Heart Disease Detection
Using Mobile Phone and Wireless Sensor Networks

by

Ng Yan Lim @ Chia Yan Lim

15989

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Electrical & Electronics)

January 2016

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Heart Disease Detection
Using Mobile Phone and Wireless Sensor Networks

By

Ng Yan Lim @ Chia Yan Lim
15989

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL & ELECTRONICS)

Approved by,

____

(Ms Zazilah bt May)

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.

Ng Yan Lim @ Chia Yan Lim

ABSTRACT

Heart disease is a leading cause of death at this era of globalization. The paper describes a heart disease detection using mobile phone and wireless sensor networks. The emergence of wearable sensor and wireless mobile technologies enable to detect and monitor the changes in health parameters irrespective of places and time. In addition, a prototype is developed that capable of wirelessly monitoring and real-time diagnosis of patient to solve the critical issue that the patients' activities is restricted with the dangling wire and weight of the electrocardiogram machine. It will be much more convenience for the patient to do a self-test diagnosis by using a wireless heart monitoring device. This prototype aims to use low cost implementation and provides reliable heartbeat monitoring result. This kind of real-time assistive medical diagnosis system consists of pulse sensor. The pulse sensor measure and senses the heartbeat and converts it into electrical signal form. The signals are amplified and sent to controller for proper processing and determination of the heartbeat. The heart disease can be detected if the threshold value of the heartbeat rate is maximally exceeded. The pulse sensor and mobile phone is connected wirelessly via Bluetooth protocol. The pulse sensors used for transmitting the heartbeat signals to the mobile phone. The mobile phone used for monitoring purpose to display the patient's heart rhythms on the screen of phone. The user can observe their heart rhythms easily by using application software. Nevertheless, the result gathered from the prototype is comparing with the existing product which is Omron HEM-7203. The percentage error of the result within two products is quite low that less than 4.1%. Thus, this paper proposes a reliable diagnosis system which is continuously and real-time monitoring of the heartbeat rate and provides a preventive method of heart ailments. In the future, adding biometric authentication can be modified to this idea. The sensors can become attached to and embedded into the body, more heart disease can be monitored by modifying the system.

ACKNOWLEDGEMENTS

First and foremost, I would like to to express my deepest gratitude to Electrical & Electronics Engineering Programme for giving me such a golden opportunity to accomplish the final year project which indirectly developed me to be an independent engineer. Throughout the duration of this project, I have faced many challenges, but with the degree knowledge, everything is solved and the project did achieve its own objectives.

I would like to express my greatest appreciation to my supervisor, Ms Zazilah bt May for her guidance and for sharing with me her experience which suggesting to me the outlines of this project and correcting my doubts. Without her supervision and constant help, this project cannot be done successfully on my own. Her willingness to spare me her time and generosity to support me both mentally and spiritually has been very much appreciated.

Furthermore, I would also like to extend my thanks to a group of UTP management associates, and several others for their help in fostering and guiding me to improve my interpersonal and communication skills and to be an effective presenter.

Last but not least, I wish to thank my parents for their unparalleled contribution and support both morally and financially throughout my life. They are my pillar of strength and I shall do my utmost to ensure their happiness and fulfillment as a filial son.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Nowadays, heart disease acts as a leading cause of death. World Health Organization (WHO) defined the heart disease a killer because of despoiling 17.1 million lives annually [1]. There are several medical conditions that bring the impact to the heart disease such as heart attack, coronary heart disease, and congestive heart failure.

According to published reports, there are 30% of the death associated with a heart disease [2]. In order to reduce the rate of death, there was a race against time for the patients to receive the early treatment as they realised the disease symptom on their body. A study states that the death rate can be decreased to 45% if the treatment offered immediately of symptom onset otherwise the risk of death will decrease to 23% if the treatment started after few hours of symptom onset [3].

American Heart Association (AHA) states that, heart disease, also referred to as coronary artery disease (CAD). CAD is a term used to describe the narrow of arteries that cause difficultly of blood flowing and consequently in heart attack [4]. The emergence of mobile monitoring diagnosis application is capable to detect the health parameters for patients with heart disease. By using these diagnosis application, an immediate action can be taken which is utmost important as few hours can save lives for people with heart disease. Furthermore, it provides an independent life for the patients with heart disease as the wireless monitoring device can continuously monitoring the patients with a reduced number of visits to hospitals.

Hence, a long-term used heart monitoring system by using mobile phone and wireless sensor networks is proposed to allow potential victims can determine their heart rhythms without the assistance of the health professional. Besides, mobile phone acts as a fundamental part of human life, it makes an ideal platform for portable, real-time assistive medical diagnosis. Mobile phone is powerful with memory availability, and batteries for storing and processing of the data. An idea of the design can be seen in Figure 1[3].

FIGURE 1: Idea of Heart Monitoring System

1.2 PROBLEM STATEMENT

Generally, the electrocardiogram (ECG) is widely used in hospital environment to diagnose cardiac arrhythmias [5]. It is one of the diagnosis techniques for heart disease but the necessary equipment needed for diagnosis is not suitable for household applications [6].The chest transmitter and strapless wrist band have been developed commercialized by using ECG technique. However, the chest strap transmitter is not appropriate for household heart rate monitor because it is not a long-term used material. The comfort of wearing of strapless wrist band still has not been entered in a satisfactory period. Moreover, there is a financial burden to the user for cardiovascular diagnosis by using ECG machine. RM75000 is charged to buy an electrocardiogram machine with automatic diagnosis application [5]. Subsequently, the patient's activity is restricted due to the wires tethered in conventional systems and the weight of the machine.

Furthermore, it is a time-consuming for the patients living in rural areas to have a visit to hospitals for a heart monitoring diagnosis. The progress for connecting and disconnecting ECG leads from people to people is wasting a lot of times. In addition, there is a risk of infection when attaching the wires on the body of patients [6].

This paper will focus on how to develop a user-friendly heart disease monitoring device that able to detect the possibility of a person experienced with heart disease. A low cost, light weight and reliable device is proposed to detect the heartbeat and pulse of the patients in real-time basis based on reasoning and computational algorithms. The proposed system can connect to the mobile phone wirelessly by using Bluetooth protocol to increase the mobility of the patients.

1.3 OBJECTIVES

- To develop a real-time diagnosis monitoring device.
- To develop a mobile application that can connect pulse sensor and a mobile phone by Bluetooth protocol.
- To develop a low cost and self-test application for long-term household use.

1.4 SCOPE OF STUDY

- Connect a pulse sensor and mobile phone by using Bluetooth protocol.
- The pulsation of the artery is detected by pulse sensor to measure heart rate. The Arduino circuit is implemented to amplify the signals for proper processing and determination of the heartbeat.

CHAPTER 2

LITERATURE REVIEW

2.1 APPLICATION OF HEART DISEASE DETECTION

There are some conventional methods have been proposed to detect heart disease, most of them are based on

I. Electrocardiography (ECG)
II. Irregular and Maximum Heart Rate
III. High Blood Pressure
IV. High Blood Cholesterol

2.1.1 Classification of Electrocardiography

Electrocardiogram captures the electrical activity (electrocardiography) of the heart. The electrical impulses released from the heart spread to all heart muscle that enable for contraction of heart. Several ECG sensors can be attached at different part of body to detect the impulse from different direction of the heart. After the ECG pattern is analyzed, the heart disease can be detected included abnormal heart rhythms and heart attack. A threshold range of ECG value is given for detection of heart disease. Table 1 shows the classification of ECG.

TABLE 1: Classification of ECG [4]

INPUT FIELD	RANGE	Result
Resting Electrocardiography (ECG)	[-0.5, 0.4] [1.4, 1.8] [1.8, 2.5]	Normal ST-T abnormal Hypertrophy

As an example, a Holter device invented with small size monitor attached with the electrode pads as in Figure 2. The patients can continuous proceed their routine activities by wearing this device. The Holter device can be placed at the arms and waist of the patient. It can records the patient's ECG for 24 hours. The recording data will be analyzed afterwards by the cardiologist.

FIGURE 2: Holter Device

In addition, Carematix, and CardioNet is a portable cardiac monitoring device with automatic arrhythmia detection and wireless ECG transmission as in Figure 3. The components of the system included a wireless transmitter, a receiver and a remote server[7]. The data gathered will be stored in the remote server. A remote heart attack detection system can automate the process to record ECG data of the user. Medication and lifestyle adjustments will be provided after the data is analyzed by the health professional[8].

FIGURE 3: Carematix, and CardioNet

Besides, Figure 4 shows a product comprised with 12 lead ECG sensors called LifeCard 12. The system has the capability to record the data to a Compact-Flash card. The data can be transferred from the memory card to a mobile phone. A week of ECG recording data can be stored in a memory card.

FIGURE 4: LifeCard 12

2.1.2 Classification of Irregular heart rate

An irregular heart rate means a disorganized heart rate, either too slow or too fast in short period. The abnormal heart rhythms are the main cause of most heart disorders such as heart attack and stroke. A pulse sensor can be used to measure the heart rate for detection of heart disease. A threshold range of heart rate value is given for detection of heart disease.

Table 2 shows estimated target heart rates for different ages. The maximum heart rate can be calculated that about 220 minus your age. About 50-69% of your maximum heart rate represents the heart rate during moderately intense activities. About 70% to less than 90% of the maximum heart rate represents the heart rate during hard physical activity [9].

TABLE 2: Classification of Maximum Heart Rate [4]

Age	Target HR Zone 50-85%	Average Maximum Heart Rate, 100%
20 years	100-170 beats per minute	200 beats per minute
30 years	95-162 beats per minute	190 beats per minute
35 years	93-157 beats per minute	185 beats per minute
40 years	90-153 beats per minute	180 beats per minute
45 years	88-149 beats per minute	175 beats per minute
50 years	85-145 beats per minute	170 beats per minute
55 years	83-140 beats per minute	165 beats per minute
60 years	80-136 beats per minute	160 beats per minute
65 years	78-132 beats per minute	155 beats per minute
70 years	75-128 beats per minute	150 beats per minute

As an example, Figure 5 shows a wearable wireless sensor system (WWSS) is designed to detect the pulse and heartbeat of the patient. The system will detect the heart rhythms of the patient in real-time and transmit to mobile phone wirelessly [8]. The received data will be sent to a central station, which enable the doctor to analyze the heartbeat data and provide his prescription remotely.

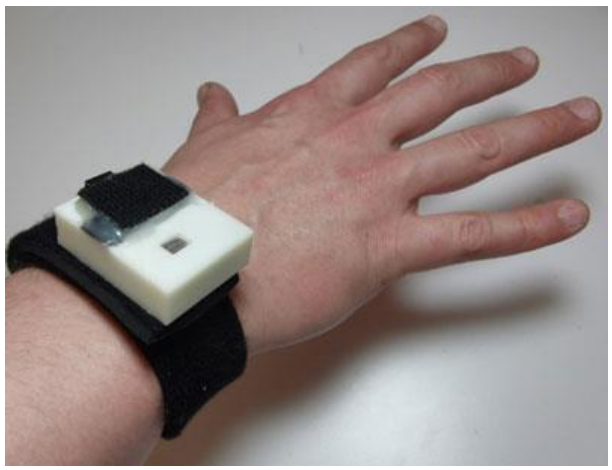


FIGURE 5: Wearable Wireless Sensor System (WWSS) [8]

2.1.3 Classification of High Blood Pressure

High blood pressure can results in heart disease and hypertension. High blood pressure causes the heart failure that muscle relaxation between become less effective. The heart will face the difficultly to pump enough blood to whole body's organ, ultimately increase the risk of heart disease. With high blood pressure, the muscle of the people will become thick and cause the insufficient of oxygen to be supplied. In addition, high blood pressure can results in thickening of the blood vessel walls. The condition will become worst if the cholesterol deposits combined in the blood vessels, it increase the risk of stroke and heart attack [10].

Table 3 below shows the hypertension threshold ambulatory blood pressure for adults by the Australian national guideline. The category corresponds to the following ambulatory blood pressure reading.

TABLE 3 : Hypertension threshold ambulatory blood pressure

Time	Hypertension Threshold Systolic/Diastolic
24-h average	130/ 80 mmHg
Day time average	135 / 85 mmHg
Night time average	120 / 75 mmHg

As an example, the Omron M6 Comfort [11] is a blood pressure monitoring device that helps to detect the hypertension. The device can indicate the heart rate and monitors the hypertension with high accuracy. The device enables to wrap around the arm with 360 degree. Hence, there is no measurement “blind spot” for the device to detect the blood pressure of a person. Figure 6 shows the product Omron M6 Comfort.

FIGURE 6: Omron M6 Comfort

2.1.4 Classification of High Blood Cholesterol

The risk of heart disease can be developed by high blood cholesterol. Cholesterol is a fat-like substance carried the body by protein [4]. Cholesterol helps to insulate nerves, produce hormones and build new cell. However, the hardening of the arteries will happened if there is too much cholesterol in the bold. The cholesterol in the blood will cause the narrowing of the arteries and difficulty blood flow to the heart. If oxygen supplied from the heart is cut-off by a blockage it will increase the risk of heart attack.

Table 4 below shows the threshold of total cholesterol level and its category. Cholesterol levels are measured in milligrams (mg) of cholesterol per deciliter (dL) of blood.

TABLE 4: Threshold of total cholesterol level

Total Cholesterol Level	**Category**
Less than 200 mg/dL	Desirable
200-239 mg/dL	Borderline High
240 mg/dL and above	High

As an example, Figure 7 shows a CardioChek analyzer which is a blood analyzer with fast, portable, and features. The CardioChek test system includes an analyzer and separately available CardioChek test strips/MEMo Chip®. This test system is intended for in vitro diagnostic use to test whole blood. A small size sample of blood is used to measure the different components in blood. The CardioChek test system is capable to measure the components in blood including Cholesterol, and HDL Cholesterol.

FIGURE 7: CardioChek Home Blood Testing Device

2.2 RELATED WORK

This project is carried out on determining the different application of heart monitoring application. Table 1 shows the analysis on the advantages and disadvantages of these devices.

TABLE 5: Literature of the related work

No	Author	Year	Title	Heart Attack Detection System	Advantages	Disadvantages
1	Peter Leijdekkers [7]	2007	A Self-test to Detect a Heart Attack Using a Mobile Phone and Wearable Sensors	Heart Attack Self-test Application	Perform on the spot diagnosis on heart attack in short time	Expensive
2	Kala John Kappiarukudil [12]	2007	Real-Time Monitoring and Detection of Heart Attack Using Wireless Sensor Network	Wearable Wireless Sensor System (WWSS)	Real-time monitoring and transmitting the ECG data	Not suitable for long term household
3	Joseph John Oresko [6]	2010	Portable Heart Monitoring System Using Smart Phones To Detect Life Threatening Arrhythmias	ECG Sensor Manager	Systematically classify the ECG data	The correct arrhythmia cannot be easily interpreted
4	Alauddin Al-Omary [4]	2014	Heart Disease Monitoring System Using Web and Smartphone	The Android Patient Application	Can show the patient's medical history.	The developed hardware and software took long time.
5	Amita Murthy [13]	2014	Developing Trends in Cardiac Monitoring Systems	Cardiac Monitor	Have body worn unit with transmitters to transmit ECG acquired.	Heavy device

6	Mayur R. Bhoyar [5]	2008	Design of A Fully Autonomous Mobile Pipeline Exploration Robot	Omron HCG-801	300 measurements data can be stored	Less accuracy of the data
7	Siddhartha Mal [11]	2010	RFID-Enabled Wireless Heart Monitoring System	RFID-Enabled Wireless Heart Monitoring System	The data can be downloaded into mobile phone.	Wearable on hand only.
8	Mr. Sukhwant Khanuja [9]	2015	Carematix Wireless Solutions for Welness Monitoring	Carematix	System can automate the process to record of the patients	The devices should be used by health professional.
9	Jeffrey [14]	2010	Holter Monitor	Holter	Can record ECG data for 24 hours.	Not running in real time.
10	Siddhartha Mal [11]	2010	RFID-Enabled Wireless Heart Monitoring	LifeCard 12	Record the data to a Compact-Flash card	Not available for real-time monitoring

2.3 CRITICAL ANALYSIS

The related work above presents a lot of improvement and consideration for the heart monitoring application from many aspects such as sizing, cost, portability and the design complexity.

An ideal system is proposed by using a pulse sensor and a mobile phone to detect pulsation of the arteries wirelessly. In this project, a flexible and low cost pulse sensor is adopted for sensing the changing of heartbeats in beat per minute (BPM). The possibility of a person experienced with a heart disease can be determined when the heart rate goes above or below a fixed threshold. In addition, mobile phone is a common device that has enough available memory, energy, and processing power. The limitations of wireless sensor network technology for transmitting and processing of the data can be solved by using mobile technology nowadays[12]. The pulse sensor and the mobile phone should be connected wirelessly during the measuring phase. The pulse sensor acts as a transmitter to send the real-time measurement data to a mobile phone via Bluetooth communication protocol, and eventually the data recording result will be shown on the screen of the phone[15].

The advantage of this project is providing a small size and portability of design. The Bluetooth protocol is fabricated to transmit the real-time transmission data. This real-time monitoring device enables the patient to diagnose the heart disease regardless of places and time and make a convenience situation for the patient.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

After reviewing different application of heart monitoring application, a pulse sensor assorted with a mobile phone is considered as the most suitable to be implemented on the heart monitoring system. The idea of utilizing the pulse sensors and mobile phone is to monitor the wellbeing of the cardiac patients by analyzing real-time heart rhythms. The purpose by using pulse sensor is to make sure the transmission of data can be faster and analyzing task can be done via Bluetooth protocol with a higher accuracy.

The final result of the experiment will be compared with the existing heart attack detection system in order to achieve a more reliable result. The flow of project methodology is shown in Figure 8.

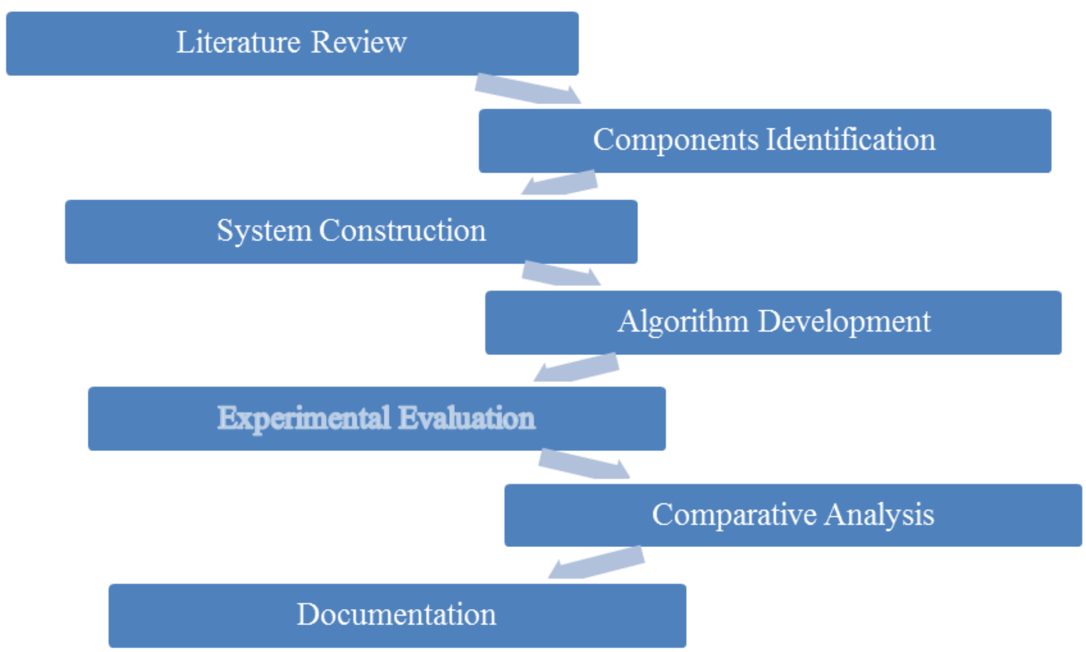


FIGURE 8: Project Methodology

3.1.1 Project Overview

This chapter covered the development of a mobile application that can display the heart rate of the user. The collected data from the pulse sensor is sent to the microcontroller and the heart rate value is transmitted to mobile phone by using HC-05 Bluetooth Module. Hardware development of Arduino Uno microcontroller circuit together with HC-05 Bluetooth module is discussed in details.

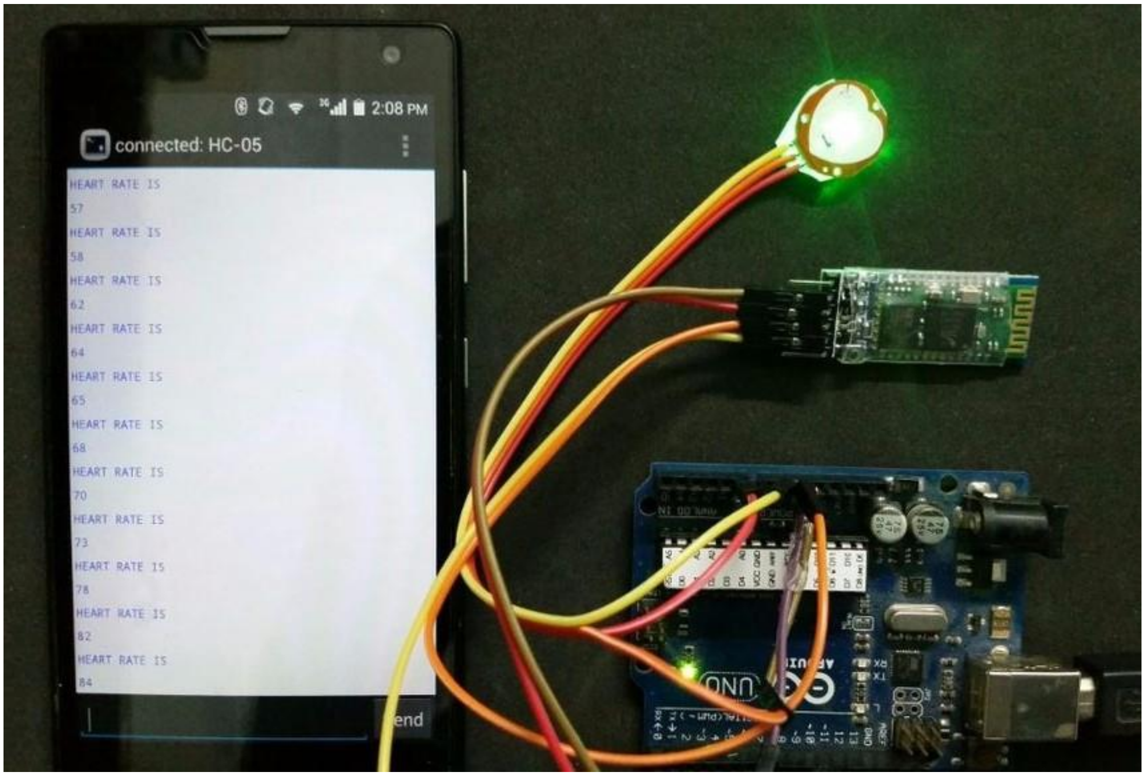


FIGURE 9: Project Overview

Project overview is as attached in Figure 9. First of all, human's heartbeat is measured by using pulse sensors. The electric signal is converted from the analog to digital value by undergoing Analog- To- Digital conversion (ADC) process. Once the signal is being converted, the mobile phone which acts as a receiver will collect the recording data from the microcontroller by using Bluetooth protocol.

Nevertheless, a monitoring mobile application is developed in the mobile phone in order to let the patient can continuously to monitor their heartbeat in real time. This kind of user-friendly application can help the patient detect their heartbeats immediately by themselves.

Furthermore, the mobile phone is used to interface with the microcontroller and display the heart rhythms on the phone screen. The Arduino which is a microcontroller is transmitting the data recorded to the mobile phone wirelessly by using Bluetooth protocol. A command is sent from phone to microcontroller before starting the monitoring phase to make sure the phone and microcontroller is calibrated and ready to receive the signals. Table 6 and Table 7 shows the functions of software and materials used in this project.

TABLE 6: Functions of Software

Software	Function
Arduino 1.0.5	To do coding for mobile application development

TABLE 7: Functions of Materials

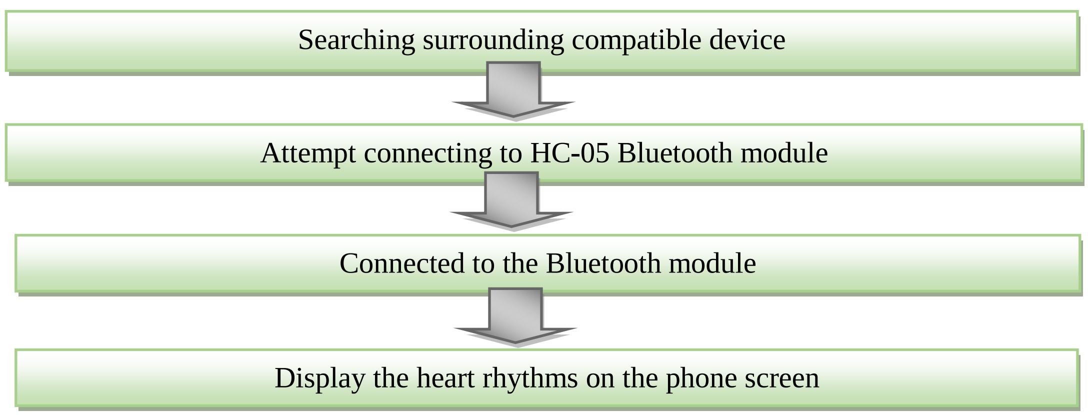
Materials	Function
Mobile Phone	Interface with microcontroller and display the heart rhythms on the screen
Arduino	Analog To Digital conversion of signal and the data transmission between Bluetooth Module and Mobile Phone
HC-05 Bluetooth	Connect the pulse sensor and mobile phone for transmission of data.
Pulse Sensor	Sensing the pulsation of heart

3.2 SOFTWARE DEVELOPMENT

This session discuss about the connection of the mobile phone and the Bluetooth module. A mobile phone is connected wirelessly with the Bluetooth module to interface the microcontroller and continuously receiving the signal from pulse sensor.

3.2.1 Bluetooth Development

A mobile application is developed in the mobile phone to connect the phone with the Bluetooth module. Once the application is running, it can searches the device surrounding which compatible with, and eventually connect with the device. HC-05 Bluetooth is the Bluetooth module used in this project. The flow of Bluetooth connection between mobile phone and HC-05 Bluetooth module is as below:



3.3 HARDWARE DEVELOPMENT

The transmitting of pulse signals using Arduino, Pulse sensor and HC-05 Bluetooth module is discussed.

3.3.1 Arduino

FIGURE 10: Arduino Uno R3

Figure 10 shows an Arduino which is a microcontroller board that can undergoes analog-to-digital (ADC) conversion for the pulse signal. Moreover, the communication between the pulse sensor and the mobile phone can be controlled by this kind of microcontroller.

Arduino works to detect read the serial communication. The size of the command will be read by Arduino in this project. Subsequently, Arduino will start to process the command and compare the data after receiving the data. The process compare the data is using 'st*ring compare'*. If the process is success, Arduino will proceed to next step that create a while loop to receive the pulse signals. Then, the collected data will transmit to the phone. The program flow is illustrated in Figure 11.

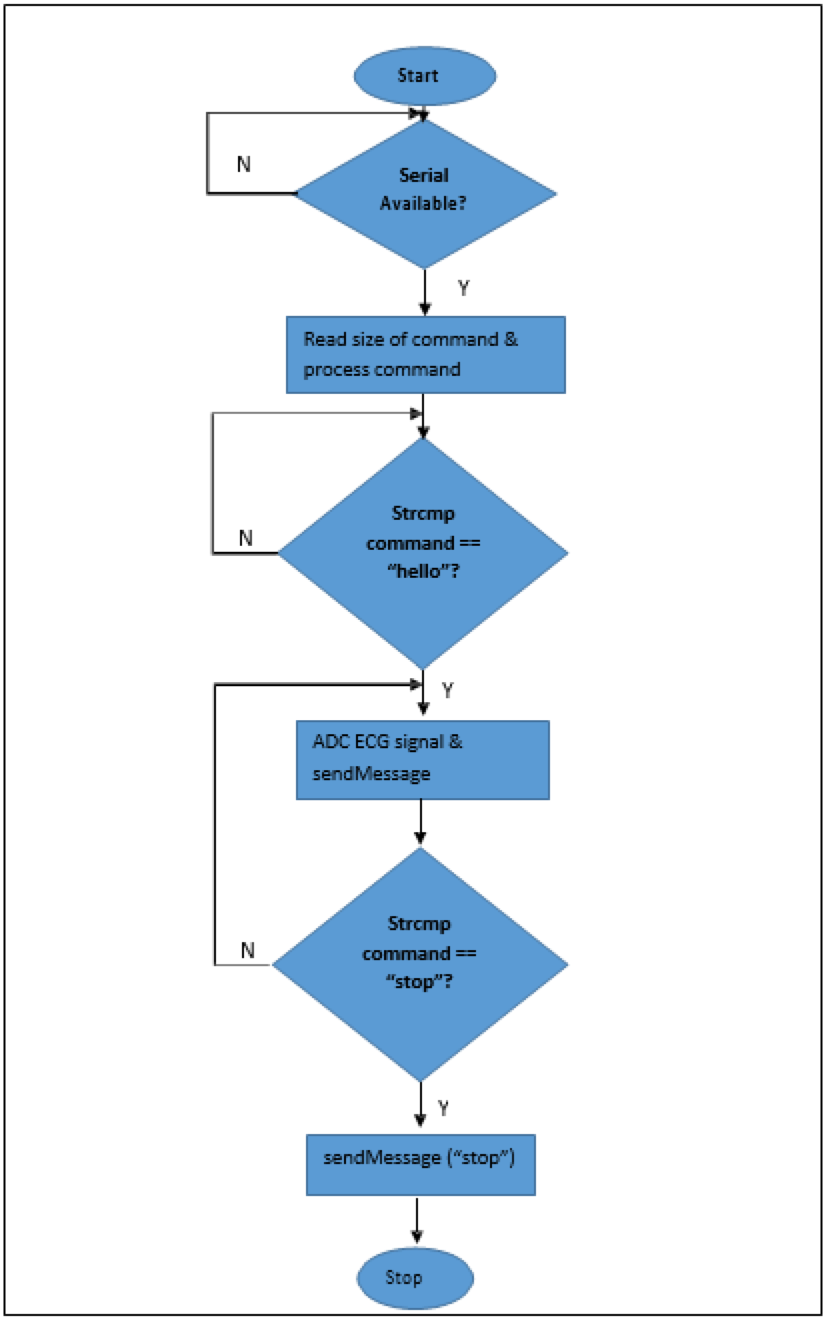


FIGURE 11: Overall Flow Chart

3.3.2 Pulse Sensor

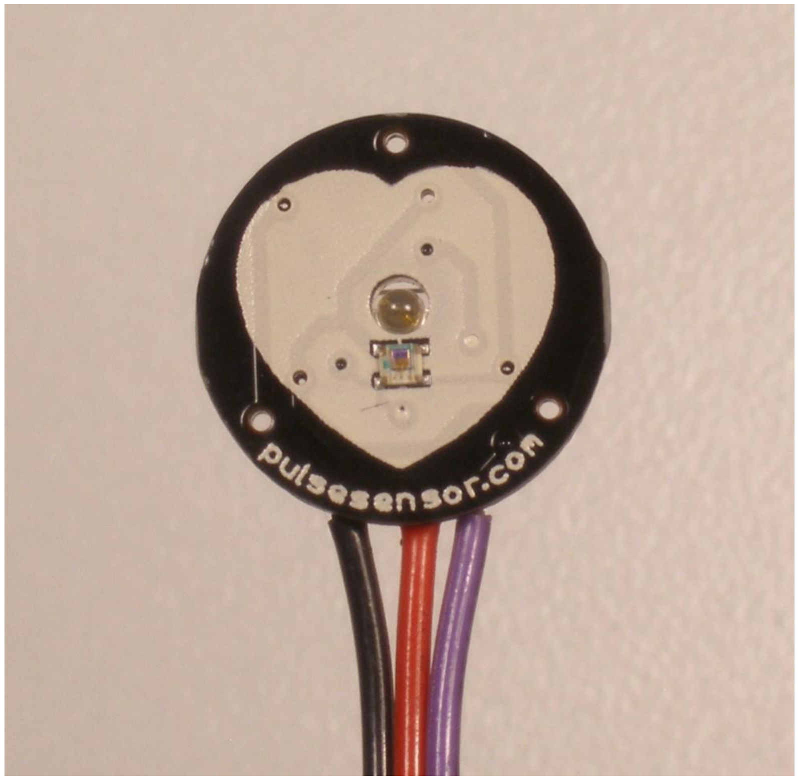


FIGURE 12: Pulse Sensor

A Pulse sensor as shown Figure 12 above is a monitoring component that enables to capture the pulsation of the heart in Beats per Minute (BPM) rate. The pulsation signals received from the heart represent the rhythmic contraction and expansion of the arteries corresponding to heart. The beat LED is keep flashing to sense the signals once the sensor is powered. The electric signal will collected and sent to microcontroller for proper processing and determination of the heartbeat. The most obvious spots for measuring the pulses are wrist, neck, chest, inside of the elbow and ankle joint.

3.3.3 Bluetooth Protocol: HC05-Bluetooth Module

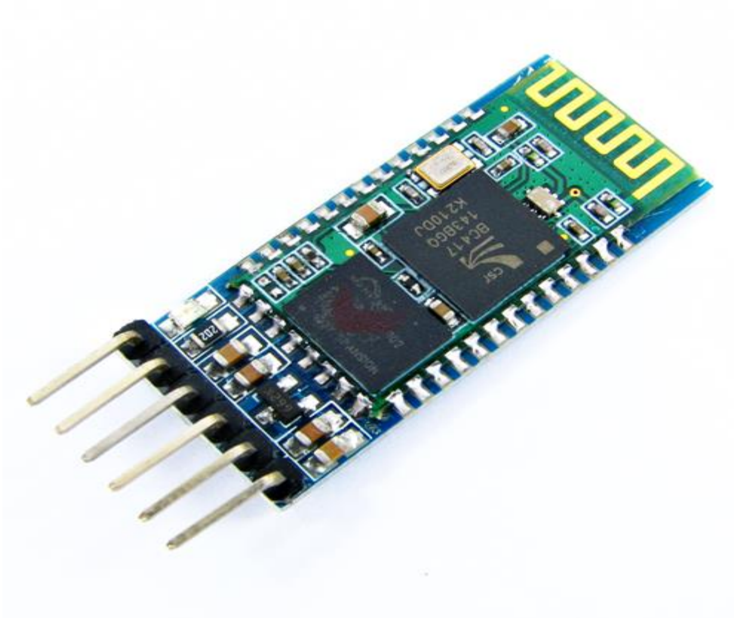


FIGURE 13: HC05-Bluetooth Module

Figure 13 shows HC05-Bluetooth Module which is a Bluetooth module used to transmit the pulse signals. The module gives an option of both master and slave. HC05-Bluetooth Module can be tested by transmit the data to computer with simple coding. After finishing the testing, it will implement to Arduino. Finally, the pulse signals will be amplified by Arduino collected can be transmitted to phone using Bluetooth protocol after the transmission is succeeded. Datasheet of HC05-Bluetooth shown in Figure 14.

PIN Name	PIN #	PAD Type	Description
GND	13,21,22	VSS	Ground Pot
3.3 VCC	12	3.3V	Integrated 3.3V(+) supply with On-chip linear regulator output within 3.15-3.3V
AIO0	9	Bi-directional	Programmable input/output line
AIO1	10	Bi-directional	Programmable input/output line
AIO0	23	Bi-directional RX EN	Programmable input/output line, control output for LNA (if fitted)
AIO1	24	Bi-directional TX EN	Programmable input/output line, control output for PA (if fitted)

FIGURE 14: Datasheet of HC05-Bluetooth

CHAPTER 4

RESULTS & DISCUSSION

4.1 OVERVIEW OF MOBILE APPLICATION

A user-friendly mobile application is developed to records the heart rhythms wirelessly. The HC-05 Bluetooth module and mobile phone is connected to record the heart rate of a person.

The icon shown from Figure 15 to Figure 18 included a set of buttons assigned to different function. The Step to start the application is as below:

1. Start the application shown in Figure 15.

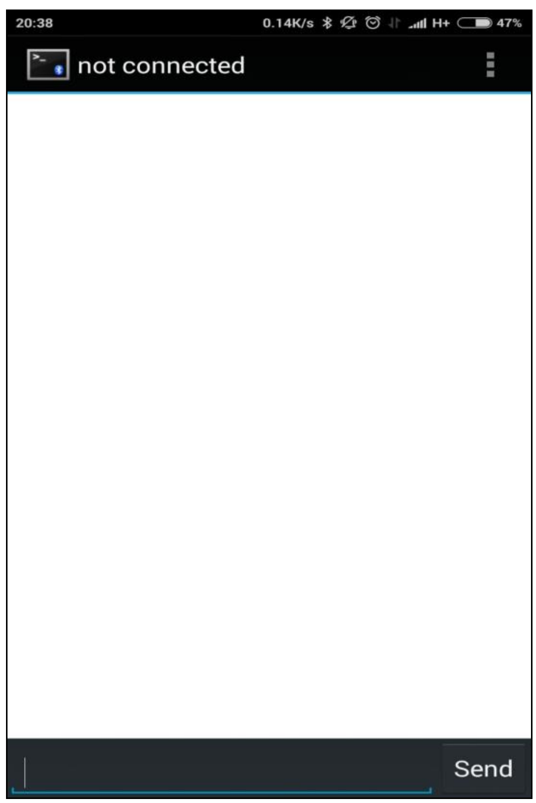


FIGURE 15: Starting of Application

2. Click the ‘Option’ button Shown in Figure 16.

FIGURE 16: ‘Option’ Button List

3. Connect to HC-05 Bluetooth Module shown in Figure 17.

FIGURE 17: Device to Connect

4.2 RESULT FROM MOBILE PHONE

Once the signal is being converted, the mobile phone which acts as a receiver will collect the recording data from the microcontroller by using Bluetooth protocol. The results are shown at the screen of mobile phone to let the users indicate and monitor their heart rate. The heart rate shown represented the pulse signal captured from the body every 2mS. Figure 18 shows the heart rate result from the mobile phone.

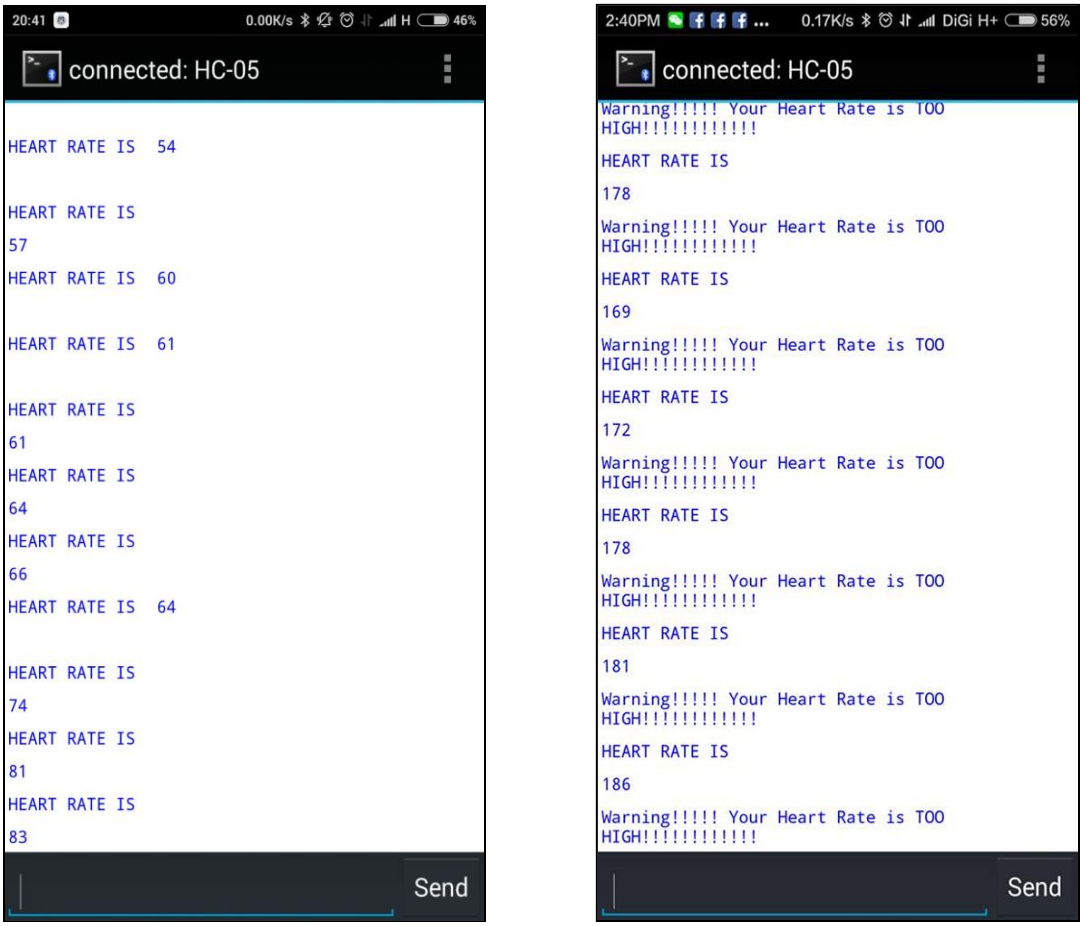


FIGURE 18: Heart Rate Result

4.3 RESULT FROM COMPUTER

Figure 19 shows the result from the Pulse Sensor Amped Visualizer. The graph indicates the amplitude of the pulse signal in the pulse waveform curve. In addition, the big red heart shown at the top screen represents the heart rate of the user. The graph is synchronized with the user to show the Beats Per Minute every 2mS. When the Pulse Sensor touched the user’s fingertip, a nice saw-tooth waveform is generated and shown. The pulse sensor amped works as pulse sensor to capture the pulse of the arteries corresponding to the heart. The pulse sensor amped incorporates amplification and noise cancellation circuitry into the hardware. It is compatible with 3.3 microcontroller and 5v microcontroller. The pulse signals are given to the microcontroller for calculating the heat beat rate, given by the formula:

BPM (Beats per minute) = 60*F, where F is the pulse frequency.

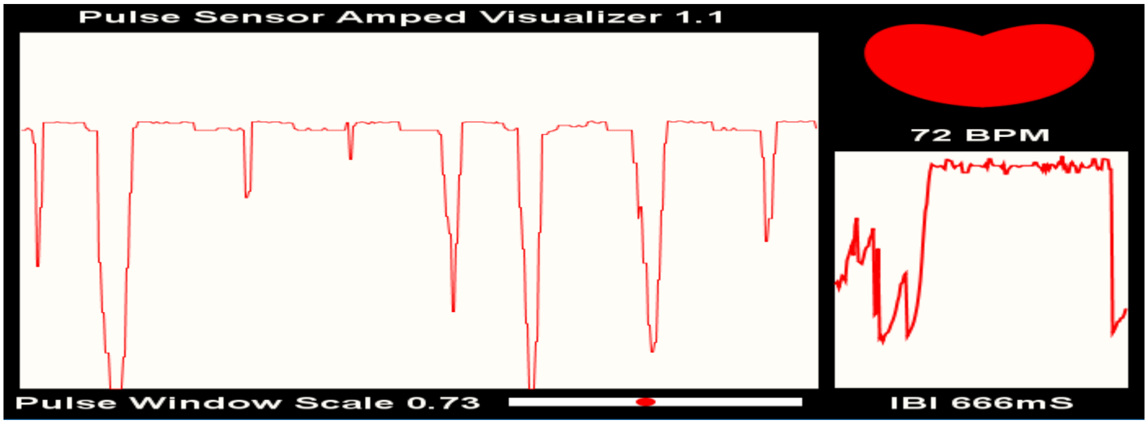


FIGURE 19: Result From Pulse Sensor Amped Visualizer

4.4 COMPARISON WITH EXISTING PRODUCT

The result gathered from the prototype is comparing with the existing product which is Omron HEM-7203. The percentage error of the result within two products is quite low that less than 4.1% shown in Table 8. The experiment has been conducted among 5 students. The heart rate of the students is measured by the prototype and the existing product Omron HEM-7203 as table 8 below. Figure 20 shows the result comparison with Omron HEM-7203. The percentage error is calculated given by the formula:

$$\frac{|\text{Experimental Value} - \text{Theoretical Value}|}{|\text{Theoretical Value}|} \times 100\%$$

TABLE 8 : Percentage Error of Results

Students	Reading of Prototype, (BPM)	Reading Omron HEM-7203, (BPM)	Percentage Error,%
1	69	72	4.1%
2	99	97	2.0%
3	83	83	0.0%
4	114	110	3.6%
5	130	133	2.3%

FIGURE 20: Result Comparison with Omron HEM-7203

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Throughout this project, a heart monitoring device using mobile phone by wireless sensor network will be able to detect the heart disease by analyzing the heart rate. A real-time monitoring system is presented appropriate for users with heart attack disease. The device can receive the real-time measurement data and transmit the data via Bluetooth protocol. The proposed system is based on a simple and inexpensive wearable sensor that detects heart rate and sends it wirelessly to a mobile device via an Arduino microcontroller. The percentage error of the result within the prototype and existing product Omron HEM-7203 is quite low that less than 4.1%. All the objectives are achieved.

In the future, adding biometric authentication can be modified to this idea. The sensors can become attached to and embedded in the human body, more heart disease can be monitored by modifying the system. The monitoring devices can added with the minimum and maximum thresholds which can be adjusted if necessary.

REFERENCES

1. Romero, I., B. Grundlehner, and J. Penders, *Robust beat detector for ambulatory cardiac monitoring.* Conf Proc IEEE Eng Med Biol Soc, United States, 2009. Vol.**4**(5) :p. 950.

2. Kasper Dennis L, *Principles of Internal Medicine, 16th ed.* 2005:pp. 1425-1430.

3. Rad, M.Z., et al., *Real Time Recognition of Heart Attack in a Smart Phone.* Journal Acta Inform Med, 2015. Vol.**23**(3): pp. 151-4.

4. Al-Omary, A., *Heart Disease Monitoring System Using Web and Smartphone.* International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2014. Vol.**3**(4): pp 8265- 8273.

5. Bhoyar, M.R., *Heart Attack Detection System Using Android Phone.* International Journal For Engineering Applications And Technology, 2010. Vol. **2**(1): pp 2321-8134.

6. Yi Shu, *A Pressure Sensing System for Heart Rate Monitoring with Polymer-Based Pressure Sensors and an Anti-Interference Post Processing Circuit.* IEEE Trans.Biomed. Eng United States,2010.Vol. **14**(2):pp.1248-1903.

7. *Carematix Wireless Solutions for Welness Monitoring.* Retrieved October 29, 2015, from http://www.carematix.com/.

8. *New England Healthcare Institute, Remote Physiological Monitoring: Innovation in the Management of Heart Failure, NEHI Innovation Series.* Retrieved October 14, 2015, fromhttp://www.nehi.net/CMS/admin/cms/_uploads/docs/HF%20Report%20Exec%20Summary.pdf.

9. Leijdekkers, P., *A Self-test to Detect a Heart Attack Using a Mobile Phone and Wearable Sensors.* 21st IEEE International Symposium on Computer-Based Medical Systems, 2007.Vol.**5**(3):pp 1829-1888.

10. F.Caren, J., *Holter Monitor*. 28th Annual International Conference of the IEEE,United States,2010.Vol. **1**(1):pp 1678-1681.

11. Mal, S., *RFID-Enabled Wireless Heart Monitoring* . 4th Consumer Communications and Networking Conference of IEEE,2010.Vol. **4**(2):pp732-736.

12. Kappiarukudil, K.J., *Real-Time Monitoring and Detection of Heart Attack Using Wireless Sensor Network.* 2010 Fourth International Conference on Sensor Technologies and Applications, 2010.Vol.**2**(2):pp135-1048.

13. Murthy, A., *Developing Trends in Cardiac Monitoring Systems.* International Journal of Advanced Research in Computer and Communication Engineering, 2014. Vol.**3**(1):pp778-886.

14. Jeffrey F. Caren, *Holter Monitor*. Diplomates American Board of Internal Medicine & Cardiovascular Diseases ,2010.Vol. **2**(2): p148.

15. El-Aty, A.A., *Wireless Wearable Body Area Network (WWBAN) for Elderly People Long-Term Health-Monitoring.* Proceedings of 29th Annual International Conference of the IEEE EMB, United States ,2010.Vol. **1**(2): pp1206-1708.

APPENDIX A: GANTT CHART AND KEY MILDSTONE

Referring to Table 9 and Table 10, the project timeline for FYP I and FYP II has been scheduled.

TABLE 9: Timeline for FYP 1

Details/Week	FYP 1													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature Review (Feature extraction and classification methods)	■	■	■	■	■	■	■	■						
Methods Selection								◆						
Preparing platform									■					
Platform ready									◆					
Collection the project components										■	■			
Project components ready											◆			
Developing the program coding and algorithm(Pre-processing)												■	■	■
Testing the initial result of the coding algorithm														■ ◆

■ Project Activities

◆ Key Milestone / Project Achievements

TABLE 10: Timeline for FYP 2

No.	Details/ Week		FYP II														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Algorithm Development		■	■	■												
2	Experimental Evaluation			■	■	■	■			■	■	■	■				
3	Comparative analysis						■	■	■			■	■	■			
4	Pre-sedex											◆					
5	Project Viva														◆		
6	**Documentation**	Progress Report							◆								
		Draft Final Report											◆				
		Dissertation (soft copy)												◆			
		Technical Paper												◆			
		Dissertation (hard bound)															◆

APPENDIX B: DATASHEET OF HC-05 BLUETOOTH MODULE

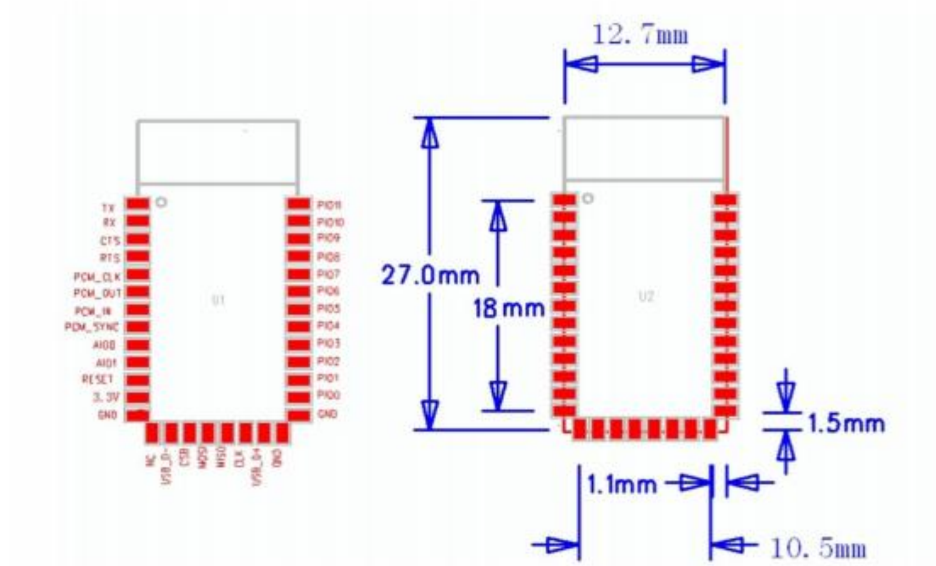


FIGURE 21: Hardware of HC-05 Bluetooth Module

PIN Name	PIN #	PAD Type	Description	Note
GND	13,21,22	VSS	Ground Pot	
3.3 VCC	12	3.3V	Integrated 3.3V(+) supply with On-chip linear regulator output within 3.15-3.3V	
AIO0	9	Bi-directional	Programmable input/output line	
AIO1	10	Bi-directional	Programmable input/output line	
AIO0	23	Bi-directional RX EN	Programmable input/output line, control output for LNA (if fitted)	
AIO1	24	Bi-directional TX EN	Programmable input/output line, control output for PA (if fitted)	

PIN Name	PIN #	PAD Type	Description	Note
PIO2	25	Bi-directional	Programmable input/output line	
PIO3	26	Bi-directional	Programmable input/output line	
PIO4	27	Bi-directional	Programmable input/output line	
PIO5	28	Bi-directional	Programmable input/output line	
PIO6	29	Bi-directional	Programmable input/output line	
PIO7	30	Bi-directional	Programmable input/output line	
PIO8	31	Bi-directional	Programmable input/output line	
PIO9	32	Bi-directional	Programmable input/output line	
PIO10	33	Bi-directional	Programmable input/output line	
PIO11	34	Bi-directional	Programmable input/output line	

FIGURE 22: Datasheet of HC-05 Bluetooth Module

APPENDIX C: DATASHEET OF ARDUINO UNO

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

FIGURE 23: Summary of Arduino Uno

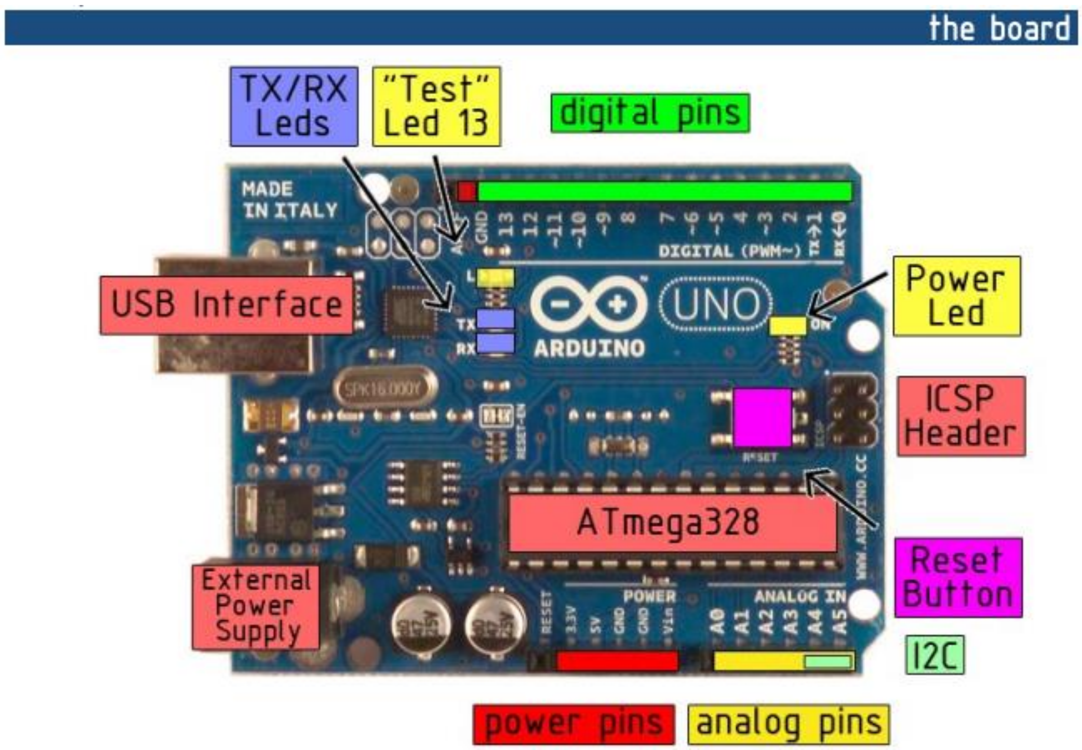


FIGURE 24: The Board of Arduino Uno

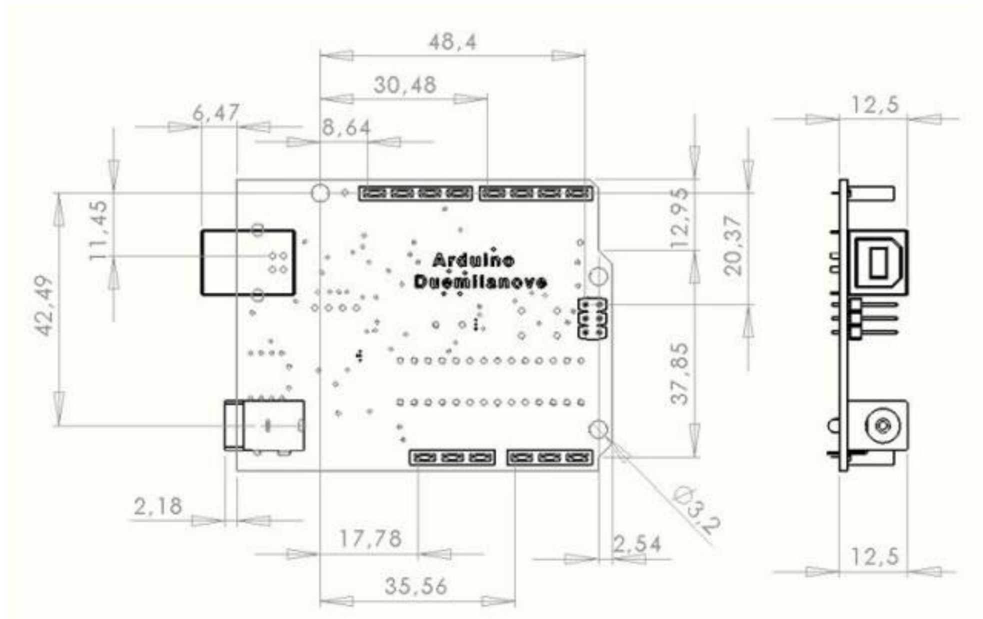


FIGURE 25: Dimension Drawing of Arduino Uno

APPENDIX D: PSEUDOCODE FOR PULSE SENSOR AND MOBILE PHONE

Initialize counter to zero

Initialize heart rate to zero

While counter is equal to ten

    print “average of heart rate”

if the average of heart rate is more than 120 or less than 60

    print the “the heart rate too high or too low”

else

    print “normal heart rate”

APPENDIX E: ARDUINO CODING FOR PULSE SENSOR AND MOBILE PHONE

```
#include <SoftwareSerial.h>// import the serial library
SoftwareSerial Genotronex(10, 11); // RX, TX
int ledpin=12; // led on D13 will show blink on / off
int BluetoothData; // the data given from Computer

//  Variables
int pulsePin = 0;                 // Pulse Sensor purple wire connected to analog pin 0
int blinkPin = 13;                // pin to blink led at each beat
int fadePin = 5;                  // pin to do fancy classy fading blink at each beat
int fadeRate = 0;                 // used to fade LED on with PWM on fadePin

// Volatile Variables, used in the interrupt service routine!
volatile int BPM;                   // int that holds raw Analog in 0. updated every 2s
volatile int Signal;                // holds the incoming raw data
volatile int IBI = 600;             // int that holds the time interval between beats! Must be seeded!
volatile boolean Pulse = false;     // "True" when User's live heartbeat is detected. "False" when not a "live
beat".
volatile boolean QS = false;        // becomes true when Arduoino finds a beat.

// Regards Serial OutPut  -- Set This Up to your needs
static boolean serialVisual = true;   // Set to 'false' by Default.  Re-set to 'true' to see Arduino Serial
Monitor ASCII Visual Pulse


void setup(){
  pinMode(blinkPin,OUTPUT);         // pin that will blink to your heartbeat!
  pinMode(fadePin,OUTPUT);          // pin that will fade to your heartbeat!
  Serial.begin(115200);             // we agree to talk fast!
  interruptSetup();                 // sets up to read Pulse Sensor signal every 2mS
   // UN-COMMENT THE NEXT LINE IF YOU ARE POWERING The Pulse Sensor AT LOW
VOLTAGE,
   // AND APPLY THAT VOLTAGE TO THE A-REF PIN
//   analogReference(EXTERNAL);
Genotronex.begin(9600);
  Genotronex.println("Bluetooth On please press 1 or 0 blink LED ..");
  pinMode(ledpin,OUTPUT);
}


//  Where the Magic Happens
void loop(){

    serialOutput() ;

  if (QS == true){     //  A Heartbeat Was Found
                     // BPM and IBI have been Determined
                     // Quantified Self "QS" true when arduino finds a heartbeat
        digitalWrite(blinkPin,HIGH);     // Blink LED, we got a beat.
        fadeRate = 255;         // Makes the LED Fade Effect Happen
                                // Set 'fadeRate' Variable to 255 to fade LED with pulse
```

```
      serialOutputWhenBeatHappens();   // A Beat Happened, Output that to serial.
      QS = false;                      // reset the Quantified Self flag for next time
     }
    else {

    digitalWrite(blinkPin,LOW);           // There is not beat, turn off pin 13 LED
    }

  ledFadeToBeat();                     // Makes the LED Fade Effect Happen
 if (Genotronex.available()){
BluetoothData=Genotronex.read();
  if(BluetoothData=='1'){   // if number 1 pressed ....
  digitalWrite(ledpin,1);
  Genotronex.println("LED  On D12 ON ! ");
  }
 if (BluetoothData=='0'){// if number 0 pressed ....
 digitalWrite(ledpin,0);
  Genotronex.println("LED  On D12 Off ! ");
 }
}
 delay(20);                            //  take a break
}
```