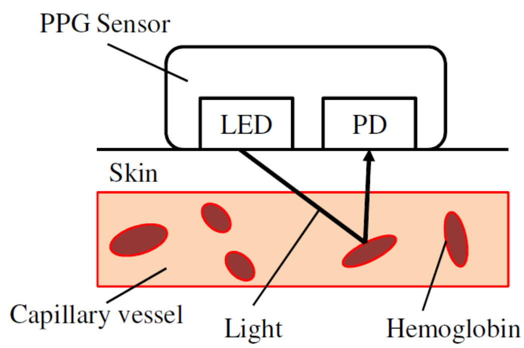


Figure 2.3 Operation of PPG sensor in reflectance mode

The main theory of pulse oximeter is the measure of light absorbed through the human tissue at a different wavelength. The variability of oxygen saturation in the blood causes the amount of light absorbed to be variable. In the blood vessel, the concentration of the oxygenated haemoglobin ($HbO_2$) and deoxygenated haemoglobin (Hb) are used in measuring oxygen saturation level whereby Hb absorbs more light compared to $HbO_2$. The amount of light transmitted that is the light that is not absorbed is measured. The signal produced fluctuated with time due to the different between absorption ratio as shown in Figure 2.5.

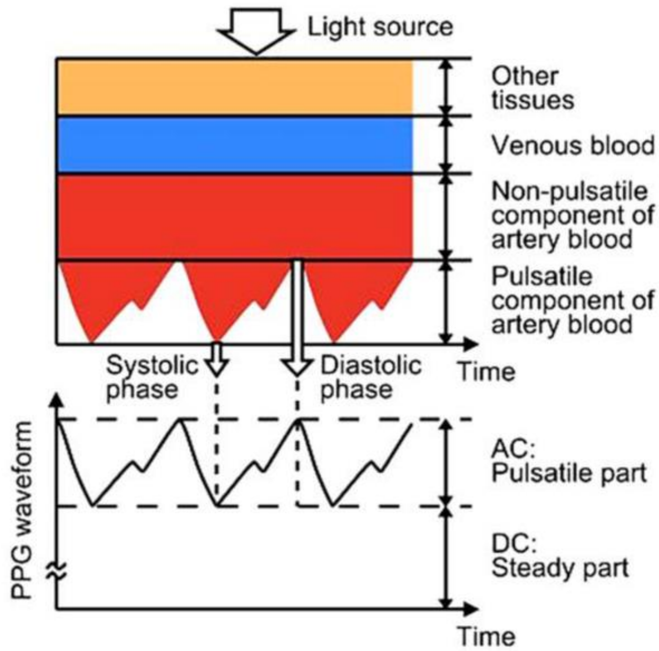


Figure 2.4 Light absorbance of tissue components

In each heartbeat, the blood flows to capillary vessel and the flowing action is the major constituent of change of volume. Hence, the periodicity of PPG correlate to that of ECG where the period corresponds to the HR [14]. Previous work as presented by [15] and [16] and employ Photoplethysmography (PPG) to extract pulse signal from finger which is equivalent to the heartbeat signal.

Monitoring the HR using PPG signal has some advantages over ECG such as minimized cost and simpler hardware implementation. However, motion artefact (MA) contaminate the output signal of the PPG in the form of noise due to placement of PPG sensor on the finger, wrist or neck. MA is mainly due to leaking of ambient light between the gap of PPG sensor and surface of the skin where the gap can easily enlarge during body movement. Therefore, to obtain an absolute accuracy compared to ECG is very challenging.

## 2.3 Comparison between ECG and PPG

Measures of heart rate are widely used for various purpose that requires an accurate and reliable method to measure it. The most common method used is via ECG, which is widely available and non-invasive. As presented by [10] and [11] where the ECG sensor used is not only non-intrusive but it does not require the use of conventional electrode to obtain the ECG signal. Nevertheless, ECG requires complex recording and analysis as for example in work done by [8], utilize Discrete Fourier Transform (DFT) from Fast Fourier Transform (FFT) Model to analyse the signal. ECG signal produces P-wave, QRS complex, and T-wave, therefore, correct analysis must be done to distinguish the different pattern that require a complex analysis.

PPG on the other hand is also non-intrusive method but what favor PPG over ECG is the simpler analysis. This technique measures pulse waveform that is proven a practical basis to measure heart rate. Instead of measuring the electrical activity of the heart, PPG measures the change of saturation of oxygen in blood where signal variation is produced. The variation of the signal is used to measure the heart rate as the work done by [16], [17] and . The reliability of the signal produced by PPG is comparable to ECG signal as shown in research by [14] and [18] proved that PPG technique is a practical alternative to ECG. However, PPG technique suffers known drawback, which is motion artefact caused by body movement during the measurement. Various research is done to remove this main disadvantage as in work by [11] and [14].

## 2.4 Microcontroller

In determining the HR, microcontroller is used to calculate the number of pulses detected by the sensor and process the acquired data. Microcontroller consist of Central Processing Unit (CPU), memory, and various peripheral device. Typical function of microcontroller are to read incoming data, perform calculation on the received data and control the environment based on the calculated data. In the work done by [12], Phillips P89V51RD2 IC is used for data processing, it contains algorithms for HR calculation and HR abnormality algorithm. However, the circuitry requires external circuit for clock generation, which would consume more space on the overall design.

Ramlee et al. presented a low-cost heart monitoring device, thus to attain the low-cost device, PIC 16F877A microcontroller is used where it is much cheaper compared to ATMEL microcontroller [16]. The microcontroller is connected to a heart beat circuitry, LCD, and Bluetooth transmission modem. In another work [18], the author use Arduino pro mini as their main processing unit due to the number of pins offered i.e. 14 digital pins and 8 analog pins. Besides that, it is relatively small board, which suit their project objective i.e. to build a wearable pulse oximeter. The microcontroller functions control transmission of data, LCD, Bluetooth transceiver, control analog to digital conversion and calculation of input data.

## 2.5 Telemedicine

One of the important features of health monitoring especially heart rate monitoring is to employ remote patient monitoring. This device operates by collecting and transmitting data to a monitoring hub for display, analysis, and record. Telemedicine is one of the methods used to provide clinical health care and even emergency situation at a distance which would improve medical services that would not only limit to urban area but also in distant rural communities.

Telemedicine allows medical device like heart monitoring device to send data wirelessly through communication such as Bluetooth [5] [16], [19], GSM modem [20], [21], monitoring system using ZigBee module [21], [22] et cetera. Today, health device based on telemedicine interestingly growing as increased awareness towards health. It also due to the increased in incident of sudden death in home or area far from medical facility. This incident may happen to anyone, thus, continuous monitoring is important especially to the elderly and patient with cardiovascular disease.

Work done by [16] is regarding on PPG imaging using Bluetooth technology for wireless data transmission to computer. Their monitoring device consist of two part, which is the sensing unit and computer unit. The sensing unit that consist of sensor, microcontroller, and Bluetooth transceiver. Computer side receive the transmitted signal using Bluetooth receiver, communication module and displayed the result in using Graphical User Interface (GUI). The transmission range between the Bluetooth transmitter and receiver are between 15m – 20m only that is only for short distance remote monitoring thus this system are not suitable to be implemented at home.

In other work by Anh, microphone detect the sound of heartbeat, which then boost received signal and filtered. The signal are sampled and fed to the microcontroller and transmit wirelessly to the ZigBee module for monitoring purpose [22]. Hou presented remote HR monitoring system using GSM modem [20]. Microcontroller records the heart rate from conventional ECG HR sensor. If the HR exceed pre-defined threshold value, microcontroller will control GSM modem to send data in form of text message to certain personnel such as specialist.

# CHAPTER 3

# METHODOLOGY

## 3.1 Project Flow Chart

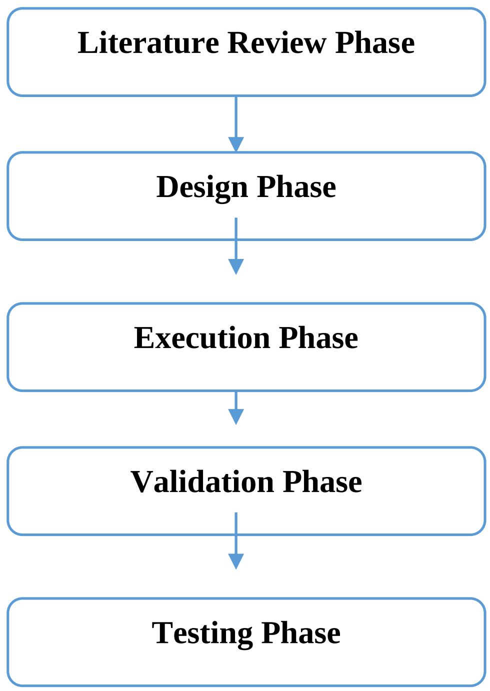


Figure 3.1. Project flow chart

The project undergoes the stages as shown in Figure 3.1. In the first stage, extensive study on the existing research paper which is related to the scope of the project is thoroughly done in the literature review phase. The next phase is design phase, whereby, based on the data gathered during literature review phase, the possible method and procedure for project implementation is specified. After taking consideration of design feasibility such as functionality, cost, hardware specification and etc., the prototype is built based on the design outlined. Each of the component are tested and later test the functionality of the prototype. For example, heart rate sensor is tested working before assembled into a complete sensing unit together with the microcontroller. The result obtained from a working prototype is verified by using the available heart rate monitor in market which will act as reference

## 3.2 Overall system block diagram

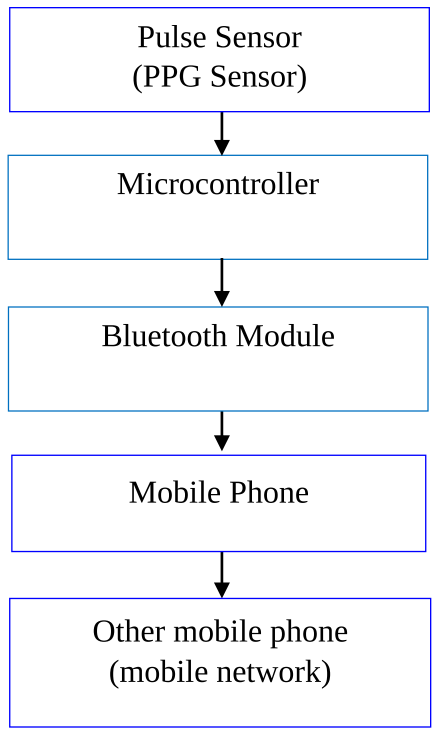


Figure 3.2 Block diagram of the project overall architecture

Referring to the block diagram in Figure 3.2, the heart-monitoring device comprises a sensing unit and a receiving unit. The sensing unit consist of the PPG sensor, microprocessor, and Bluetooth transceiver module. The receiving unit is the mobile phone with Bluetooth connection. The pulse sensor will record the pulse signal and microcontroller will analyse the received signal. The microcontroller will perform computation, decision and finally send the heart rate data to Bluetooth module. A mobile phone which connected to the Bluetooth module will receive the transmitted data. The mobile phone will text message to other mobile phone which contains the heart rate information and GPS location of the user.

### 3.3 Design Approach

### 3.3.1 Heart Rate Sensor

The subject's HR is monitored using PPG sensor, which can sense the subject's pulse. This method of detecting HR is reliable as ECG sensor. A green or red LED is used to transmit the light into the skin, the reflected light is captured by photodiode (PD). PD.will detect any slight variation in the skin. For this project "pulse sensor amped" is used to obtain the pulse as in Figure 3.3. The measurement of HR is taken from either the finger or the wrist of the subject as shown in Figure 3.4.

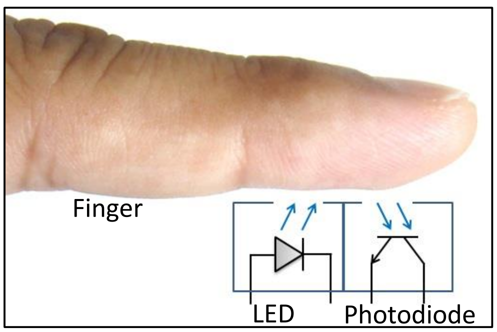


Figure 3.3 Heart rate measuring taken from finger


Figure 3.4 Pulse Sensor Amped

### 3.3.2 Processing Unit

Data from the sensor is fed into microcontroller which contains the calculation algorithm regarding heart rate is processed. The microcontroller also contains the decision-making algorithm to determine whether the HR is in irregular pattern or in normal condition. In this project, Arduino NANO will be the 'heart' to process the signal. Small, multiple pins and numerous resources for references are some of the advantages of the microcontroller.

Figure 3.5 Arduino NANO

### 3.3.3 Transmission unit

The processed data from the microcontroller needs to be transferred to the mobile phone. Therefore, Bluetooth technology is used to establish the connection between the microcontroller and the mobile device. As shown in Figure 3.6, the Bluetooth module has a few advantages over other communication options, which includes small size, miniature size and have higher applicability for this project.

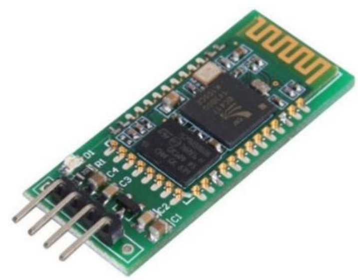

Figure 3.6 Bluetooth Serial Port Module for Arduino

### 3.3.4 Phone Application

The application is developed on android platform because Android platform has better freedom in using API such as Bluetooth API and text message API compared to other popular platforms like IOS or Windows. The function of the mobile application is to receive data from the microcontroller such as heart rate and send an alert to another mobile phone in form of text message. The text message contains information like heart rate and GPS coordinates.

### 3.3.5 Pulse Detection

This section will describe the analysis done for pulse detection. The “Pulse Sensor Amped (PSA)” sensor is used to detect the pulse and the pulse signal is sent to Arduino for processing. PSA is equipped with a filter and amplifier to increase the amplitude of the pulse wave and to normalize the signal around a reference point. The output from the sensor is an analog fluctuation in voltage.

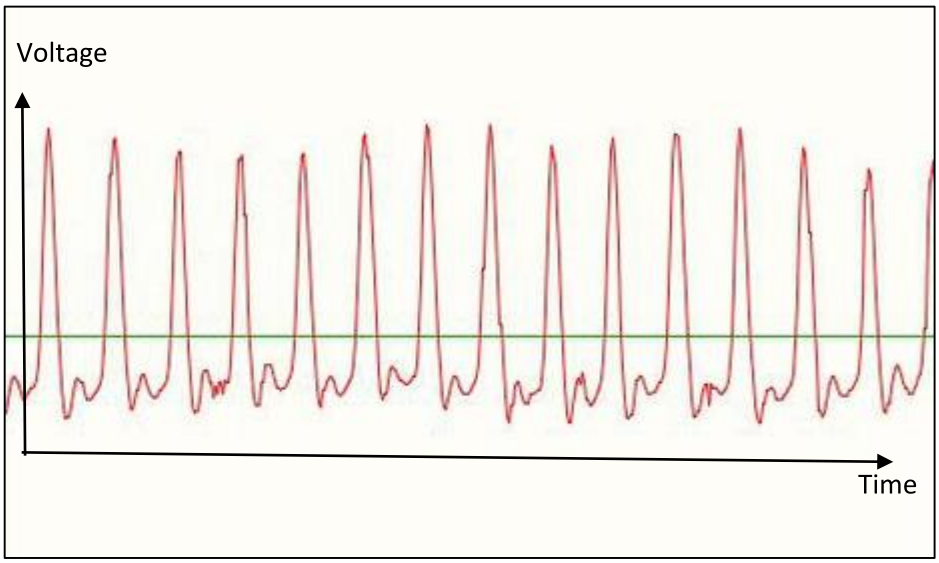


Figure 3.7 Heartbeat waveform detected using PSA

When PSA is in contact with the skin (fingertip or wrist), the signal will fluctuate as PSA detect the change in reflected light when the blood is pumped through the whole body. As shown in Figure 3.7, the horizontal line in the waveform indicates the midpoint or threshold of the voltage (V/2). When the analog signal rises above the horizontal line, the Arduino will decide that a pulse is found, then, when the signal drops below the midpoint Arduino will get ready to obtain the next signal.

Threshold value is set to the middle of the analog signal (V/2). As shown in Figure 3.7, pulse is determined when the signal is a peak which above the threshold value. To achieve the recognition of rises or drops of the pulse, the program coded into the Arduino needs to find inter-beat interval (IBI) i.e. by measuring the time between successive periods to find instantaneous heartbeat.

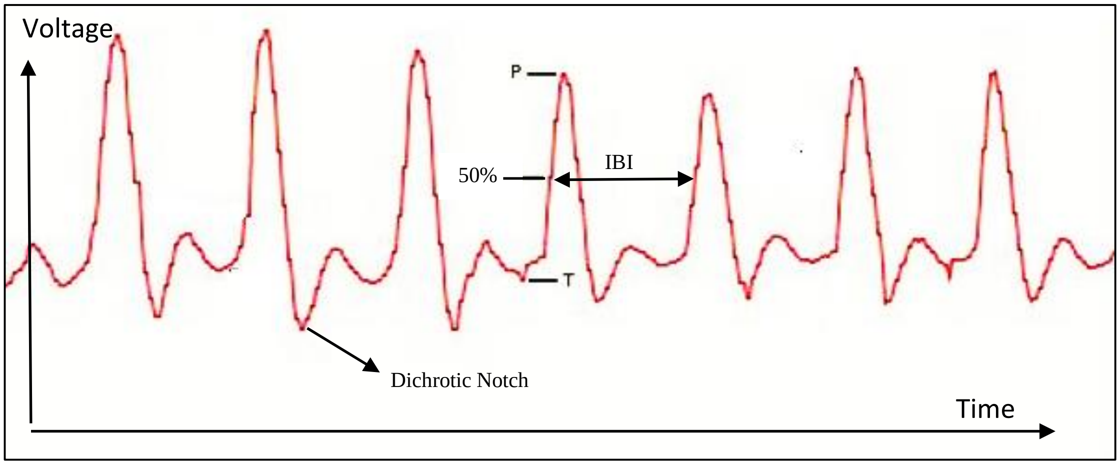


Figure 3.8 Waveform form the PPG sensor

To achieve this, when the signal is 50% of the amplitude, IBI will be measured as shown in Figure 3.8.

#### 3.3.5.1 Calculation for Heart Rate

The heart rate in BPM is formulated by taking the average of the previous 10 IBI times. The program will count up to 10 IBI, and restart counting again. After the tenth IBI, the following formula will calculate the HR. IBI is inversely related to HR by the equation:

$$HR = \frac{60000ms}{Ave\ of\ 10\ IBI} \quad (1)$$

#### 3.3.5.2 Flowchart of Pulse Detection

The process involved to determine the signal recorded by the pulse sensor is a pulse is summarized in the following flowchart.

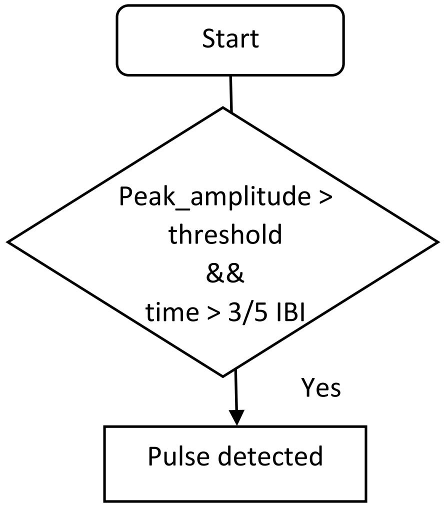


Figure 3.9 Flowchart of pulse detection

The flowchart in Figure 3.9 describes the process of pulse detection. When the wave signal which is identifies as peak with amplitude higher than the threshold value (horizontal midpoint as in Figure 3.7) and the timing for the signal has passed 3/5 of IBI is true (as shown in Figure 3.8), it will determine that the signal is a pulse [23]. The reason to wait for 3/5 of IBI to pass is to avoid noise and false reading from dichroic notch as shown in Figure 3.8.

## 3.4 Flowchart for Overall System Architecture

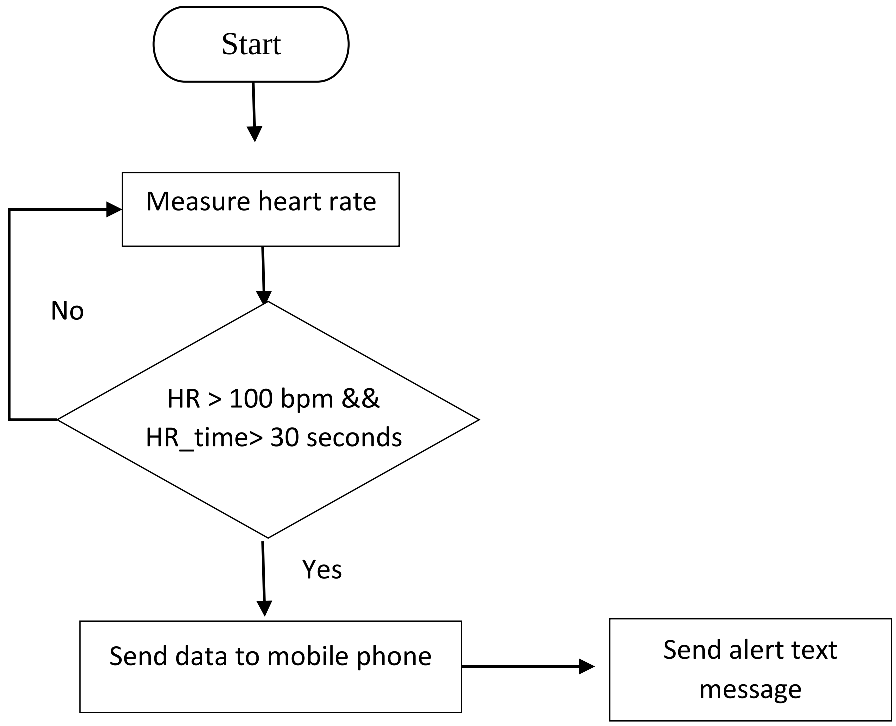


Figure 3.10 Overall system flowchart

Figure 3.10 shows the flowchart diagram of the whole system architecture. On power on, the microcontroller reads the pulse obtained from the pulse sensor. If a pulse is detected, the microcontroller will calculate the heart rate based on the algorithm coded into the microcontroller. The program will determine whether the heart rate calculated is more than 100bpm and the duration of the heart rate is continuous for 30 second to determine whether the pulse detected is irregular or normal. If the heart rate is exceeding the determined range, the data will be sent to mobile phone via Bluetooth and a text message will be automatically sent to another mobile phone via mobile network.

## 3.5 Gantt chart and Key Milestone

### 3.5.1 Final Year Project (FYP) 1

Table 3.1 describes the Gantt chart and milestone for FYP 1.

Table 3.1 Gantt chart and key milestones for FYP 1

| No | Detailed Work | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Project Selection | ■ | | | | | | | | | | | | | |
| 2 | Literature reviews (research) | | ■ | ■ | ■ | | | | | | | | | | |
| 3 | Completed research | | | | | ◆ | | | | | | | | | |
| 3 | Basic design methodology | | | | | ■ | ■ | | | | | | | | |
| 4 | Determine hardware specification | | | | | | | ■ | ■ | | | | | | |
| 5 | Testing PPG Sensor | | | | | | | | | ■ | ■ | | | | |
| 6 | Testing Microcontroller | | | | | | | | | | | ■ | ■ | | |
| 7 | Testing Bluetooth hardware | | | | | | | | | | | | | ■ | ■ |
| 8 | Completed component testing | | | | | | | | | | | | | | ◆ |

◆ Milestone
■ Task

### 3.5.2 Final Year Project (FYP) 2

Table 3.2 below describes the Gantt chart and milestone for FYP 2.

Table 3.2 Gantt chart and key milestones for FYP 2

| No | Detailed Work | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Establish communication between the microcontroller and mobile phone | ■ | ■ | ■ | | | | | | | | | | | |
| 2 | Testing Bluetooth communication with mobile phone | | | ■ | ■ | | | | | | | | | | |
| 3 | Send text message to mobile phone | | | | ■ | ■ | | | | | | | | | |
| 4 | Completed communication link testing | | | | | ◆ | | | | | | | | | |
| 5 | Send GPS coordinate | | | | | | ■ | ■ | ■ | | | | | | |
| 6 | Build mobile phone application | | | | | | | ■ | ■ | ■ | | | | | |
| 7 | Build prototype | | | | | | | ■ | ■ | ■ | ■ | | | | |
| 8 | Testing and troubleshooting prototype | | | | | | | | | | | ■ | ■ | | |
| 9 | Completed Prototype | | | | | | | | | | | | ◆ | | |
| 10 | Verification of result | | | | | | | | | | | | | ■ | ■ |

# CHAPTER 4
# RESULT AND DISCUSSION

## 4.1 Component Testing

### 4.1.1 Pulse Sensor

The measurement for the pulse is taken from the finger as shown in Figure 4.1. The pulse sensor has three pins, which is VCC pin, Ground pin, and Analogue 0 pin. The pins are connected to the Arduino NANO. The objective of the testing is to detect pulse and calculate heart rate which to be displayed in Serial Monitor of Arduino Integrated Development Environment (IDE) software.

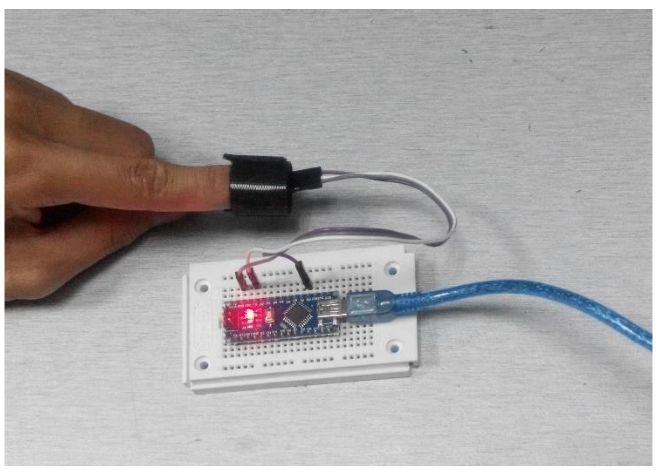

Figure 4.1 Pulse took from finger

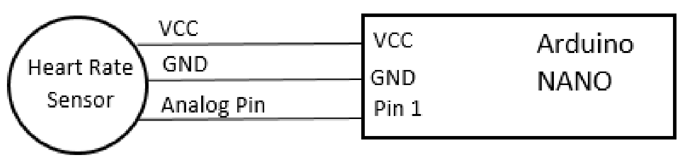


Figure 4.2 Pin connection from pulse sensor to Arduino NANO

Figure 4.2 shows the pin connection of the pulse sensor to the Arduino NANO. The sensor is powered by connecting the VCC and GND pins of the sensor to the 5V pin and Ground pin on Arduino board respectively. The analog pin of the sensor is connected to the analog input pin of Arduino to receive input from the sensor.

A 'C program' which contain code to detect the pulse and calculate the heart beat is uploaded into Arduino NANO. To observe the output obtained from the sensor, Serial Monitor in Arduino software is used where it will display heart beat in bpm when the pulse is detected.

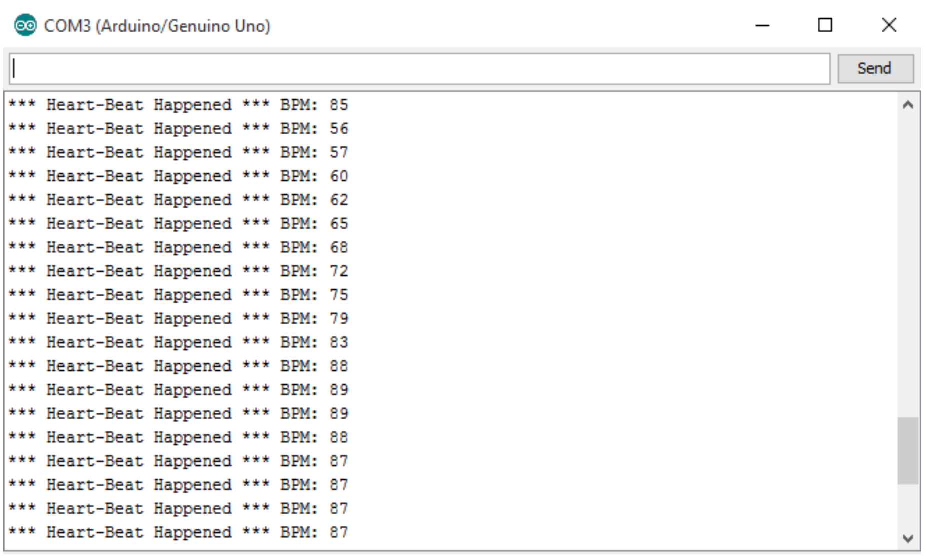


Figure 4.3 Serial Monitor displaying heart rate in bpm

The data displayed in the Serial Monitor is updated almost instantaneously (approximately 1 second). Heart rate displayed in Serial Monitor as in Figure 4.3.

### 4.1.2 Bluetooth module

The connection between Arduino and HC-05 Bluetooth modules are established by connecting 4 pins which are RX, TX, Ground and VCC pins from the Bluetooth module to Arduino. The end goal of this testing phase is to establish communication and send data from Arduino and Bluetooth module to an android mobile phone. Once the Bluetooth module is powered up, any device with Bluetooth capability can be connected or 'paired' with the module. Figure 4.4 shows the Bluetooth module is connected to Arduino.

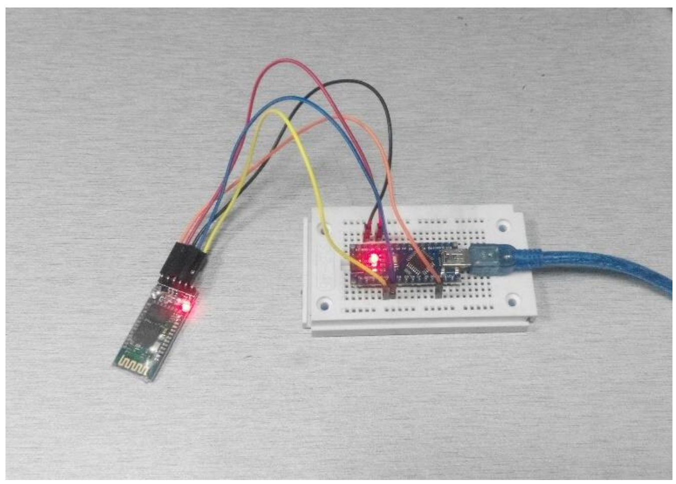

Figure 4.4 Testing Bluetooth module

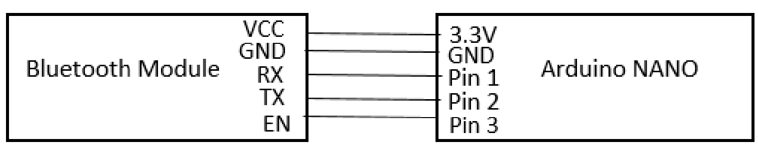


Figure 4.5 Pin connection from Bluetooth module to Arduino NANO

The mobile phone (Android device) will be communicating with the Bluetooth Module (HC-05) that is connected to Arduino NANO. The connection of the components is as in Figure 4.5. The power supply for Bluetooth module is connected to the 3.3V pin and Ground pin is connected to Ground pin in Arduino NANO. RX and TX pin is represented as receiver and transmitter respectively.

RX be will ready to receive input sent by microprocessor and TX pin will transmit input from the Bluetooth module to the microprocessor. However, in this project, the transmission (TX) part of Bluetoth module is used and not the receiver (TX) part.

EN pin is used to enable the Bluetooth module, when the pin is connected to ground, the module is disabled. As for the implementation in the project, EN pin is connected to a pin which will be triggered to LOW when no irregularity in heart rate is detected. In other word, the Bluetooth module will be disabled when the heart rate is normal. EN pin also will act as precautionary procedure to avoid the system give false alarm when the heart rate is only irregular for a short period. Thus, the mobile phone will not receive the false data and alert will be not sent.

To test the functionality of the Bluetooth module, an application called 'Bluetooth Terminal' is used to facilitate serial communication between Arduino and android mobile phone via Bluetooth module as the medium.

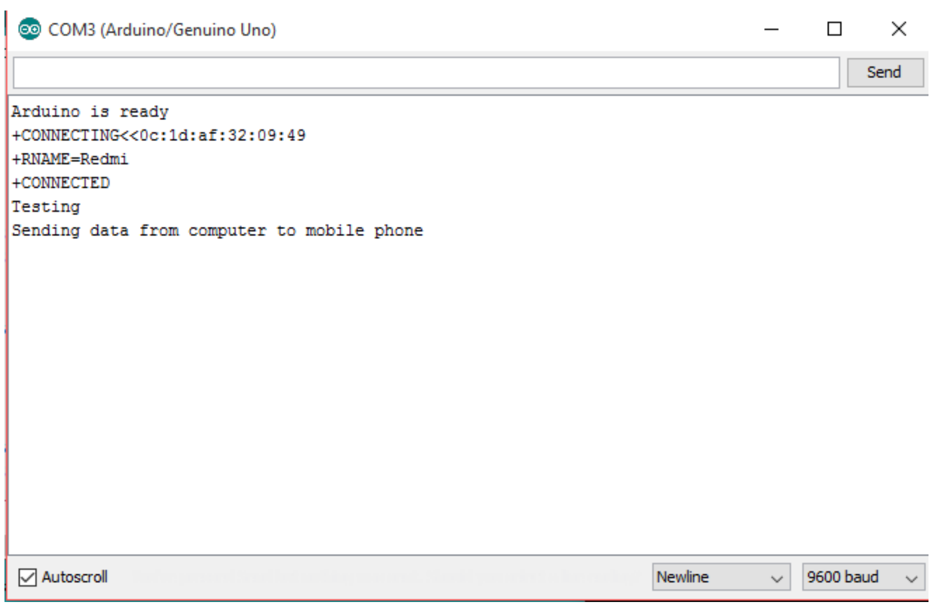


Figure 4.6 Send data from Serial Monitor

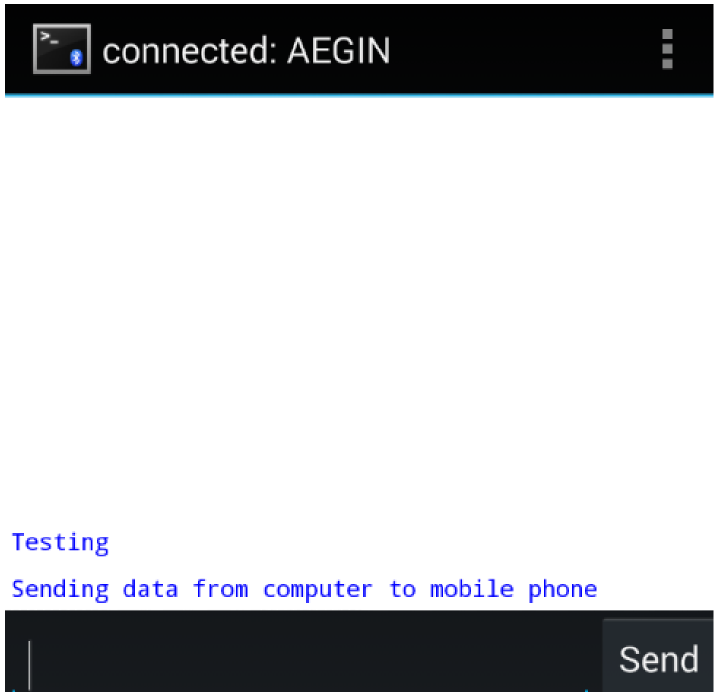


Figure 4.7 Data received are displayed in Bluetooth Terminal mobile application

A simple program is uploaded to Arduino where the code is capable of sending text from the computer via Serial Monitor to the mobile phone. Figure 4.6 shows the data sent to the mobile phone through Serial Monitor and the data received by the mobile phone and displayed in Bluetooth Terminal application is shown in Figure 4.7.

### 4.1.3 Receiving Data from Bluetooth Module

Android Studio is used as the main programming environment to program the mobile application. In order for mobile phone to be able to receive data from the Bluetooth module, there are few issues that the application need to check. First, the application need to determine whether the Bluetooth module support Bluetooth technology and if it does, then the mobile phone can successfully connect to the Bluetooth module.

In order to receive the data, the mobile phone must be 'paired' with Bluetooth module to ensure that communication between mobile phone and Bluetooth module is established. As illustrated in Figure 4.8, Bluetooth module with the name 'HC-05' is paired with the mobile phone.

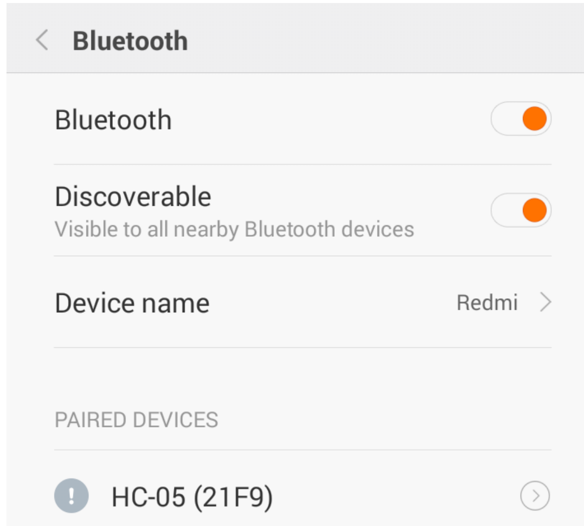


Figure 4.8 HC-05 is paired device in mobile phone setting

At this stage, the mobile phone is already connected to the Bluetooth module and the end goal is to receive the heart rate information when heart rate is irregular and continuous for 30 seconds. To achieve this objective, the microprocessor must decide whether heart rate is normal or irregular. Figure 4.9 shows the code snippet for the decision making.

```
if (BPM >=100)// heart rate greater than 100bpm
{
   delay(5000); // 5 second for every sample
   count = count+1;
if (count ==6) // sample for 6 times * 5 second = 30 second
{
  BTserial.print("Heart rate condition: IRREGULAR and BPM is : ");
  BTserial.println(BPM);
  count=0;
}
```

Figure 4.9 Code snippet to determine heart rate is irregular

When heart rate is above 100 bpm and if the HR is continuous for 30 seconds, data from the microprocessor will be sent to the Bluetooth module and it will be transmitted over Bluetooth to mobile phone. Figure 4.10 shows the heart rate being displayed in the mobile application.

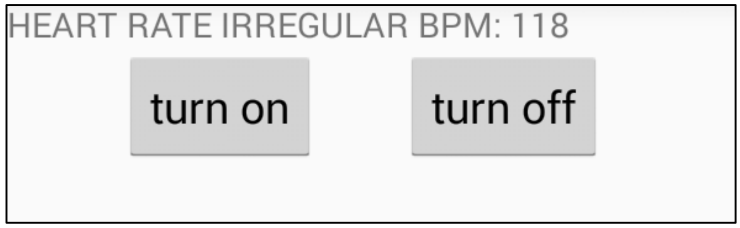


Figure 4.10 Heart rate data received in the mobile application

False alarm is disregarded in early stage by disabling Bluetooth module if HR is irregular in short period. Thus, when HR information is received by the mobile phone, it is certain that the user is having arrhythmia and alert needs to be sent to the specified recipients. The content of the text message is the heart rate recorded when the user is experiencing arrhythmia. In order to send the text message, the phone number of the recipients is required, user needs to input the phone number once before using the device and the inputted phone number will be saved. However, in the early version of the application, the phone number is defined within the code as shown in Figure 4.11.

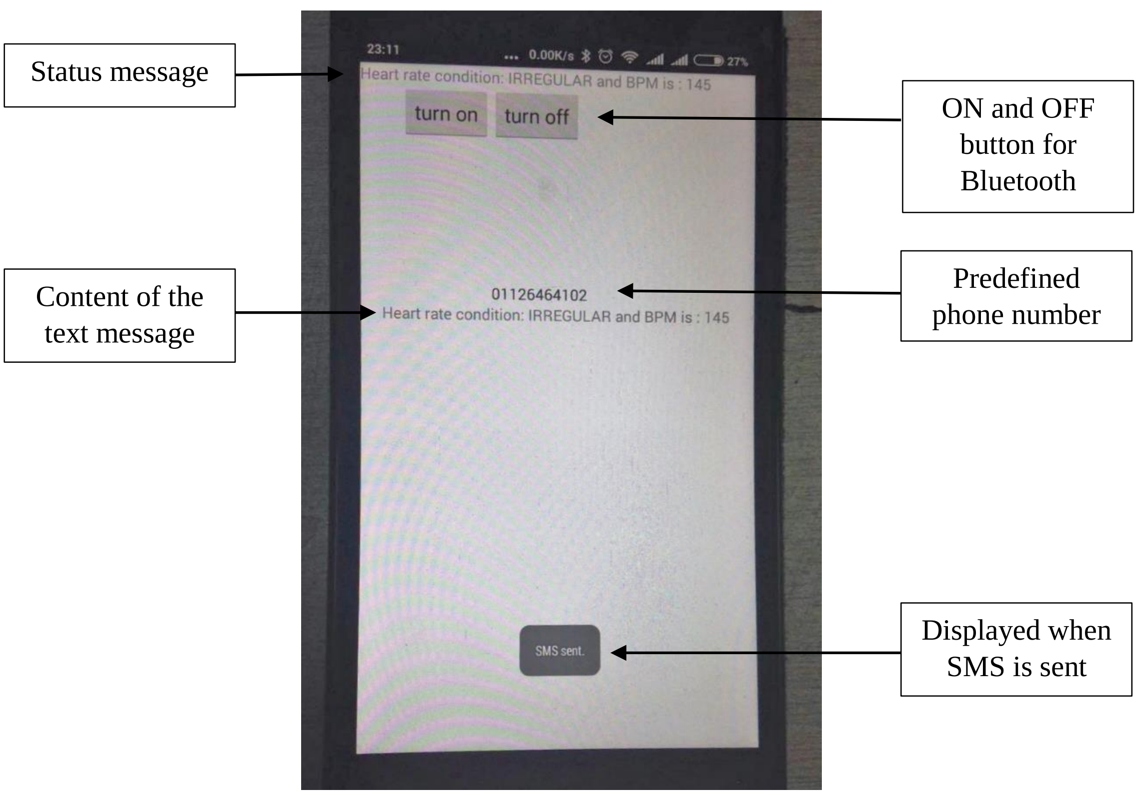


Figure 4.11 Phone number and content of the text message

When heart rate is irregular, the mobile phone will receive the data from the sensor and a text message will be sent automatically. Figure 4.12 shows the specified recipient receiving the text message.

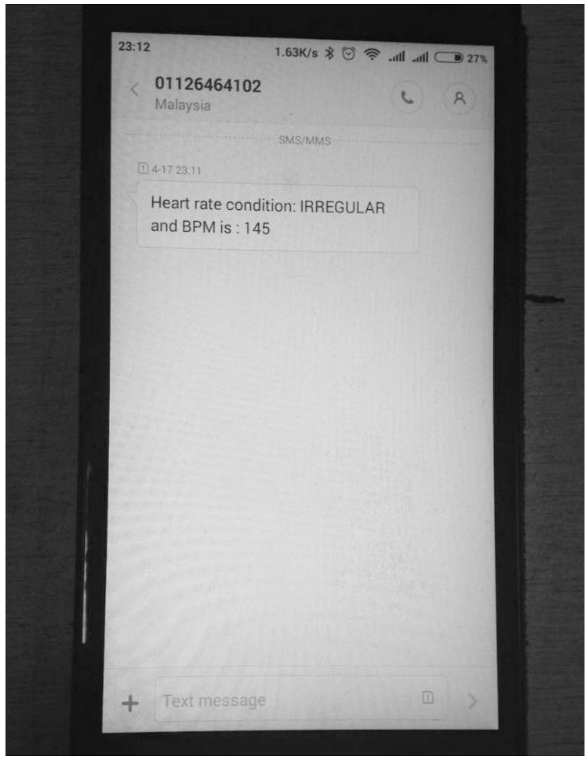


Figure 4.12 Alert sent to specified phone number

Figure 4.13 shows GPS coordinate being sent to the specified recipient and Figure 4.14 shows the the recipient receiving the text message which contains the GPS location.

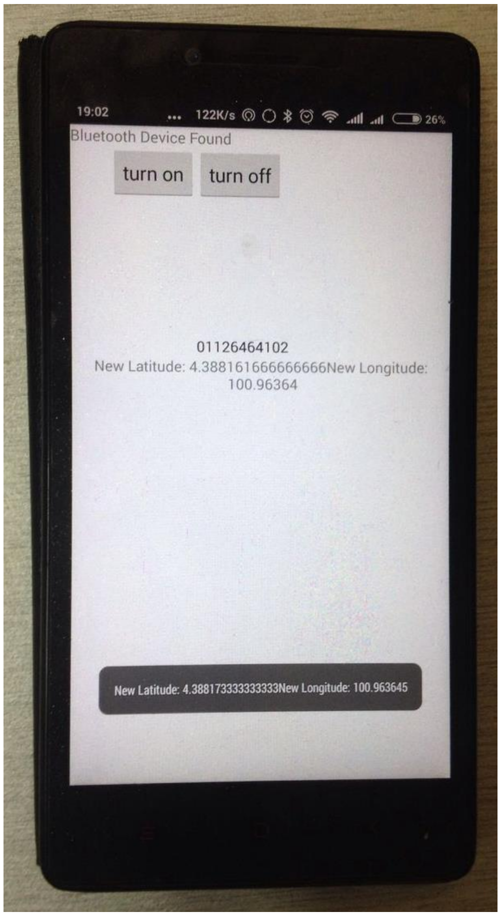


Figure 4.13 Sending GPS coordinate to specified phone number

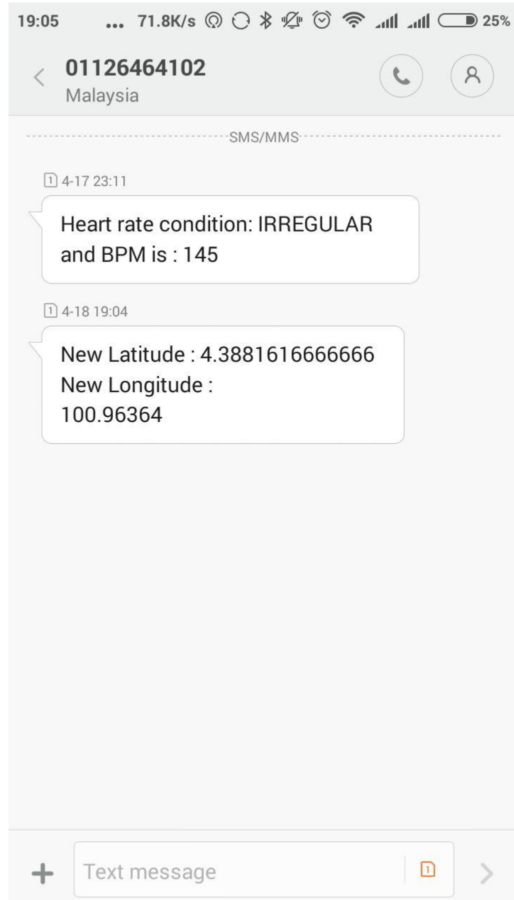


Figure 4.14 GPS location received by the recipient

## 4.2 Output Validation

Verification methodology is needed to ensure the accuracy, sensitivity, specificity and precision of the heart rate monitoring device. The procedure to verify the device output includes comparing the device output (prototype) with the output form an existing heart monitoring device from the market as shown in the confusion matrix table as follows.

Table 4.1 Normal and irregular condition of HR

| | **Existing Heart rate monitor** | | |
|---|---|---|---|
| **Prototype Output** | Condition | Irregular | Normal |
| | Irregular | True Positive (TP) | False Positive (FP) |
| | Normal | False Negative (FN) | True Negative (TN) |

When a test is carried out and the HR is irregular it is classified as irregular, while when HR is normal it is classified as normal. When the prototype detects irregular HR and the heart rate monitor also recorded irregular HR, it is classified as True Positive. It is classified as True Negative when the output from prototype and heart rate monitor shows normal HR. However, the test may yield to wrong result when the prototype falsely classifying the HR as irregular if in fact the HR recorded from heart rate monitor is normal (classified as False Negative), or by classifying the HR as normal if in fact the HR is irregular (classified as False Positive). To summarize:

- True positive (TP): Irregular heart rate correctly identified as Irregular
- False positive (FP): Normal heart rate incorrectly identified as Irregular
- True negative (TN): Normal heart rate correctly identified as Normal
- False negative (FN): Irregular heart rate incorrectly identified as Normal

### 4.2.1 System Performance

Accuracy and precision are the term used interchangeably to describe the measurement error. In definition, accuracy refers to the deviation of measurement from a true value of the quantity measure. Accuracy is calculated by the following equation:

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+ TN+ FP+FN}} \tag{2}$$

Precision relates to the quality of an operation by which result is obtained. It is distinguished from accuracy, which relates to the quality of results. Precision or positive predictive value is defined as proportional of true positive against all positive result (both true positive and false positive). Precision is defined as:

$$\text{Precision} = \frac{\text{TP}}{\text{TP+ FP}} \tag{3}$$

Sensitivity also called as true positive rate, a measure of proportion of positive that are correctly identified as such. In this case, sensitivity refers to the proportion of HR which is irregular that will have positive result. Sensitivity is defined as:

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP+ FN}} \tag{4}$$

Specificity refers to the ability of the device to identify the HR data are normal. It is the proportion of the HR, which is normal that will have negative result. Mathematically specificity is:

$$\text{Specificity} = \frac{\text{TN}}{\text{TN+ FP}} \tag{5}$$

#### 4.2.1.1 Validation of result

To test for the system performance, the output from the prototype is compared with the pulse oximeter as shown in Figure 4.15.

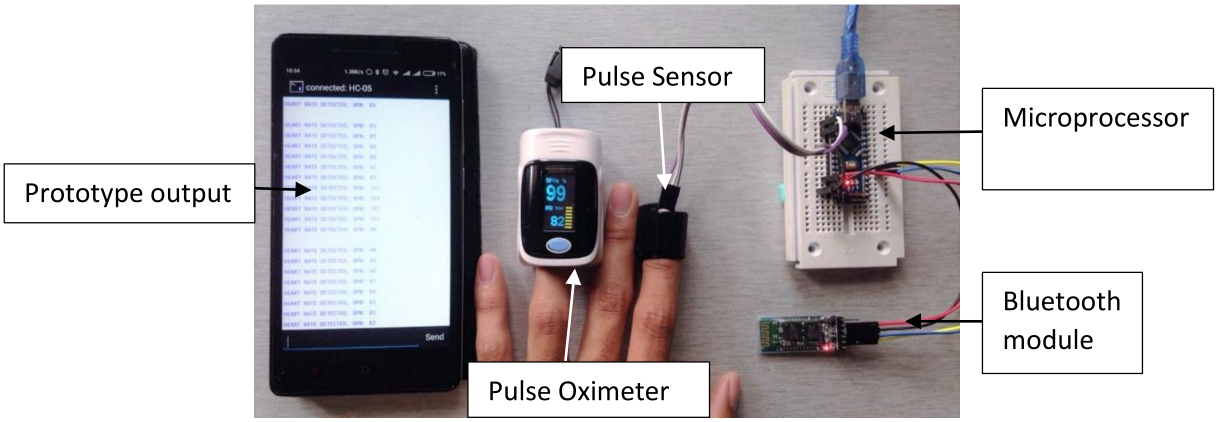


Figure 4.15 Comparison of prototype output and pulse oximeter

To calculate the accuracy, precision, sensitivity and specificity, a test is carried out by comparing the number of TP, FP, TN and FN. The output from prototype and pulse oximeter is compared and the test is performed for a period of 5 minutes. During the testing period, the test subjects are required to keep their body movement as minimum as possible to avoid false reading and to obtain an accurate output result. In order to test irregular heart rate, the test subjects need to increase their heart beat by performing physical exercise of moderate intensity. After few minutes of exercise, the test subjects have to wear both prototype and pulse oximeter. The recorded heart rate values are recorded and summarized in Table 4.2.

Table 4.2 Confusion matrix for irregular heart rate and normal heart rate

| | | **Pulse Oximeter** | |
|---|---|---|---|
| **Prototype Output** | Heart Rate Condition | Irregular | Normal |
| | Irregular | TP = 140 | FP= 5 |
| | Normal | FN= 1 | TN= 55 |

The outcomes for accuracy, precision, sensitivity and specificity of the prototype is formulated in Table 4.3.

Table 4.3 Percentage of the system performance

| **System Performance** | **Percentage (%)** |
|---|---|
| Accuracy | 97.50 |
| Precision | 96.55 |
| Sensitivity | 99.29 |
| Specificity | 91.67 |

The accuracy of the device is 97.50% where the device is able to accurately determine irregular HR and normal HR 97.50% of the time. The precision value is 96.55% which shows that the device has high precision. Sensitivity of 99.29% shows the device are able to correctly detect irregular HR 99.29% of the time while specificity of 91.67% relates to the device’s ability to correctly detect Normal heart rate.

# CHAPTER 5
# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

This project presents a heart rate monitoring device that will detect irregularities in heart rate and send out an alert to another mobile phone. The main component includes PPG sensor, Arduino NANO as the microcontroller, Bluetooth modem, and mobile phone. This project also includes designing mobile phone application based on Android to receive data from the microcontroller and transmit data to another mobile phone using GSM network. The data sent is in the form of a text message that contain the details of heart rate and GPS coordinates. When a victim experience heart irregularities and need medical attention, this device would help increase the respond rate to undergo treatment process. When an early alert is sent to the person in charge of the victim, harm or even death could be avoided.

In this project, all the tasks planned in the Gantt chart have been completed. The mobile application developed are able to receive HR information when HR is irregular (more than 100bpm) and the duration of the HR is continuous for more than 30 seconds The alert is successfully sent automatically to specified recipient. The text message contained the details of HR information and the GPS location of the user. The developed system has accuracy of 97.50%, precision of 96.55%, sensitivity of 99.29% and specificity of 91.67%

## 5.2 Recommendation

In completion of the project, few recommendations can be made to improve the functionality and performance of the system. The output signal of the pulse sensor used in this project can be contaminated with motion artefact which could introduce noise and false signal into the output signal. Therefore, for future work, motion artefact can be removed to make sure the designed system has high accuracy.

To improve the functionality of the alert system, alert can be broadcast on the mobile phone display or through audio to tell the bystander what they should do when a person is having irregular heart rate or cardiac arrest. Besides that, the user-interface of the mobile application can be further improved for a user-friendly interface.

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