A Low-Cost Sensor Based Smart and Efficient Health Monitoring System for Elderly People Using Internet of Things

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A thesis submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of
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Declaration

It is hereby declared that

1. The internship report submitted is my original work while completing degree at Brac University.
2. The report does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The report does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

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Approval

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has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Masters of Science in Electrical and Electronic Engineering on 16th October 2020.

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Ethics Statement

This is to certify that this thesis titled "A Low-Cost Sensor Based Smart and Efficient Health Monitoring System for Elderly People Using Internet of Things" is the result of my study for partial fulfillment of Master of Science in EEE degree under supervision of Dr. Md. Shohrab Hossain, Professor, Department of EEE, BUET and no part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. A part of this thesis has been published as a conference paper in ICASERT 2019, East West University, Dhaka, Bangladesh. Any material reproduced in this project has been properly acknowledged.

Abstract

A smart and connected healthcare system is one of the most popular applications enabled by the Internet of Things (IoT). It is possible to get a rich informative indication of our physical health using networked sensors either worn or embedded in our living environments. As the aging population is constantly rising both in rural and urban areas, there is a need for an IoT-based health monitoring system to continuously monitor their health. As a result, visits to the doctors for a regular check-up is minimized and doctors can save many lives by providing valuable services in emergency purpose. In this research, a progressive method for IoT-based health monitoring system has been proposed. An architecture customized for healthcare applications is proposed and implemented as a prototype. The proposed system collects data from a patient's body using different sensors such as an ECG sensor, Pulse Oximeter sensor, and Temperature Sensor and sends it to the cloud where it is processed and analyzed. A video surveillance camera has also been used here to continuously monitor a patients' movement. In this study, a system is designed to frequently monitor the ECG signal, blood oxygen level, temperature, heart rate from the patient's body using wearable sensors, and the data is stored in the database which can be accessed by authorized personnel only. When any abnormalities are found in a patients' body an automatic email has been sent to the users and doctors for analyzing the critical conditions of the patients and provides emergency health assistance. The prototype of the proposed system for remote health monitoring has been built to demonstrate its performance advantages and the result shows that the system is efficient for remote health monitoring. It can be invoked from a remote location and in any case of abnormalities found in the patient's body an emergency email will be sent automatically to the authorized doctors and users.

Dedication

This study is wholeheartedly dedicated to my beloved parent and sisters, who have been my source of inspiration and gave me strength when I thought of giving up.

Acknowledgement

First, I would like to express my heartiest gratefulness to Almighty Allah for the blessings. Without his blessings it would not possible to complete my thesis successfully. I would like to express my gratitude to the people who helped and supported me throughout this thesis.

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Tamanna Shaown

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List of Acronyms

AAL	Ambient Assisted Living
BPM	Beat Per Minute
CoAP	Constrained Application Protocol
ECG	Electrocardiogram
HR	Heart Rate
HTTP	Hyper Text Transfer Protocol
IoT	Internet of Things
ITU	The International Telecommunication Union
IR	Infrared
MQTT	Message Queuing Telemetry Transport
M2M	Machine to Machine
NFC	Near Field Communication
PDA	Personal Digital Assistant
SDA	Serial Data Line
SCL	Serial Clock Line

List of Symbols

n	Sample Size
n-1	Degrees of Freedom
s	Sample Standard Deviation
$\bar{X}$	Sample Mean
μ	Hypothesized Population Mean

Chapter 1

Introduction

This chapter describes the background and the motivation for this research work done by briefly introducing the field of Internet of Things (IoT). This chapter also includes objectives, contributions and concludes by pointing out the outlines of the research area.

1.1 Introduction to Internet of Things

The Internet of Things (IoT) is one of the most progressive and developed in information and communication technology. It is a concept of reflecting a connected set of anyone, anything, anytime, anyplace, any service, and any network. The IoT is a significant trend in next-generation technologies that can impact the whole business spectrum and can be thought of as the interconnection of uniquely identifiable smart objects and devices within today's internet infrastructure with broadened benefits. Benefits typically include the advanced connectivity of these devices, systems, and services that go beyond machine-to-machine (M2M) scenarios [1]. Therefore, the IoT provides appropriate solutions for a large-scale of applications such as smart cities, traffic congestion, waste management, structural health, security, emergency services, logistics, retails, industrial control, and health care. A rising portion of IoT devices is created day by day for consumer use and lessen their burden also including connected vehicles, home automation, wearable technology, connected health care system, and appliances with remote monitoring capabilities [2]. The interested reader is referred to [1]–[6] for a deeper understanding of the IoT. The emerging paradigm of the Internet of Things (IoT) is specially focused on collecting and processing data everywhere and all the time [7]-[10]. This is essentially a platform where embedded devices are connected to the internet, so they can collect and exchange data with each other. It enables devices to interconnect, collaborates, and, learn from each other's experiences just like humans do. IoT is a network in which all physical objects are connected to the internet through wireless communication technology and facilitates the sharing of information among them. The most important properties of IoT include artificial intelligence, connectivity, sensors, active engagement, and using small devices. IoT applications bring enormous value into our lives with wireless network, useable different sensors, and comprehensive computing capabilities, the Internet of Things could be the next frontier in the race for its share of the wallet. Fig. 1.1 shows how the Internet of Things (IoT) is connected for a wide range of applications such as smart cities, intelligent transportation, waste management, agriculture, structural health, security emergency, smart grid and metering, connected objects, and smart homes, emergency services, logistics , retails, industrial control and healthcare.

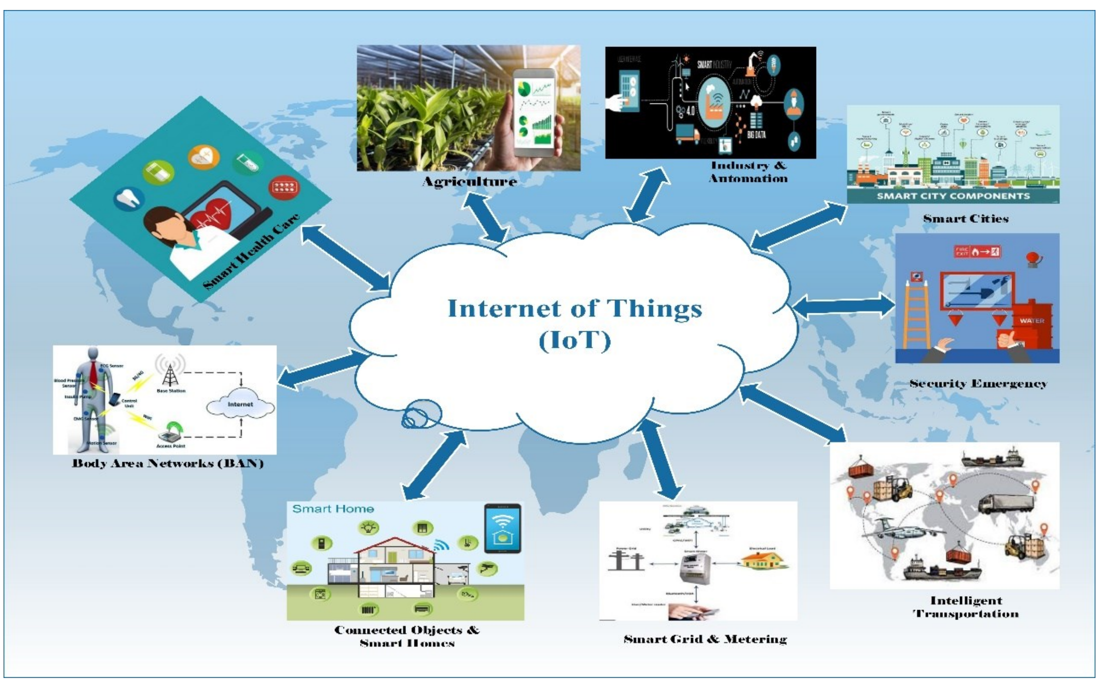


Figure 1.1: Uses of Internet of Things (IoT)

1.2 Internet of Things in Health Care system

Health-care is one of the most attractive applications of the Internet of Things (IoT) in the present era [11]. Treatment with willingness and medication at home by healthcare providers is another important application of IoT. Now –a –days various medical devices, sensors, and diagnostic can prospect as smart devices or objects form a core part of the Internet of Things (IoT).

The Internet of Things (IoT) has many purposes in medical areas such as distant patient monitoring, dietary program, testimony of chronic diseases, elderly people care, hygiene monitors, sleep monitors, blood pressure monitoring, heart rate monitoring, ECG monitoring, glucose level sensing, oxygen saturation monitoring, rehabilitation system, wheelchair management, calorie count, etc. The elderly population is rising continually both in rural and urban areas, so observing their health regularly with the desire of staying at home and at low cost is one of the basic appeals. As a direct consequence, the average percentage of elderly people, a person who is above 65 years old is 7% worldwide [12]. The percentage can more likely to rise in the nearer future. So this situation claim challenges to the government and healthcare sector to maintain the health of elder people and enhance the quality of their life. Among all the healthcare facilities provided for old people such as hospitals, health centers, and home care, private clinics – home care is preferred by the majority of elderly people [13]. Healthcare personnel can assess, diagnose, and prescribe elderly people by gathering medical information from remote regions by using IoT. The significant part of IoT can be used in so many medical equipments, sensors, and imaging devices to primarily determine the patient's health statuses and to deliver the proper care in the shortest possible time. The IoT-based healthcare system can be implemented at low cost hereby maximizing the satisfaction of users. In the area of healthcare, devices are being designed for many purposes such as patient monitoring to help them manage particularly chronic conditions [14], recovering from injuries [15], or design of Ambient Assisted Living (AAL) environments [16]. Related to this idea, mobile health things (m-health) is a new concept of using smart mobile devices to create efficient healthcare services and solutions [17].

Therefore, various medical devices, sensors, and diagnostic and imaging devices can be viewed as smart devices or objects constituting a core part of the IoT. The main purpose of IoT based health care system is the ease of cost. Effective interactions through seamless and secure connectivity across individual patients, clinics, and healthcare organizations are an important trend.

1.3. Research Motivations

As mentioned above, the Internet of things (IoT) has attracted great attention in the health sector for both maximizing the satisfaction of users with minimizing cost. In developing countries like ours, medical treatment is very time-consuming and expensive. In traditional period healthcare professionals play a major role in patient's check-up. The patient always needs to visit the doctors for diagnosis and advising. This is a very time-consuming process as the patients need to get the appointment firstly and then check-up. Due to this long-term process, elderly people sometimes tend to ignore check-ups or postpone it. Then this is a very common case that, the doctors need to monitor his regular patient from a remote area which sounds very expensive. With the growing rate of elderly people's health monitoring, rehabilitation is an emerging challenge as they require seamless networking between people, medical instruments, and doctors. This initiates the need for reasonably priced, low power, dependable devices that will improve the quality of life for many elderly and physically disabled people. Thus, an IoT-based health monitoring system can be implemented to give proper care to elderly people. Health conditions of aged people needed to be checked on a regular basis which is a greater challenge both in medical research and hospitals. The IoT-based health monitoring system can reduce the time and cost of visiting doctors on a regular basis and can be very helpful in the primary diagnosis of major health-related problems within the shortest possible time. The heart rate, ECG report, body temperature, blood pressure, blood oxygen saturation level are the primary parameters to diagnose diseases in an emergency.

The system proposed an architecture of IoT- based smart health monitoring system for elderly people. Here, different sensors have been used such as ECG sensor, temperature, pulse oximeter, and heart rate sensor, and a camera for video surveillance for regularly monitoring of a patient's health. Raspberry pi has enabled the sensors which are in contact with the human body and monitor his or her physiological parameters. Sensors will collect the data from the patient's body and send it to the IoT cloud using Wi-Fi. And in any case of abnormalities found in the patient's body such as -abnormal ECG, abnormal pulse rate, abnormal temperature, and abnormal movement the system will send an email to the doctors in the hospital and the patient's relatives thus detecting the critical health conditions of elderly people. So basically, our system is useful in health monitoring for elderly people without visiting the doctors frequently and can get valuable service in times of need.

1.4 Research Contribution

This thesis studied the communication-related aspects of Internet of Things devices and systems in the context of eHealth for Smart regions. In the next several years, the medical era is expected a revolution in health monitoring using IoT and flourish through new e- Health IoT devices and applications.

- Cardiovascular disease is one of the main causes of death worldwide. People can also be disabled by cardiovascular disease. Due to the late detection of heart attack, we are unable to save human life. Heart rate monitoring is a very secure way to predict sudden death. An intelligent IoT-based heart monitoring system, as a sudden death predictor, is proposed in this paper.

- An ECG monitoring system is also introduced here, which can collect ECG data from the human body and compare it with ideal data on the website and can normally detect heart-related problems of the patients and doctors can prescribe them in case of emergency. So there is no need for continuous visiting doctors in hospitals.
- This system also able to collect temperature related data of a patient, and oxygen saturation level of a patient.
- A video camera is also attached in this proposed system to continuously monitoring of a patient.
- A sensor-based system is developed which can take all the data from the human body and will be saved in the database and compare it with some real-time references then send an email in case of emergency of a patient.

The contributions of this thesis work are to propose a trustworthy IoT-based health monitoring system for elderly people and implementing the system as a prototype. The novelty of our proposed model is to implement a low-cost, affordable, integrated system for personal health-care and it can be used in hospitals also. The system provides a real-time ECG monitoring system is introduced in this proposed system, so the doctor can prescribe patients by checking ECG data from the website. Patients' can take care of their health by avoiding regularly visit doctors in hospitals. Thus can people live a smart ambient assisted living.

1.5 Organization of the Thesis

This Thesis book contains five chapters.

Chapter 1 where I briefly describe the Internet of Things (IoT) and the uses of IoT in the healthcare system in nowadays. Then I discuss my research motivations in the field of health care sector using the Internet of Things (IoT) and also include the research objectives of the total thesis work.

Chapter II Provides the backgrounds and literature survey of IoT- based health monitoring system and also focused on familiarization of the elements and devices and there features those used in this project.

Chapter III presents the proposed system architecture using different sensors of IoT based health monitoring system.

Chapter IV focuses on the implementation of a prototype of the proposed system and also the methodology is described.

Chapter V describes the results and their analysis with the major findings of this research.

Chapter VI concludes the thesis by summarizing the total research, as well as identifying several potential research opportunities for future works.

1.6 Chapter Summary

This chapter has identified the introduction of the Internet of things (IoT) and also the importance of uses of IoT in the healthcare system. Next, a concise form of the research motivation objectives and contribution of this research is provided. Finally, for the convenience of the readers in following this research, a chapter-wise outline of the thesis is presented.

Chapter 2

Background and Literature Survey

This chapter summarizes the background and literature work on health monitoring using Internet of Things, including examples of smart health monitoring system.

2.1 Background

IoT provides promising technology for smart and assisted living. Remote healthcare monitoring for elderly people has increased average life expectancy and decreased mortality rate. Internet of Things (IoT) is one of the most promising technologies in Information and Communication Technology (ICT) for the last decades. At the center of the IoT example lies the idea of adding more defining, sensing, computing, and communication abilities to physical devices that previously not designed for this purpose. The improvement of IoT allows devices to communicate with each other, as well as other services and systems, thus gaining new information and obtaining new functionalities. The main hardware technology enablers of the Internet of Things are Radio-frequency identification (RFID), near field communication (NFC), and Sensor Networks; the software enablers of IoT are middleware and search/browsing [18]. The main purpose of IoT is to transform data into information, knowledge and finally wisdom. As a result, humans can build a reference or characterized view of the object of interest and act accordingly. There is a long list of existing IoT applications, and the list is still going on. IoT is currently present in energy management, environmental management, healthcare, transport & traffic management, logistics, and inventory management. All applications of the Internet of Things can be grouped into four main application domains: transportation & logistics, healthcare, smart environment (home, office, plant), and personal & social [19]. IoT has also been recognized as a turning point in reshaping the modern healthcare system with an aspiring vision that includes economical, technological, and social benefits. Nowadays a number of emerging applications in the healthcare section are being developed for various environments. A number of body wearable sensors devices have been developed commercially for continuous monitoring of health, personal activity, and physical awareness and fitness. Researchers have proposed so many new clinical applications of wearable or wireless technologies for remote health monitoring which records long term medical status recording and access to physiological information of the patient [20]. Internet of Things (IoT) related devices are fulfilled with higher resources related to storage, memory, processing, and analyzing which provides new features for controlling the system of IoT. Recently many researchers are trying to develop a number of wearable clinical devices in case of remote health monitoring for the individual health conditions of a patient. [21]. Thus a patients' health condition can be monitored from remote areas and provide emergency health support to them. Figure 2.1 shows the relation between healthcare with people, technology, and the economy. Thus the main objective of this research is to design a health monitoring system for elder patients based on IoT which also economic, scalable, and efficient. So that, the aged patient can check up their health status in a frequent manner and need not visit the doctors regularly.

IoT establishes a new illustration because of active content, product, or service engagement and utilizes purpose-built small devices to offer its limpidity, scalability, and versatility [22].

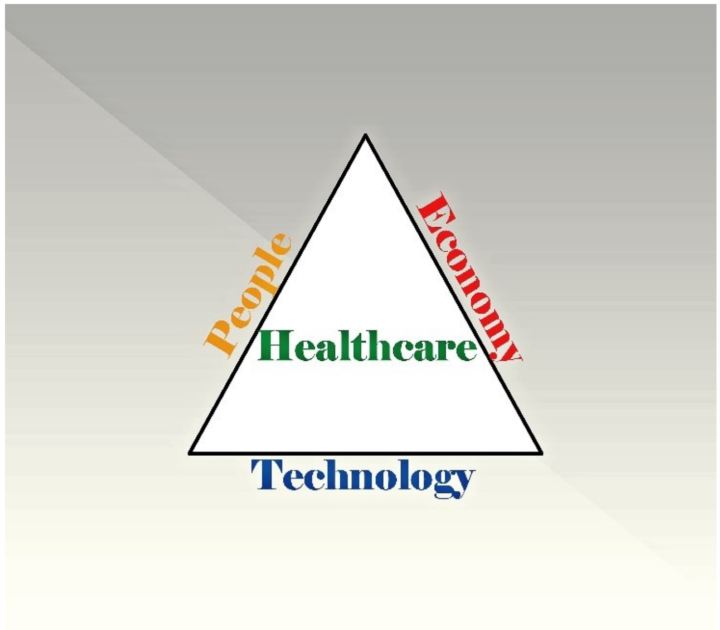


Figure 2.1: The relation among people, technology, and economy with healthcare system.

2.2 Internet of Things Standardization and Protocol

The Internet of Things (IoT) will provide technology to creating the means of smart actions for machines to communicate with one another with different information. The success of IoT depends on standardization which provides the ability to exchange and use information in a large heterogeneous network made up of several local area networks, compatibility, reliability, seamless and cost-effective operation on a global scale. However, according to Cisco IBSG's prediction, there will be around 50 billion machines connected electronically to the Internet by 2020 [23]. Fig. 2.2 shows the growth of things connected to the internet from 1992 to forecast 2020 [23]. In IoT, a massive number of M2M devices will need access to the network periodically to transmit their payloads with very low data rates requirements. These devices include wireless sensors, weather change, and environmental sensors, and vehicular communication, health monitoring, etc [24].

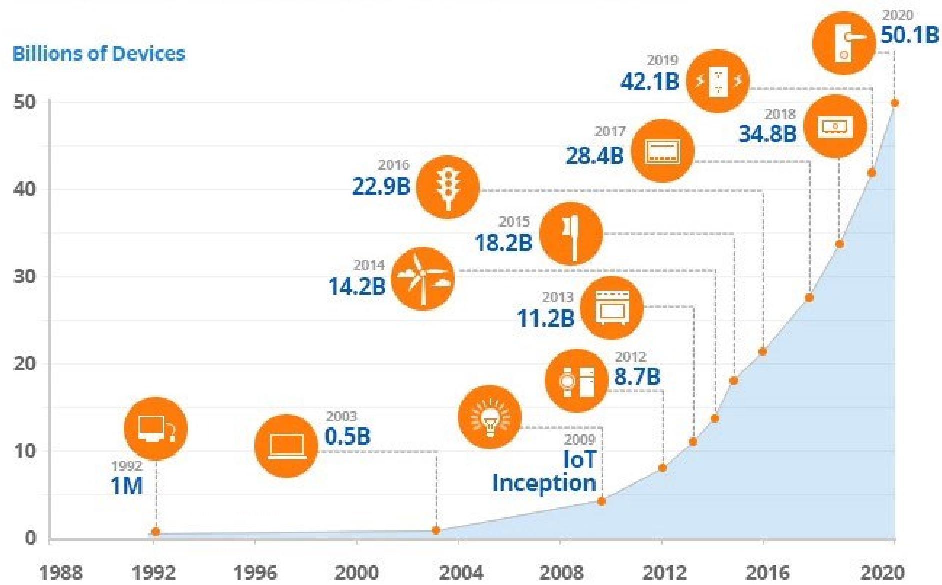


Figure 2.2: Expected umber of connected devices to the internet [23].

2.3 Literature Survey

Internet of Things (IoT) has recently been presented great attention due to its prospective capacity to be integrated into any complex system. As a result of the rapid development of sensing technologies such as radio-frequency identification, sensors, and the convergence of information technologies such as wireless communication and the Internet, IoT is emerging as an important technology for health monitoring systems.

IoT is used in patient monitoring where various types of wireless sensors are connected to the patient body that communicates with the IoT network and provides all the necessary information of the patient under treatment. All the applications of this technology are using to ease, facilitate, and better management, thereby developing the quality of life for human beings [25].

In 2001 the MIT Auto-ID center represented their Internet of Things (IoT) vision. The International Telecommunication Union (ITU) released ITU Internet Report 2005 that presents that, IoT can understand the interconnections between thing to thing depending on sensors and other connected equipment [26]. The core of IoT is to achieve interconnection, communication between things, and exchange of information. The definition and scope of IoT have changed and its coverage has been greatly expanded.

The rising Internet of Things (IoT) technologies for interconnected medical devices and sensors are performing a vital role in the healthcare section. A remote health monitoring system can help to detect the sudden death of patients. This focused on the relation between heart rate and pulse transit time during paced respiration [27].

Spine, Pascoli, Iannaccone, et al. developed a low-power wearable ECG monitoring system for multiple patient remote monitoring [28]. The authors developed a low-power ECG monitoring system with a wearable facility ZigBee protocol for data transfer from sensors but there was no real-time notification in this system. And the data transfer rate is lower in the ZigBee protocol compared with Wi-Fi.

Qiang et al. presented advances in wireless technology and have made it possible to record and transmit digital ECG signals from remote locations to the computer of hand-held PDA (Personal Digital Assistant) of a healthcare service holders instantly, but the system was very time consuming [29].

Sneha et al. [30] Proposed an architectural framework using mobile to monitor the ECG of cardiac patients. The main drawback of the system was it cannot be controlled without a mobile application. And the signal is transmitted firstly by using Bluetooth which is unable to cover huge areas. It can only detect primary cardiovascular diseases.

An integrated wireless system was proposed for heart failure patients who can detect ECG signals, Heart Rate Variability (HRV) continuously using a software-based algorithm [31]. IoT can be used in identifying human diseases since heart failure is a major problem nowadays. ECG monitoring is necessary both in homes and hospitals. A configurable and low power mixed-signal SoC for portable ECG monitoring applications. [32].

In hospitals, ECG data is collected using 12 electrodes. Basically, the ECG instrument measures the difference in voltage potential between each of the electrodes. In medical equipment which consists of 12 electrodes waveforms, only 8 waveforms can be measured and the rest of the 4 is extrapolated by measured waveforms. The equipment which is used in hospitals is not portable and also expensive for regular use at the home. So patients need to go to hospitals for their regular checkups. A low-cost ECG monitoring system for home and hospital use is highly needed. A low power mixed-signal SOC for portable ECG monitoring using Bluetooth protocol has been introduced. This system is portable because electrodes are usually less than traditional methods [33].

Azariadi et al. [34] proposed an algorithm for ECG signal analysis and arrhythmia detection using IoT for 24 hours of continuous monitoring. They used a Galileo board to implement the design.

Ghosh et al. [35] has implemented a healthcare system for hospital management which involved the relatives and doctors for continuously monitoring patient’s health condition using ARDUINO UNO. But the system does not provide any SMS or email alert.

Kumar et al. [36] has proposed a raspberry pi-controlled patient monitoring system where heartbeat, body temperature, respiration rate, body movement has been measured using sensors. But it provides no security as anybody can access the web and see the health-related data of a patient.

Telemedicine represents a very important role in assisting patients in their daily life. Custodio et al. [37] has been presented a review on architectures and communication technologies for the wearable health monitoring system.

Vassis et al. [38] proposed a pervasive architectural framework for providing remote medical treatment. The sensors acquire data from the patients and in emergency cases, the prototype sent alert messages to the users.

Wanda a remote health monitoring system for heart failure system consists of a smart-phone based data collection gateway, internet-scale data storage, and search system also is presented in [39].

Iannaccone, et al. [40] implemented a wearable low power ECG monitoring system for patient monitoring. Here ZigBee protocol is used for data transfer from the sensor but no real-time notification.

An open IoT platform has been proposed in [41] which is designed as a self-management model for chronic diseases, but the architecture was not extended to have a remote health monitoring system.

Mohammed et. al. [42] proposed an android-based health monitoring system using the IoT platform. This paper presents information about the infrastructure of the IOIO microcontroller, communication protocols, database management system, and large file compression system.

Gjoreski et al. [43] implemented a health monitoring system consisting of an ECG sensor and an accelerometer. The data supplied here was analyzed to extract physiological parameters from patients' bodies with related sensors.

The proposed design by Abo-Zahhad et.al. [44] is capable of measuring vital signs such as heart rate, blood pressure, blood oxygen level, and ECG of the patient and sending results using the internet. But for abnormal readings, alerts or data are sent through GPRS for the doctor and GSM for the patient's relatives to minimize the cost of sending data. But the authors did not provide tests and results to prove that their proposed design is working properly.

An IoT based heart rate monitoring system using sensors is easy to carry and can detect the abnormalities of the patient before exercise and recovery time. Electrocardiogram (ECG) heart rate monitoring system was first invented in 1977 for training aid in the Finnish National Cross-Country Ski team and retail sales of this system started in 1983.That time after detecting a heartbeat a radio signal is transmitted which is used by the receiver to determine the current heart rate. The signal may be a simple radio pulse signal from the chest strap, after that it confines one user's receiver from using signals from other nearby transmitters which are known as cross-talk. Now a day's heart rate monitoring system comprises a chest strap transmitter and a mobile phone. A Jorge Gmez et al. [45] system is proposed and developed a patient monitoring system based on the internet of things. The main objective of the article is to develop an architecture-based system capable of monitoring health and workout routine suggestions to patients with chronic diseases. The proposed architecture consists of the relationship between server and client. They developed an architecture based on an ontology that is not only capable of monitoring the health but also workout routine recommendations to patients with chronic diseases.

Kumar et al. [46] implemented a remote patient monitoring system using an android mobile. LM35 and ppm sensors are connected with microcontroller and data sent to an android based mobile application via Bluetooth and GSM module.

Jasses et al. [47] focused only on monitoring body temperature and pulse rate of a person using raspberry pi. The main idea of the paper is based on the integration of wireless health sensor networks and cloud computing.

Singh et al. [48] proposed a ZigBee and GSM-based patient health monitoring system which has also a lower data transfer rate than Wi-Fi.

Addressing all the limitations mentioned above, a system has been proposed for an IoT-based health monitoring system for elderly people. Here, the proposed system has been enabled the measurement of body temperature, pulse rate, ECG, patient's motion, blood oxygen level to evaluate the physical health status of elderly people. In this model, a video surveillance camera is introduced for continuous health monitoring of senior citizens. The system is affordable because we have used low-cost components in implementation.

2.4 Research Objectives

The main objective of this research is to propose an architecture of IoT-based health monitoring system using different sensors and also build up a prototype for health care in a cost effective manner. Thus, the objectives of this thesis can be summarized as below.

- To propose a new architecture for IoT-based Health Monitoring System.
- To implement a prototype for the proposed system.

- To collect health-related data such as ECG, Pulse Rate, Temperature, and the blood carrying the oxygen level from the patient's body using different sensors, motion, and visual sensing by camera sensor from patients room.
- To analysis all the data in the cloud database and send emergency mail to the authorized doctors and users in case of any abnormalities found in the patient's body.
- So the doctors can easily log in and check the patient's body conditions to study, prescribe and provide emergency services in times of need.
- This system will provide flexibility in health management system in a cost effective manner.

2.5 Chapter Summary

This chapter briefly describes the background of IoT for smart and assisted living for elderly people and a small survey of the number of rising internet-connected devices till 1992-2020. Then, this chapter includes a literature review from previously worked done in the area of health care using IoT.

Chapter 3

Proposed Architecture

3.1 Proposed Architecture of IoT-based Health Monitoring System

The main idea of the proposed system is to continuous monitoring of patient's health data using the Internet of Things (IoT). In this model, different sensors have been used such as an ECG sensor, temperature sensor, pulse oximeter sensor, and heart rate sensor, and a camera for continuous monitoring of a patient's health data.

Raspberry pi is enabled with the sensors which are in contact with the human body and monitor his or her physiological parameters. Sensors will collect the data from the patient's body and send it to the IoT cloud using Wi-Fi. And in any case of abnormalities found in the patient's body such as- abnormal ECG, abnormal pulse rate, abnormal body temperature, abnormal movement, and inaccurate blood oxygen level the system will send an email to the doctors in the hospital and the patient's relatives thus detecting the critical health conditions of elderly people. So basically, this system is useful in health monitoring for elderly people without visiting the doctors frequently.

An email can be sent using Wi-Fi to connected doctors or users in any case of emergencies. Existing systems for health monitoring basically use Bluetooth or ZigBee for data transfer, but in this system, Wi-Fi has been used which has a larger data transfer rate and wider coverage areas [49]. Being connected to the healthcare system through the internet of things doctors can view all the necessary data on command and check real-time patient's conditions and provide emergency health-care services.

The *contributions* of our work are to propose a trustworthy IoT-based health monitoring system for elderly people and implementing the system as a prototype. The *novelty* of our proposed model is to implement a low-cost, affordable, integrated system using *wi-fi* for personal health-care and it can be used in hospitals or other healthcare centers also.

A system architecture of our proposed health monitoring system is shown in Fig. 3.1.

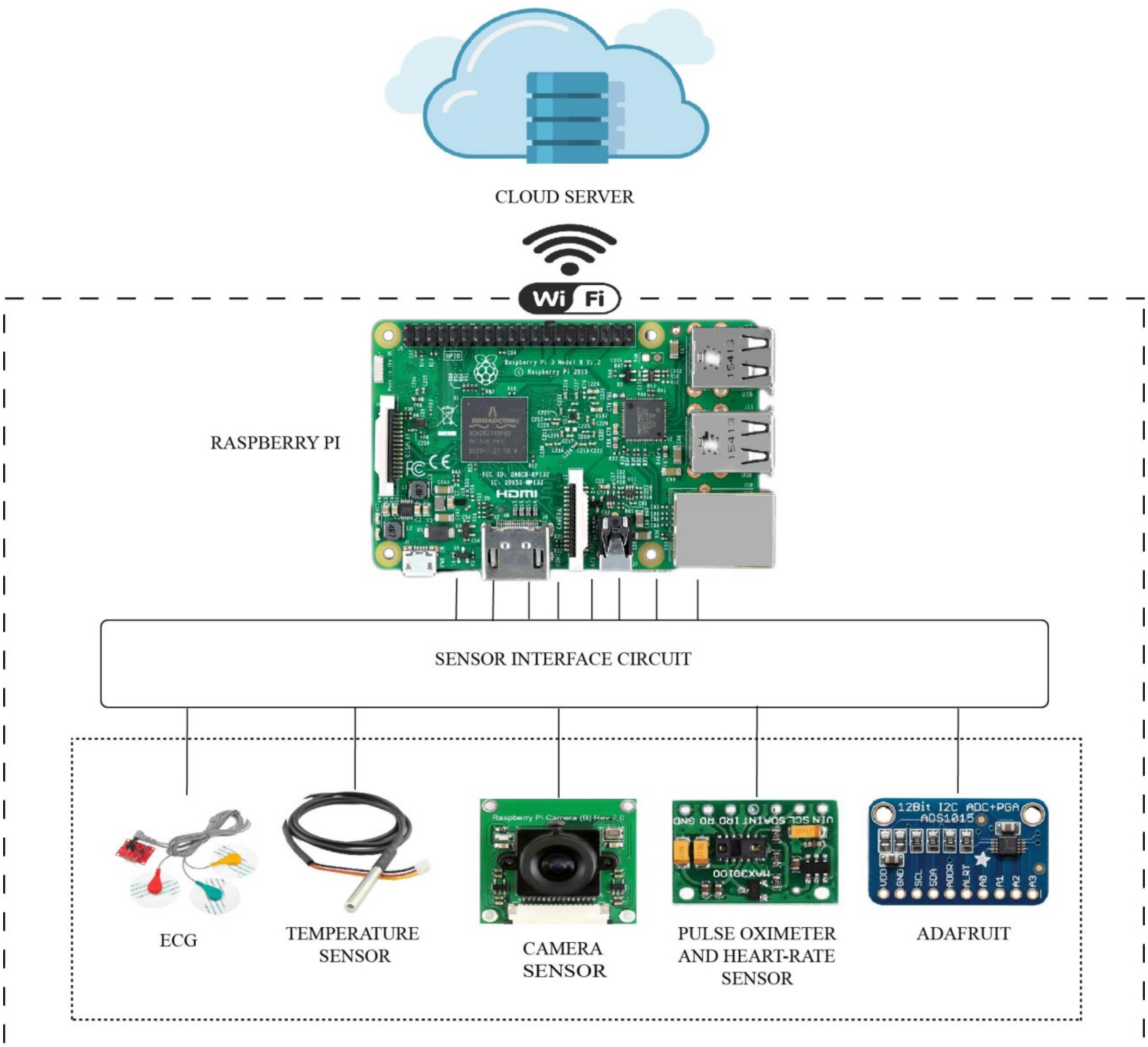


Figure 3.1: Proposed Architecture IoT-based health monitoring system.

In this research, a customizable IoT-based health monitoring system can be used to collect necessary data from the human body to improve the quality of living for elderly patients. The system designed with low-cost components, so that it can easily be used both in hospitals and homes.

ECG sensor, temperature sensor, and pulse oximeter, and heart rate sensor have been used to get primary health-related problems identification. A video camera is used here to collect the actual movement of the patient. An Electrocardiogram (ECG sensor), AD8232 is used here for primary data collection of certain heart diseases. A three-lead placement is adequate to analyze the primary features of the ECG signal [50]. Three lead ECG system hereby connecting electrodes on the patient's body.

In medical institutes or hospitals, conventional 12 leads systems are used to collect ECG signals from the patient's body. This device is too expensive to use at home or for personal use and cannot be used as portable. It takes a huge amount of time for routine checkups during each visit to hospitals and manual recording can also cause a human-made error. In such a manner, a low-cost portable system for continuous ECG monitoring is highly required. Most of the available ECG monitoring devices use smartphones for secondary data processing [51]. The uses of smartphones in data transfer and processing have great consequences on regular use due to its limitations of power and computational effectiveness. The prototype can also measure the pulse rate from the ECG sensor by connecting with ADA fruit. A camera is used here to sense the motion of a patient. A Raspberry Pi camera V2.1 8MP is used here for continuous monitoring of a patient. The proposed system worked with the Raspberry Pi 3B model.

The data are gathered from sensors that are collected from the patient's body are transmitted to the IoT cloud via a specific wireless protocol such as Bluetooth, Wi-Fi, ZigBee, etc. [52]. With satisfying energy consumption, all these three protocols can transfer enough data rates for transmitting all signals. Moreover, due to the limited communication ranges of Bluetooth and ZigBee, *Wi-Fi* is used in this proposed system. Comparisons among various types of ECG sensing networks are given in Table 3.1.

Table 3.1 Comparison among typical health monitoring system networks such as *Wi-Fi*, Bluetooth and ZigBee.

Standards	***Wi-Fi*-based health monitoring system network**	**Bluetooth-based health monitoring system Network**	**ZigBee-based health monitoring system Network**
Protocol	IEEE 802.11	IEEE 802.15.1	IEEE 802.15.4
Coverage	20-200 m	20-30 m	2-20 m
Data Rates	11-54 Mbps	3-24 Mbps	10-250 Kbps
Power Consumption	Medium	Low	Low
Terminal Dependency	Data Collection is independent of smart terminals	Smart terminals are needed for receiving and forwarding sensed data	Smart terminals are needed for receiving and forwarding sensed data

3.2 Physical Sensor

Different physical sensors are used in this system to collect user health information. ECG sensor, temperature sensor, Pulse Oximeter Sensor are used to get primary health-related problems. Electrocardiogram (ECG sensor), AD8232 is used here for primary data collection of certain heart diseases, here a three-lead ECG monitoring system is used by connecting electrodes in patients' body. It can also measure the pulse rate of a patient from the ECG sensor by connecting it with ADAfruit. A temperature sensor LM 35 is used to measure the body temperature of the patient and a Pulse Oximeter sensor is connected here to calculate the blood oxygen saturation level of a patient. This is small, inexpensive, easy to use, low power sensors. A Raspberry Pi camera V2.1 8MP is used here for continuous monitoring of a patient.

3.3 Sensor Interface Circuit

The signal collected from the sensors such as heartbeat, ECG, temperature, blood oxygen saturation level patients are sent to the Raspberry Pi via a sensor interfacing circuit that converts an analog signal coming from the sensors into digital signals. This system worked with the Raspberry Pi 3B model. It is responsible for collecting data from different sensors interfaced with it and send the data to a cloud server for further processing. The data gathered from the sensors can be transmitted through the cloud by IEEE 802.11 Wi-Fi wireless transceivers interfaced with Raspberry pi 3B.

3.4 Cloud Server

The data collected from patients' bodies are sent to a cloud server for analysis of the data and compared with normal data saved in the database. The cloud server is a large database that has enough space to store data for different sensors for a long time. Through the cloud, an email has been sent to the doctor or any registered person informing the abnormal heart rate, ECG data for cardiovascular diseases, critical temperature, critical blood oxygen saturation level of the body, and motion after detecting abnormal conditions.

With the help of an IoT cloud, computation-intensive data process and analysis task can be carried out so efficiently which greatly eases the burden of smart devices [53]. An IoT cloud server for health monitoring system mainly consists of four functional modules such as data cleaning, data storage, data analysis, and disease warning.

3.5 GUI (Graphical User Interface)

Graphical User Interface (GUI) is used for data imagination management. It contributes to the easy entry of the data in the IoT cloud. Users can log onto the cloud to acquire visualized ECG data in real-time. Generally, mobile applications and web pages are the two kinds of GUI's are available for users to visualize data. Although the mobile apps can ensure immediate response but web pages are the best options in terms of protection and up-gradation.

3.6 Chapter Summary

This chapter explains the proposed architecture of IoT-based health monitoring system for elderly people. It also includes a theoretical explanation of how health sensors are connected to the home gateway, fetching health-related data to the system for analyzing and monitoring.

Chapter 4

Implementation of a Prototype and Methodology

4.1 Introduction

IoT is growing rapidly. In the next several years, the medical era is expected to observe the widespread adoption of IoT and rise through new eHealth IoT devices and applications. Healthcare applications are awaited to deal with major private information such as personal healthcare data. In additionally we can say that these types of smart devices may be connected to global information networks for their access anytime, anywhere.

This chapter includes the implementation of a prototype of IoT based health care monitoring system for elderly patients using wearable sensors such as- ECG sensor, Pulse Oximeter Sensor, Pulse Rate Measurement, Temperature Sensor, and a Video Surveillance camera for 24 hours monitoring of a patient. In this chapter, all the sensors are described briefly with their specifications and the methodology of the implemented prototype.

4.2 Hardware Implementation

In figure 4.1, the raspberry pi is connected through different modules. The Arduino is connected to raspberry pi to take ECG by connecting AD8232 directly to it and also AD8232 is connected with ADS1115 for taking heartbeat for the patient. The temperature sensor is also connected to take body temperature. Here, there is another sensor named pulse oximeter sensor is connected to raspberry pi to detect the oxygen saturation level of a patient's body. Raspberry pi is also used as a server that sends data to our localhost. The Raspberry pi is powered with a power cell. We can see all the output in a 7'' LCD touch display. Then the data is analyzed and compared with the normal value and in case of emergency found it can send an email notification to connected professional care-givers and users of the device.

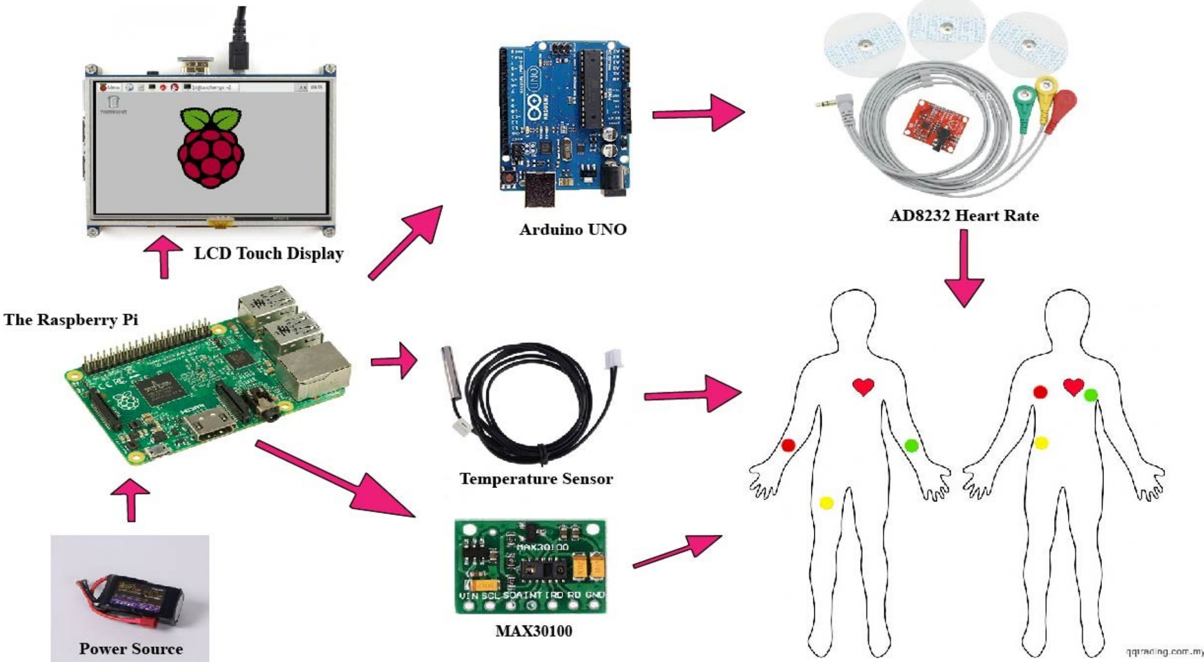


Figure 4.1: Hardware implementation of IoT-based Smart Heart Monitoring System.

Firstly, we have booted raspberry pi and calibrated its screen then I2C tools were installed to connect ADS1115 with raspberry pi. Then the ADS1115 analog input pin A1 is connected with ECG sensor AD8232 output pin and the Serial Data Line (SDA) and Serial Clock Line (SCL) pin has been connected with raspberry pi. Then the sensor collected data from the human body & automatically saved into the database and compared the data with previously stored reference data. Then if any abnormalities were found then the emergency calls will be sent automatically to the doctor and patient's introducers. A temperature sensor is also used to detect body temperature for analyzing data for certain actions. A pulse oximeter sensor is also connected to detect the oxygen saturation level of a patient's body. A video surveillance camera is also attached in the device for 24 hours halt monitoring if necessary.

4.3 System Flow Diagram

Figure 4.2, shows the flow chart of our proposed system. At first, the user switch 'on' the device, and the device will check whether all the modular are 'on' or 'off'. If the modular is 'off' then the system will remain 'off'. Otherwise, when the modular is on so the system will run and start to collect data from the human body. After that, these data will be saved automatically in a local database, when an internet connection is found data will be analyzed in a cloud database and show results for abnormal conditions and send it to the users via *Wi-Fi.*

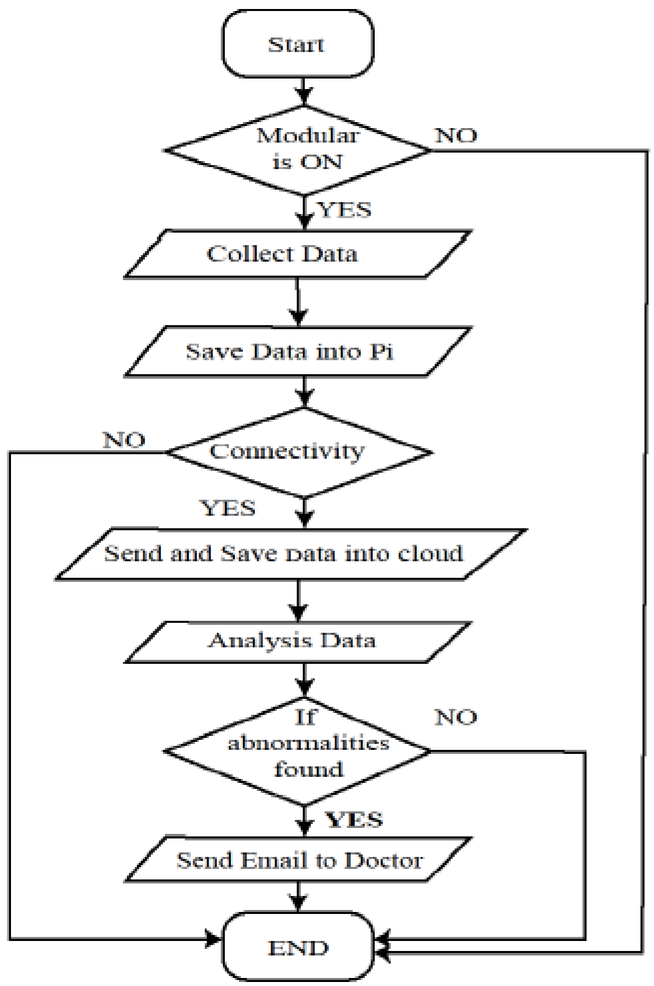


Figure 4.2: Flowchart of IoT-based Health Monitoring System.

The system proposed and implemented in this paper take ECG data, Pulse Rate, Temperature, Blood Oxygen Saturation Level from patients' body, and at any case of abnormalities an email is sent to the doctors so that, they can take necessary initiatives to prevent major health-related issues of elderly patients.

If any kind of abnormalities found in the patients' body or detects any abnormal motion, the system will send an email to the doctors and relatives of the patient. A patient's condition can also be monitored for 24 hours using video surveillance.

Cardiovascular disease is one of the major causes of mortality. By using this, IoT-based health monitoring system we can easily detect primary cardiovascular diseases that can be very helpful to prevent sudden heart attack and major damages due to cardiovascular diseases.

The proposed system is efficient, cost-effective, and easy to use in both medical institutes and homes for continuous monitoring of a patient in an effective manner.

4.4 Theoretical Studies of Used Instruments

4.4.1 Raspberry PI 3B Processor

Raspberry Pi is a powerful minicomputer with features like low cost, small sized, easily portable which can interface with many devices. Here, Raspberry pi model-3b is used .In this system Raspbian operating system is used which is Linux based. One of the most demanding feature of Raspberry Pi 3B is *Wi-Fi* is a built in characteristics in it. So we need not to connect Wi-Fi module for data sending.

The Broadcom BCM2835 SoC used in the first generation Raspberry Pi includes a 700 MHz ARM11 76JZF-S processor, Video Core IV graphics processing unit (GPU), and RAM. It has a level 1 (L1) cache of 16 KB and a level 2 (L2) cache of 128 KB. The level 2 cache is used primarily by the GPU. The SoC is stacked underneath the RAM chip, so only its edge is visible. The 1176JZ (F)-S is the same CPU used in the original iPhone, although at a higher clock rate, and mated with a much faster GPU.

The earlier V1.1 model of the Raspberry Pi 2 used a Broadcom BCM2836 SoC with a 900 MHz 32-bit, quad-core ARM Cortex-A7 processor, with 256 KB shared L2 cache. The Raspberry Pi 2 V1.2 was upgraded to a Broadcom BCM2837 SoC with a 1.2 GHz 64-bit quad-core ARM Cortex-A53 processor, the same SoC which is used on the Raspberry Pi 3, but under clocked (by default) to the same 900 MHz CPU clock speed as the V1.1. The BCM2836 SoC is no longer in production as of late 2016. The Raspberry Pi 3+ uses a Broadcom BCM2837B0 SoC with a 1.4 GHz 64-bit quad-core ARM Cortex-A53 processor, with 512 KB shared L2 cache.

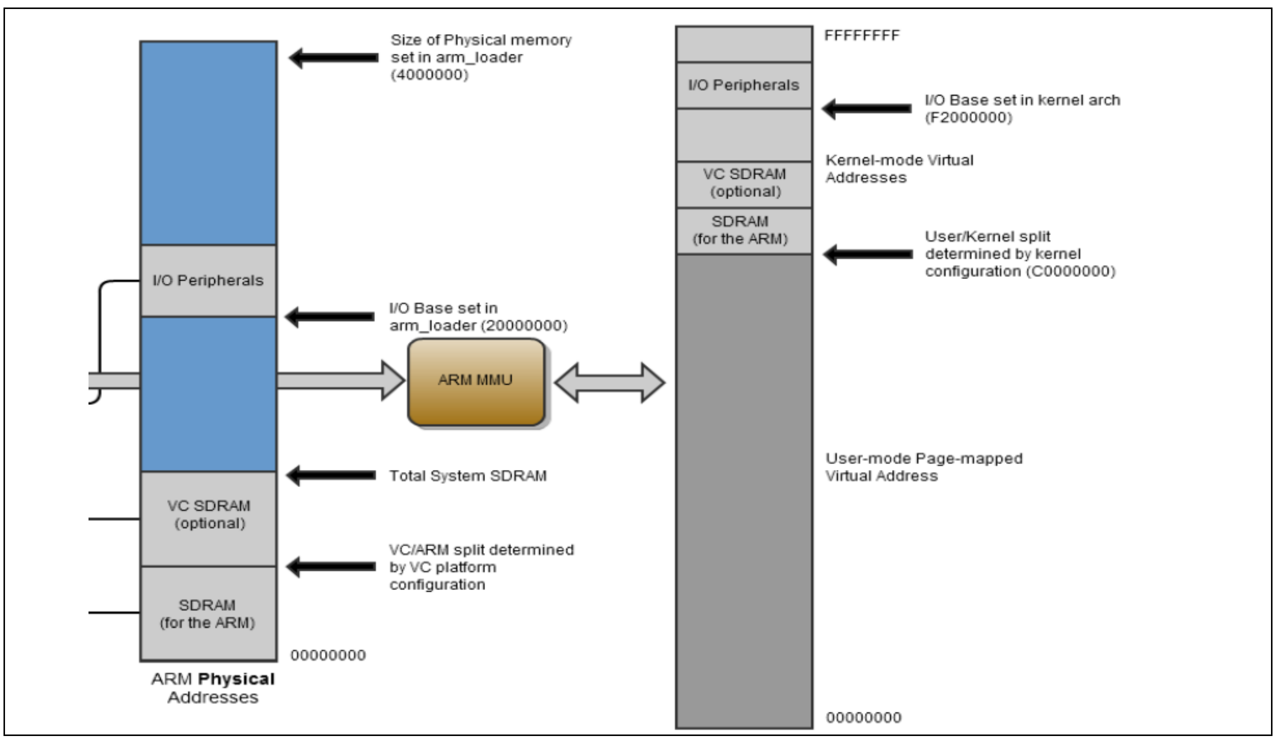


Figure 4.3: BCM2835 ARM of the Raspberry-Pi [54].

4.4.2 The Raspberry PI 3B+

While operating at 700 MHz by default, the first generation Raspberry Pi come up with a real-world performance approximately equivalent to 0.041 GFLOPS. On the CPU level the performance is similar to a 300 MHz Pentium II of 1997–99. The GPU provides 1 Gpixel/s or 1.5 Gtexel/s of graphics processing or 24 GFLOPS of nearly basic purpose computing performance. The graphical capabilities of the Raspberry Pi are in the region of equivalent to the performance of the Xbox of 2001.

Raspberry Pi 2 V1.1 included a quad-core Cortex-A7 CPU running at 900 MHz and 1 GB RAM. It was developed as 4–6 times more powerful than its predecessor. The GPU was identical to the original. In parallelized benchmarks, the Raspberry Pi 2 V1.1 could be up to 14 times faster than a Raspberry Pi 1 Model B+.

The Raspberry Pi 3B+, with a quad-core ARM Cortex-A53,64 bit processor, is detailed as having ten times the performance of a Raspberry Pi 1. This was recommended to be highly dependent upon task threading and instruction set use. Benchmarks showed the Raspberry Pi 3B+ to be approximately 80% faster than the Raspberry Pi 2 in parallelized tasks.

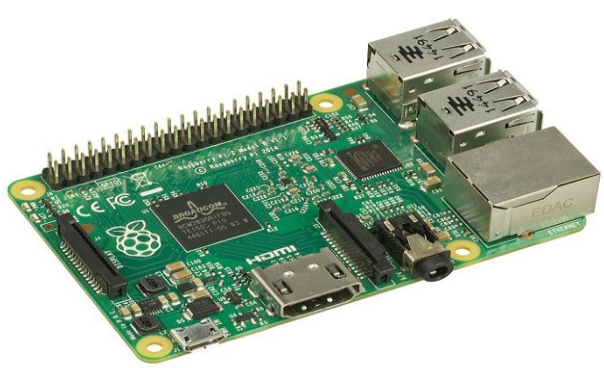


Figure 4.4: The Raspberry Pi 3B+ uses a 64-bit [72]

The Raspberry Pi 3 is powered by a +5.1V micro USB supply and 2.5A power supply from a reputable retailer will provide you with ample power to run your Raspberry Pi.

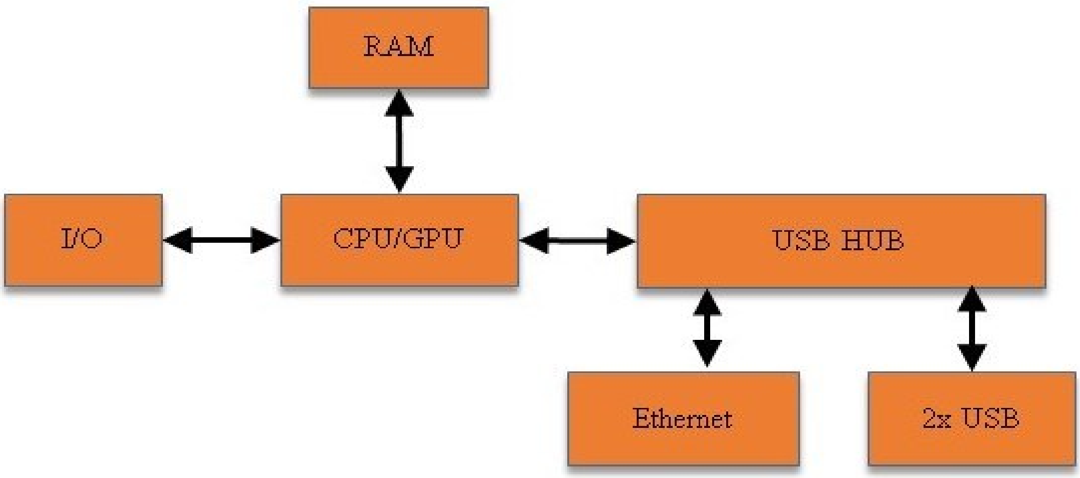


Figure 4.5: Functional block schematic of the Raspberry-Pi.

4.4.3 Why we use Raspberry PI

The Raspberry Pi is a small-sized computer which is cheap and has been picked up by the technical world to encourage people to get used to programming. The Raspberry Pi foundation provides Raspbian, a Debian-based Linux distribution for download, as well as third-party Ubuntu, Windows 10 IoT Core, RISC OS, and specialized media center distributions. It upgrades Python and scratch as the main programming language, with support for many other languages. Here, an unofficial open source is available but the default firmware is closed source. Numerous operating systems can also run on the Raspberry Pi. Other third-party operating systems is accessible via the official website include Ubuntu MATE, Windows 10 IoT Core, RISC OS, and specialized distributions for the Kodi media center and classroom management.

4.4.4 AT MEGA 328 MICROCONTROLLERS

In this system, an ATmega328 microcontroller has been used. This is the heart of the system. It is a 28 pin 8 bit microcontroller with 23 input/output peripherals. From this microcontroller it is used all the 3 port registers for my work. It is used to register B for interfacing LCD module and register D for interfacing the keypad. Port C pin number 4 and 5 have used to send a signal to activate a motor to open and close the door. And also it is used internal EEPROM (Electronically Erasable Read Only Memory) which is a nonvolatile and having a reasonable long lifespan, to store entered passwords. Since it is a nonvolatile it can store information when there is no power to the microcontroller too. In AT mega 328 microcontrollers it has 1Kbyte memory space for the EEPROM. That means it has 1024 bytes for storing data. EEPROM has mainly 3 registers naming EEPROM Address Registers, EEPROM Data Register and the EEPROM Control Register. We can write and read data to/from the EEPROM by calling functions that are related to the EEPROM registers. Below is the pin diagram of the IC.

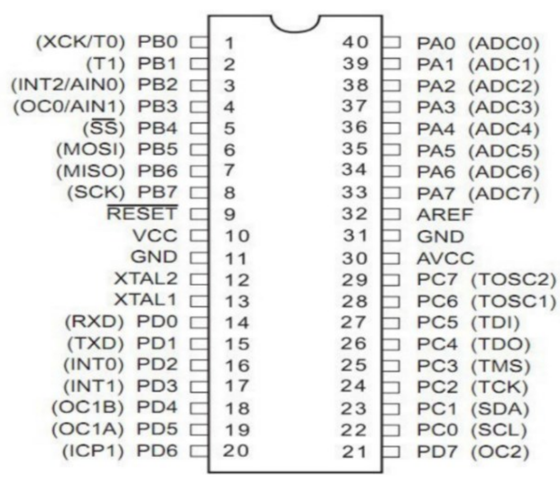


Figure 4.6: Pin diagram of AT mega 328P Microcontroller [73]

4.4.5 ARDUINO

The Arduino Uno is known as a microcontroller board based on the ATmega328. It contains14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It has everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get established. The Uno diverges from all existing boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it aspects the Atmega8U2 programmed as a USB-to-serial converter. "Uno" aids one in Italian and is named to mark the forthcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, getting advances day by day.

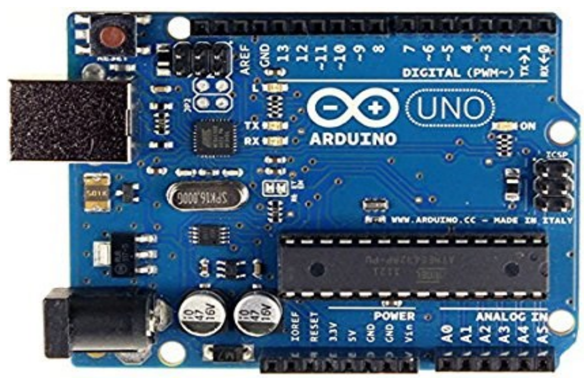


Figure 4.7: Arduino UNO [73]

The Arduino Uno can be powered via the USB connection or using an external power supply. The power source is selected automatically. The board can perform in an external supply of 6 to 20 volts. If the supply is less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and can harm the board. The actual recommended range is 7 to 12 volts.

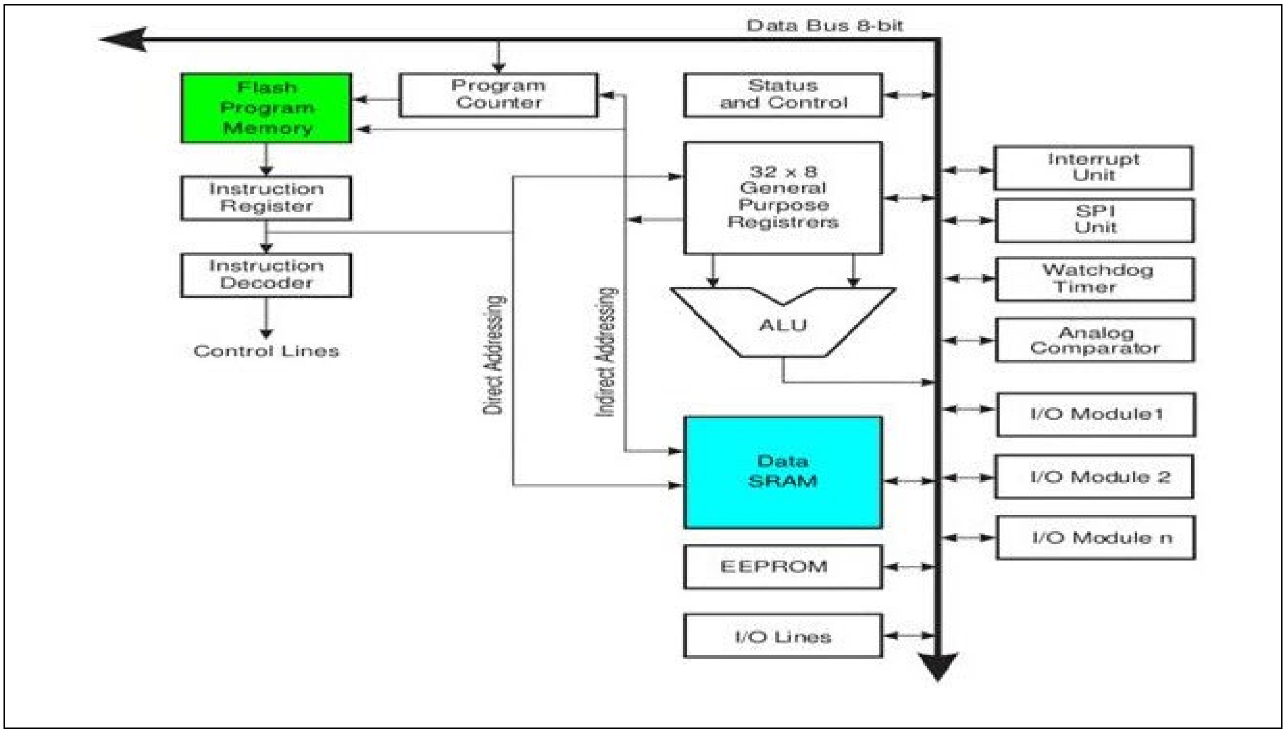


Figure 4.8: Architecture of Arduino [74]

4.4.6 Why We Use ARDUINO

Arduino has been nearly new in thousands of incompatible projects and applications. The main reason is the Arduino software is intuitive for beginners, yet adaptable enough for to facilitate users. It runs on Mac, Windows, and Linux.

Fellows and students can confidently use it to manufacture low-cost scientific instruments, to demonstrate chemistry and physics principles, or to get started to work with programming and robotics. Architects can able to build interactive prototypes. This is also useful for musicians and artists for installations and to experiment with the latest musical instruments. Makers mainly use it to assemble many of the projects exhibited at the Maker Fair. So it can be stated that, Arduino is a key tool to learn new things easily and conveniently. Anyone including children, hobbyists, artists, programmers - can start thinking and follow the step by step instructions of a kit, or sharing ideas online with other members of the Arduino community.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Net media's BX-24, Phi gets, MIT's Handy board and many others offer similar functionality. All of these tools take the convoluted details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, and it offers many advantages for teachers, students, and interested nonprofessional over other systems.

4.4.7 ARDUINO Software (IDE)

The Arduino IDE or Integrated Development Environment is the software used to program the Arduinos. This software language is written in JAVA. And the language it uses to program the MCU is like C/C++ and follows that syntax. The language is processing. And it is actually a language made for the electronic arts and visual design communities with the purpose of teaching the basics of computer programming in a visual context.

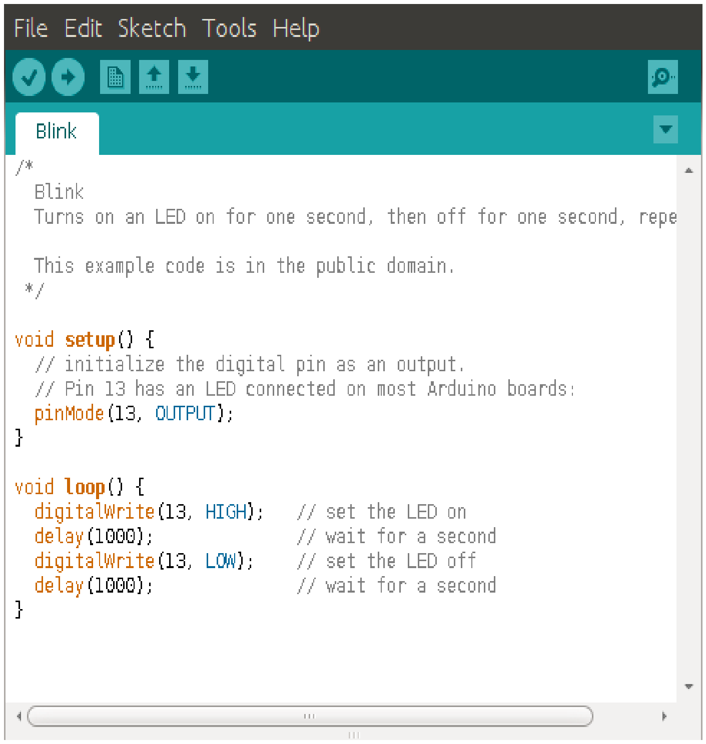


Figure 4.9: Arduino main window [73]

The window is divided into 3 fundamental portions. The top portions contain the title bar, menu bar and, some buttons which are used regularly. The next part is the main code editor part. Here the codes are written and all the coding is done. It color-codes the code for easy viewing and editing. And the third part is the status box. This is the black part in the bottom. It shows what is happening and also shows errors if something goes wrong. In the figure, 4.9 the main window page of Arduino is shown for basics.

4.5 Peripheral Apparatus

4.5.1 LCD Display

The LCD display has 800x480 high resolution; back light control to lower power consumption; High quality immerse gold surface plating. Supports any version of Raspberry Pi (directly-pluggable, only except for the first generation Pi model B which requires an HDMI cable).Driver provided (works with custom Raspbian directly).HDMI interface for displaying, no I/O is needed. (However, the touch panel still needs I/O).Not only the Pi, but also it can be used use with any other Mini-PCs like Cubie board, Mars board (resolution is limited depending on the board, and touch panel is unavailable)

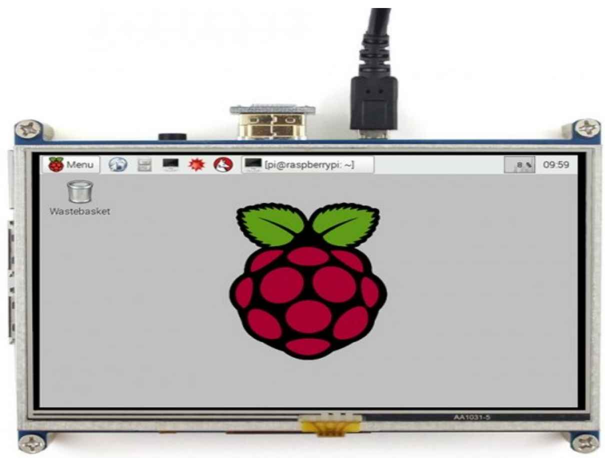


Figure 4.10: LCD Display (16x2) pin out HDMI GPIO 5-Inch 800x480 TFT LCD Display with Touch Screen Monitor Display for Raspberry. [75]

4.5.2 ECG Sensor

The AD8232 is a neat little chip used to compute the electrical activity of the heart. This electrical activity can be named as an ECG or Electrocardiogram. Electrocardiography is a process to help diagnose various heart conditions. ECG sensor AD8232 shown in “Fig. 3.9” is used for collecting ECG data from the human body by applying electrodes on the patient’s skin. In this research signals are from the human body via AD8232 using Arduino Uno; then it has been redirecting the collected signals to raspberry pi. Raspberry pi then processed the signal by using Processing 3.0 and shows the image finally on display.

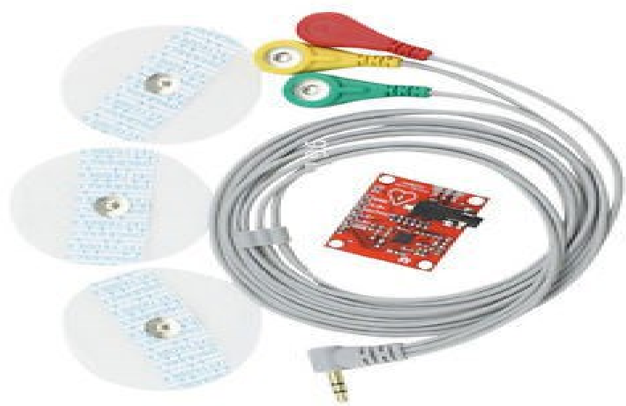


Figure 4.11: AD8232 ECG Sensor

4.5.3 Cable - Electrode Pads (3 connector)

This is a simple three conductor sensor cable with electrode pad leads. These cables are 24" long and feature a 3.5mm audio jack connector on one end with snap style receptacles for biomedical sensor pads. Each cable comes in a red/blue/black set.

Figure 4.12: Cable - Electrode Pads (3 connector)

4.5.4 Biomedical Sensor Pad

Biomedical Sensor Pads, disposable electrodes which can be used to measure various medical terms such as -EEG, ECG and EMG levels. These little pads are thoroughgoing for short-term monitoring of Neuro feedback and Biofeedback purposes. They are to be used once and are very handy because of integrated, latex-free gel. Each pad adheres very well to the skin and the snap connector can be pushed on or removed from the electrode lead with no problem or issue.

Figure 4.13: Biomedical Sensor Pad

4.5.5 16 BIT I2C ADS1115 Module

For microcontrollers without an analog-to-digital converter or when there is a need for a higher-precision ADC, the ADS1115 provides 16-bit precision at 860 samples/second over I2C. The chip can be structured as 4 single-ended input channels, or two differential channels. As a nice incentive, it even includes a programmable gain amplifier, up to x16, to help boost up smaller single/differential signals to the full range. This ADC is very useful because it can run from 2V to 5V power/logic, able to measure a large range of signals and it's remarkably easy to use. It is mainly a general purpose 16-bit converter.

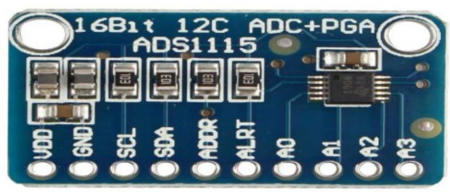


Figure 4.14: 16 Bit I2C ADS1115 Module ADC 4 Channels w/ Pro Gain Amplifier – Blue

4.5.6 Temperature Sensor

The DS18B20 Digital Temperature Probe provides 9 to 12 bit (configurable) temperature readings which stipulate the temperature of the device. Information is sent to/from the DS18B20 over a 1-Wire Interface so that only one wire (and ground) required to be connected from a central microprocessor to a DS18B20. Power for reading, writing, and performing temperature conversions can be attained from the data line itself with no need for an external power source.

Because each DS18B20 contains a unique silicon serial number, multiple DS 18B20s can remain on the same 1Wire bus.

Figure 4.15: DS18B20 Waterproof Digital temperature sensor

This allows for placing temperature e sensors in many different places. Applications where this feature is useful including HVAC environmental controls, sensing temperatures inside buildings, equipment or machinery, and process monitoring and control.

4.5.7 Pulse Oximeter and Heart Rate Sensor

The sensor heart Rate click is a heart rate monitoring and pulse oximetry measuring Click board. It consists an advanced oximeter and heart rate monitoring sensor, which depends on two integrated LEDs, a photosensitive element, and a very accurate and advanced low noise analog front end, to provide clean and accurate readings. It is enough to place an index finger on a top of the sensor to get both of the heart rate and blood oxygen saturation via the I2C interface. Properties, such as the Ambient Light Cancellation (ALC) and the discrete-time filters, ensure that no ambient light or 50/60Hz hum is interfering with the readings.

One of the more important property of this device is its low power consumption.it is possible to put the device into the Standby mode, where it consumes a very low amount of power. All those aspects make this Click board™ an ideal solution for various heart-rate and SpO2 related applications, as well as the development of new algorithms for reading blood parameters based on the red and infra-red absorbance properties of the human body, mainly for the arterial blood oxygen saturation (SpO2) and heart rate (HR).

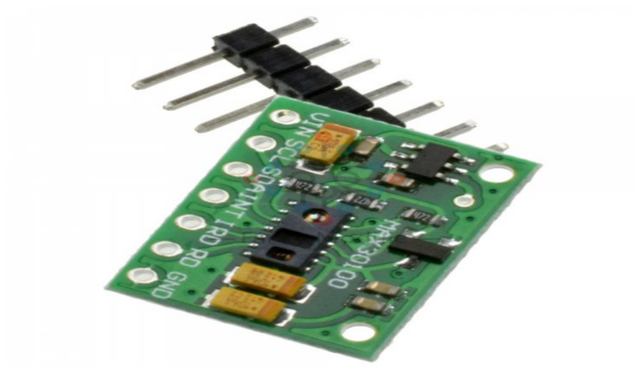


Figure 4.16: MAX30100 Pulse Oximeter and Heart Rate Sensor

4.5.8 Power Supply Unit

11.1V 1100mah 3S 30C lipo battery.11.1V lipo battery, Perfect for RC Hobby, Discharge C-rate 35C, Certification Approval. High energy density, High working voltage for single battery cells, Pollution-free, Long cycle life >500times, No memory effect, Capacity, resistance, Voltage, platform time consistency is good, With short-circuit production function this is safe and dependable, factory price & high quality, excellent consistency, low self-discharge, lightweight, small and customized size, a wide range of applications for electronics and industry and also environmentally suitable.

Figure 4.17: 5V DC Adapter

4.5.9 Connecting wires

An electrical connector is an appliance that is used for joining electrical circuits together using a mechanical assembly. The connection may be temporary or serve as a permanent electrical joint between two wires. Electrical connectors can be a hundred types. Connectors may join two lengths of wire together or connect a wire to an electrical terminal.

Figure 4.18: Connecting Wires

4.6 System Flow Chart of IoT-based Health Monitoring System

Start

Step 1: Patient registration is done after turned on the device.

Step 2: Login to the device.

Step 3: Collecting data (Heart Rate, ECG, Body Temperature and Oxygen Saturation Level) from patient's body.

Step 4: Detect the motion through video footage of a patient.

Step 5: Check if the monitoring system is ready or not.

If YES go to step 6

Else it will show an error message.

Step 6: Checking while the remote server is connected or not.

If YES go to step 7

Else it will show error message

Step 7: Send patients data to database via Wi-Fi module.

Step 8: Analysis the data in cloud database.

Step 9: If any case or abnormalities found then it will send alert email to the doctors and relatives of patient.

Else it will save the data in the IoT-cloud.

Figure 4.19. System flow diagram of IoT-based Health Monitoring System.

Fig 4.19. Shows, the flow diagram of the total system. After turning on the device, the device will collect data (heart rate, ECG data, temperature, oxygen saturation level) from the patient's body and it senses the motion whether the patient is out of the critical range or not and saved it into the cloud and process the data for further analysis. If any kind of abnormalities found in the patients' body or detect any abnormal motion, the system will send an email to the doctors and relatives of the patient. A patient's condition is also be monitored for 24 hours using video surveillance. As a proof of this proposed system, a prototype has been implemented to evaluate the IoT-based health care monitoring system. This system has been implemented to collect data from the patient's body by using listed sensors such as- ECG sensor, temperature sensor, and pulse oximeter sensor thus monitoring the primary health conditions of elderly people. This device has been tested on several elderly people and verified successfully with reliability in health monitoring.

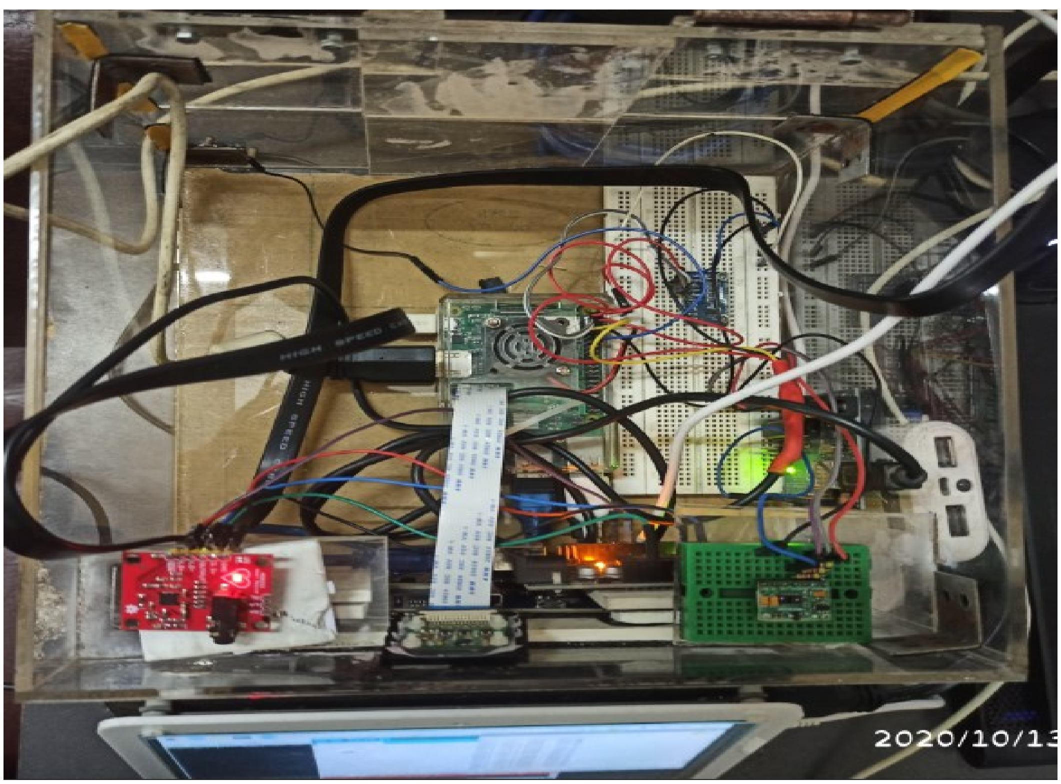


Figure 4.20: Physical appearance of health monitoring device

Figure 4.20 shows, the prototype of the health monitoring device. The proposed system has been successfully tested with reliability in health monitoring which can aid primary diagnosis of health conditions efficiently .Thus the patients' health conditions can easily be monitored without visiting the doctors regularly and hospitals frequently.

4.7 Network Protocols for IoT based Health Monitoring System

The most popular application protocols known as Hypertext Transfer Protocol (HTTP), Constrained Application Protocol (CoAP) and Message Queue Telemetry Transport (MQTT) is briefly described in this section. This are the most popular and common application protocols used in IoT communication.

4.7.1 Hypertext Transfer Protocol

HTTP is mainly a web messaging protocol, which was originally broadened by Tim Berners-Lee. Later, it was developed by IETF and W3C jointly and first published as a standard protocol in 1997 [55]. In the client-server computing model Hypertext Transfer Protocol (HTTP) [56] is widely used. It builds up the connection between two subsistence, named as a client, for example, a web browser and server, for example, an application hosting a website.). Within the structure of internet suite protocol HTTP is a popular application layer protocol .Transmission Control Protocol (TCP) is often used with HTTP because its definition necessarily assumes an underlying and reliable transport layer protocol. HTTP can use the User Datagram Protocol (UDP) as the transport layer protocol in some uncommon cases. HTTP does not define the size of the header or messages basically it is a text-based protocol that depends on the web server or the programming technology. HTTP is a globally accepted web messaging standard that offers several features such as persistent connections, request pipelining, and chunked transfer encoding [57], [58], and [59].

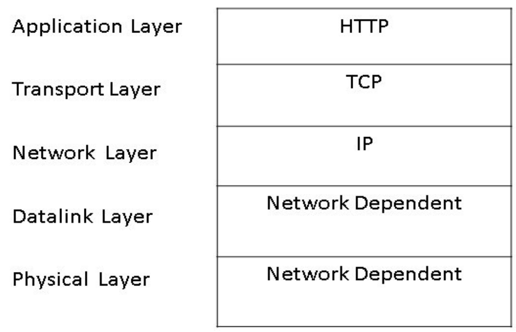
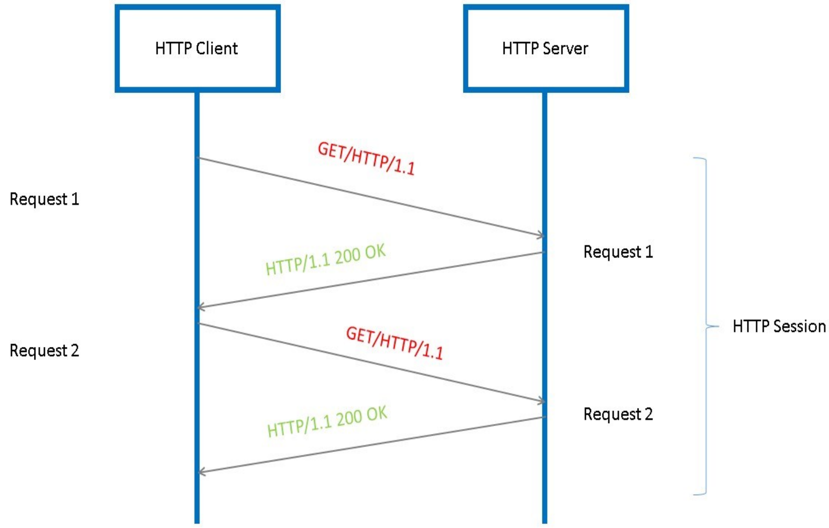


Figure 4.21: HTTP Stack

HTTP resources are recognized and came across on the network by Uniform Resource Identifier (URI) or Uniform Resource Locator (URL). An example of URI can be the following: http://en.wikipedia.org/wiki/Uniform_resource_identifier. HTTP uses HTTP session, basically a sequence of network request-response transactions.



4.22: HTTP session

The HTTP client begin a request by establishing a TCP connection to a specific port on the server. An HTTP server listening on that port waits for the client's request message. The server responds by sending back a status line such as "HTTP/1.1 200 OK" and a message body, when it receives the request. In the recent version, HTTP/1.1 reuses the TCP connection several times to send and receive too many HTTP request/response rather than creating a new TCP connection for every single response or request pair.

HTTP defines the following methods to specify the wanted actions to be accomplished on the resources such as GET, HAED, POST, PUT, DELETE, TRACE, OPTIONS and CONNECT, as described as a short explanation as following . [56]

- OPTIONS - The OPTIONS method constitutes a request for information about the communication alternatives accessible on the request/response chain connected by the Request-URI.
- GET – Whatever the information in the form of an entity is identified by the Request-URL, The GET method retrieve it.
- HEAD - The HEAD method is indistinguishable to GET method except that the server MUST NOT return a message-body in the response or feedback.
- POST – The origin server accept the entity confined in the request as a new subordinate of the resource identified by the Request-URI in the Request-Line is requested by the HTTP POST method.
- PUT – The confined or enclosed entity must be stored under the supplied Request-URL is requested by HTTP PUT method.
- DELETE - The origin server delete the resource identified by the Request-URI is requested by the DELETE method.
- TRACE - The TRACE is a method used to call on a remote, application-layer loop- back of the request message.
- CONNECT – The method name CONNECT has the specification reserves to use with a proxy that can effectual switch to being a tunnel (e.g. SSL tunneling).

4.7.2 Constrained Application Protocol

Constrained Application Protocol (CoAP) [60] is another type of dedicated web transfer protocol which used constrained networks and constrained nodes and also CoAP is a request or response protocol used in client-server computing model, although the roles of client and server are usually replaceable in M2M interactions. CoAP is basically a lightweight M2M protocol from the IETF

CoRE (Constrained RESTful Environments) Working Group. CoAP aids both request/response and resource/observe (a variant of publish/subscribe) architecture [61].

CoAP is an application layer protocol built on top of a datagram-oriented transport protocol such as UDP.

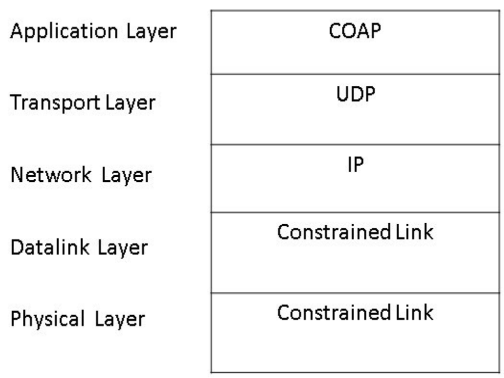


Figure 4.23: CoAP Stack

A client sends a CoAP request as like as to a HTTP request to request an action (using a CoAP method code) on a resource (identified by a CoAP URI) on a CoAP server. Based on receiving a request, the server sends back a response with a response code; this response may include a resource characterization. CoAP messages are classified as four types- Confirmable (CON), Non-confirmable (NON), Acknowledgement (ACK) and Reset (RST). CoAP supports multicast IP destination addresses.

CoAP offers two messaging models for different QoS requirements known as reliable message transmission and unreliable message transmission.

CoAP defines the following methods: GET, PUT, DELETE and POST. The brief explanation of CoAP methods are as follows. [60]

- GET – It is requested by the GET method that the proxy to return a representation of the HTTP resource recognized by the request URI.
- PUT - The PUT method requests the proxy to upgrade the HTTP resource acknowledged by the request URI with the enclosed representation.
- DELETE - The purpose of DELETE method is to request the proxy to delete the HTTP resource recognized by the request URI at the HTTP origin server.
- POST - The proxy to have the representation enclosed in the request be processed by the HTTP origin server is requested by the POST method.

4.7.3 Message Queuing Telemetry Transport

MQTT (Message Queue Telemetry Transport) which was introduced in 1999 is one of the oldest M2M communication protocols. It was developed by Andy Stanford-Clark of IBM and Arlen Nipper of Arcom Control Systems Ltd (Eurotech). Message Queue Telemetry Transport [62] is a lightweight message protocol on top of the TCP/IP protocol; it is broadly used in M2M communication for IoT devices. It features a lightweight header size of 2 bytes and lowered client's footprint. The MQTT architecture includes the publishers, the brokers and the subscribers; MQTT approves the publish/subscribe model. The broker receives the subscription from the clients on the topics they are interested in, at the same time it receives message from publishers and forward them, clients (publishers and subscribers) subscribe/publish on related topics.

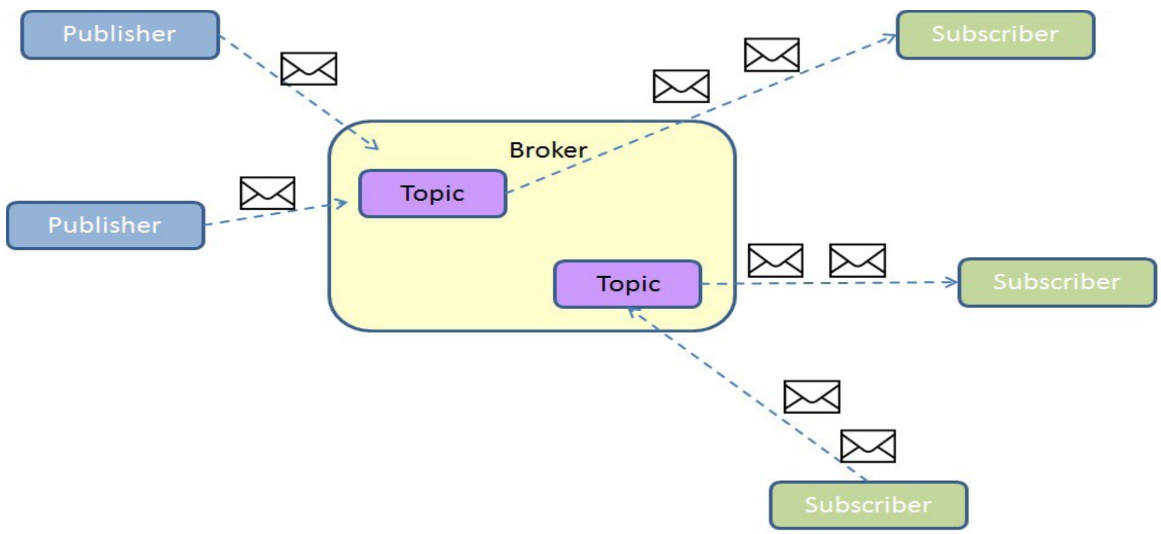


Figure 4.24: The general architecture of MQTT [63].

MQTT uses the following control packets for its data transmission. The brief explanation of MQTT method are described as follows. [62]

- CONNECT- request a connection to a server - The first Packet sent from the Client to the Server MUST be a CONNECT Packet after a network connection is established by a client to a server.
- CONNACK- Acknowledge connection request - The first packet sent to client from the server must be a CONNACK Packet. The CONNACK Packet is the packet sent by the Server in response to a CONNECT Packet received from a client.
- PUBLISH - Publish message – To transport an application message a PUBLISH Control Packet is sent from a Client to Server or from Server to a Client.
- PUBACK - Publish acknowledgement - With QoS level 1 a PUBACK Packet is the response to a PUBLISH Packet.
- PUBREC - Publish received - It is the second packet of the QoS 2 protocol exchange. With QoS 2 a PUBREC Packet is the response to a PUBLISH Packet.

- PUBREL - Publish release – It is the third packet of the QoS 2 protocol exchange. A PUBREL Packet is the response to a PUBLISH Packet with QoS 2.
- PUBCOMP-Publish complete - The PUBCOMP Packet is the response to a PUBREL Packet .It is the fourth and final packet of the QoS 2 protocol exchange.
- SUBSCRIBE - Subscribe to topics – To create one or more subscription the SUBSCRIBE Packet sent from the Client to the Server .Each subscription register a Client´s interest in one or more Topics.
- SUBACK - Subscribe acknowledgement - A SUBACK Packet is sent by the Server to the Client to confirm receipt and processing of a SUBSCRIBE Packet.
- UNSUBSCRIBE- unsubscribe from topics – To unsubscribe from topics an UNSUBSCRIBE Packet is sent by the Client to the Server.
- UNSUBACK – Unsubscribe acknowledgement- To Confirm a receipt of an UNSUBSCRIBE Packet the UNSUBACK Packet is sent by the Server to the Client.
- PINGREQ - PING request - The PINGREQ Packet is sent from a Client to the Server. It can be used to acknowledge to the server that the Client is alive in the absence of any other Control Packets being sent from the client to the server, request that the Server responds to confirm that it is alive, or exercise the network to indicate that the network connection is active.
- PINGRESP - PING response - It indicates that the Server is alive. A PINGRESP Packet is sent by the server to the Client in response to a PINGREQ Packet.
- DISCONNECT- disconnect notification - It indicates the client is disconnection clearly. The DISCONNECT Packet is the final control packet sent from the client to server.

4.8 Comparison between the Protocols

Table 4.4 Comparative Analysis between Messaging Protocols for IoT-based Systems: HTTP, MQTT, CoAP.

Criteria	HTTP	MQTT	CoAP
1.Year	1997	1999	2010
2 .Architecture	Client/ Server	Client/Broker	Client/ Server or Client/Broker
3. Abstraction	Request/Response	Publish/Subscribe	Request/Response or Publish/Subscribe
4. Header Size	Undefined	Byte	Byte
5. Message Size	Large and Undefined (depends on the web server or the programming technology)	Small and Undefined (up to 256 MB maximum size)	Small and Undefined (normally small to fit in single IP datagram)
6. Semantics	Get, Post, Head, Put, Patch, Options, Connect, Delete	Connect, Disconnect, Publish, Subscribe, and Unsubscribe, Close.	Get, Post, Put, Delete
7. Cache and Proxy Support	Yes	Partial	Yes

8. Quality of Service (QoS)/ Reliability	Limited (via Transport Protocol - TCP)	QoS 0 - At most once (Fire-and-Forget), QoS 1 - At least once, QoS 2 - Exactly once	Confirmable Message (similar to At most once) or Non-confirmable Message (similar to At least once)
9. Standards	IETF and W3C	OASIS, Eclipse Foundations	IETF, Eclipse Foundation
10.Transport Protocol	TCP	TCP (MQTT-SN can use UDP)	UDP, SCTP
11. Security	TLS/SSL	TLS/SSL	DTLS, IPSec
12. Encoding Format	Text	Binary	Binary
13. Licensing Model	Free	Open Source	Open Source

CoAP, MQTT, and HTTP have been compared against each other in terms of architecture, network performance, cost efficiency, and energy consumption.

The authors showed a characteristics comparison in [64] between CoAP and MQTT. The result showed that MQTT is a better option for applications requiring improper functionalities such as different levels of QoS, message persistence. On the other hand, in case of bandwidth requirement and round trip time (RTT) CoAP performs better than MQTT. For reliability, MQTT achieves better results where message exchanges frequently, otherwise the difference between both is not too much.

In terms of the total cost, CoAP has been compared with HTTP in [65]. The comparison acknowledged each protocol's technical parameters such as energy consumption and the amount of data generated over an application's life cycle. The comparison shows the result that, CoAP showed better performance in terms of energy consumption than HTTP.

The author [63] has done a characteristic analysis of the major protocols of IoT such as HTTP, CoAP, MQTT. The criteria of this comparison basically focused on their architecture, security system, Communication protocols, and QoS schemes. The comparison between the protocols found that every protocol has its own merits and demerits which actually depends on the need to choose the most appropriate protocol for the kind of system to be developed.

After comparing the three protocols in the proposed system HTTP is used as a communication protocol as it is the foundation of data communication for the World Wide Web. It also follows a client-server structure and message size is usually high. Two types of messages are prevalent in HTTP known as requested message and response message. HTTP protocol is used as the communication protocol and the data transferring gateway is REST API. Additionally, HTTP comes in handy when we go for big data collection. But in contrast, while working with HTTP the IP addressing needs to be kept in mind as a different IP might stop the device from communicating with the server, hence a real IP is required at that time.

4.9 eHealth System

In computer science and medicine, eHealth is a multidisciplinary domain that includes a large number of different scientific methods and technological devices. The main aim of eHealth service to the provision of the healthcare system which is independent of location, user mobility, and time limit. EHealth is now a ubiquitous healthcare example that concentrates on disease prevention of individual people, necessary actions, and increases in life quality, and also emergency home delivery care can be provided at the right time and right place whenever needed.

In this research work, architecture is proposed about IoT- based smart health monitoring system for elderly people. So basically this system can be used in health monitoring of elderly people using different sensors interfaced with raspberry pi. The proposed system consists of three phases:

(i) Data collection phase for continuous monitoring and transferring the patient data.

(ii) Data transfer for transmitting the signals between the connected sensors, hospital network, and users.

(iii) Data analysis for accessing and diagnose health conditions.

The proposed system has been successfully tested with several patients for continuously monitoring their health status and verify the output with efficiency.

4.10 Chapter Summary

Chapter four discussed the implementation of the proposed prototype and a flow chart developed for the system. This chapter overviews all the key parameters such as the sensors and peripheral devices used to implement the prototype in this total health monitoring system. Here, IoT network communication system such as HTTP, CoAP, and MQTT has also been described briefly. Furthermore, protocols are compared against each other to highlight each protocol's strengths and weaknesses. In this health monitoring system MQTT stands out as the more suitable communication protocol for the IoT domain. And finally, the eHealth system and its advantages are also discussed in the state of IoT-based health monitoring system for elderly people.

Chapter 5

Experimental Result and Analysis

5.1 Introduction

Healthcare services is a crying need in our society, thus automatic healthcare devices lessen the burden on humans and ease people to continuously monitor their health status. When abnormalities found, an emergency mail will be sent to doctors and relatives of the patient. The main purpose to develop this kind of system is to reduce healthcare costs by reducing regular visits to doctors, hospitalization, and diagnose many types of test procedures. The most demanding feature of this system is that the health condition of the patient could be monitored from home and necessary precautions can be taken for emergency purposes. As it is a sensor-based implemented system, it can be reduced human-made errors. A prototype to evaluate the performance and efficiency of our device. In this chapter, results will be discussed in terms of different sensors.

5.2 ECG Analysis

The ECG waveforms have five major points named as P, Q, R, S and T. Figure 5.1 shows that, the ECG waveform points and the interval of major points. P wave is the arch before QRS complex. Q wave is the first negative deflection of the QRS complex followed by R wave which is the positive deflection. S wave is the negative deflection after the R wave and T wave is the last arch after the QRS complex [66]. The intervals of these waves are used to diagnose a variety of heart diseases. Among all the features of these waves, four are most commonly used in medical diagnosis, i.e. RR interval, PR interval, QT interval and QRS complex.

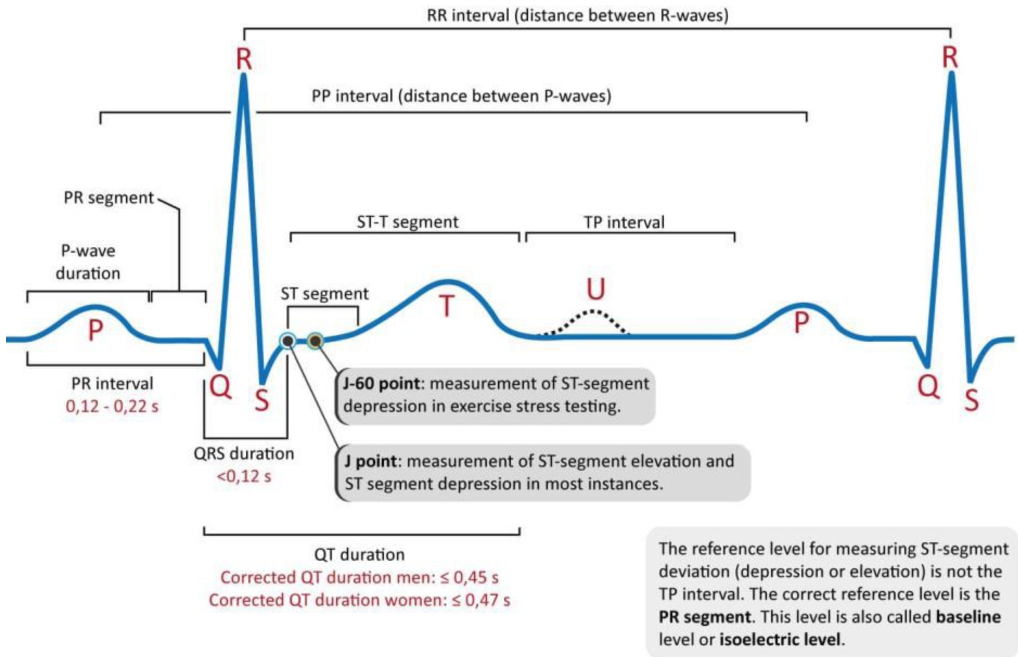


Figure 5.1: Standard ECG signal. (ECG waves, 2017)

• **RR** interval: As one of the most conspicuous characteristics, the R wave is often used to identify the period of an ECG signal. RR interval indicates the time interval between two adjacent R waves, which may become irregular in the event of some heart diseases, for example, the arrhythmia.

• **PR** interval: The PR interval measures the time between the beginning of the P wave and the QRS complex. It indicates the time the impulse takes to reach the ventricles from the sinus node.

• **QT** interval: QT interval represents the time between the start of the Q wave and the end of the T wave, which is related to the ventricular depolarization and repolarization. There is an increased risk of ventricular fibrillation or even sudden cardiac death if the QT interval exceeds the normal value.

• **QRS** complex: QRS complex is mainly associated with the Ventricular depolarization, which consists of three important waves, i.e., Q wave, R wave and S wave. By analyzing the QRS complex, certain diseases are likely to be detected such as drug toxicity and electrolyte imbalance.

According to [50] and [67] normal values of ECG parameters are listed in Table II.

Table 5.1. Normal Values of ECG Key Parameters

Features	Normal Range (seconds)
RR Interval	0.6-1
PR Interval	0.12-0.20
QT Interval	0.32-0.44
QRS Complex	<0.12

Abnormalities are found when the conditions are not valid. Finally, if any disorders are found then an emergency email has been sent to the users or doctors that, they can take emergency steps to prevent severe damage to the patients. This can reduce the mortality rate and any kind of damages that causes due to heart failure.

In medical institutes conventional 12 lead systems are used to collect ECG signals from patients' bodies. This system cannot be used as portable. But for a sudden analysis of a patient's condition 3-lead system is sufficient [68].

A 3-lead placement is adequate to analyze the primary features of the ECG signal [50] compared to conventional 12-lead ECG monitoring devices used in hospitals. In order to best sample the ECG signal, the electrodes need to be placed around the heart and form a triangle. Figure 5.2 shows, 3-lead placement for ECG illustrated in this prototype, and Figure 5.3 shows, the physical appearance of the 3-lead ECG monitoring system [69]. Several tests have been conducted on healthy volunteers to test the reliability of this prototype.

To perform a waveform comparison between a 12-lead ECG device and the 3-lead ECG device prototype each parameter is recorded and a comparative result has been conducted to determine the efficiency of this prototype.

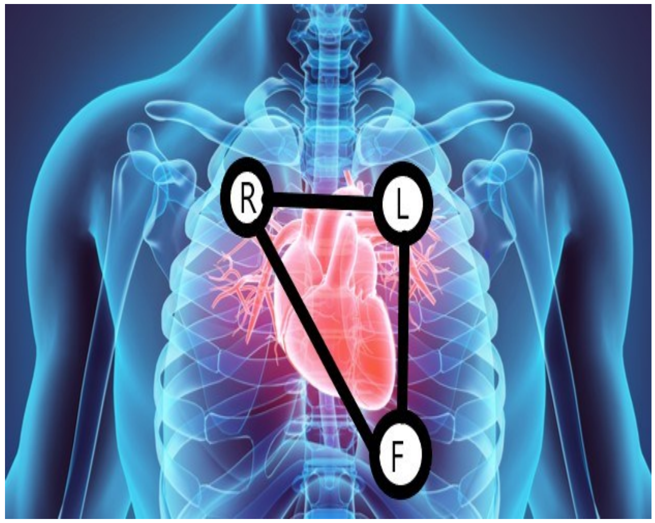


Figure 5.2: 3-lead ECG Placement in human body.

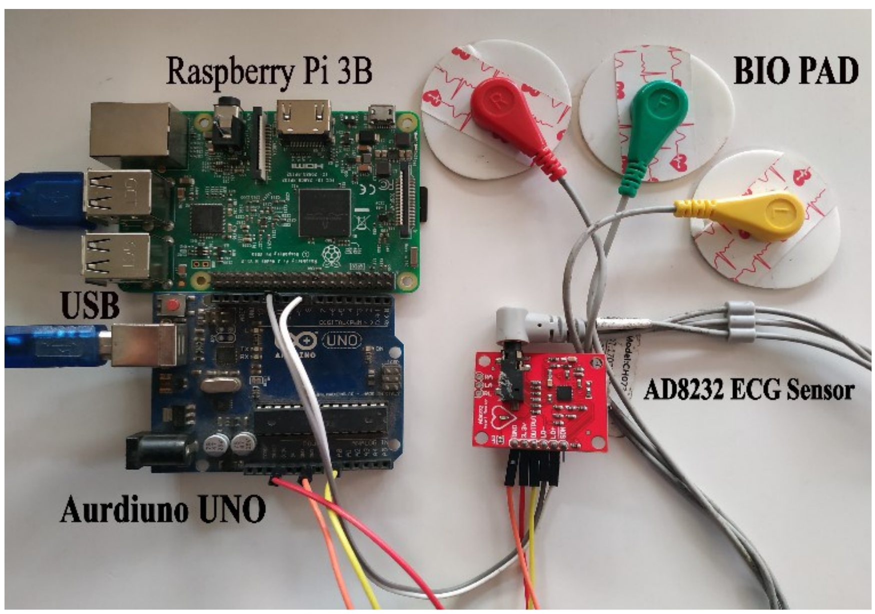


Figure 5.3: Physical appearance of ECG monitoring system [69].

To get the most proper data for sudden analysis of patient's condition 3 lead electrodes are placed in a triangular shape around the heart. Figure-5.4, shows, the ECG data collected from a 40 years old healthy person. It is evident that the intervals between adjacent R waves (RR interval) are nearly the same, which shows no risk of developing arrhythmias.

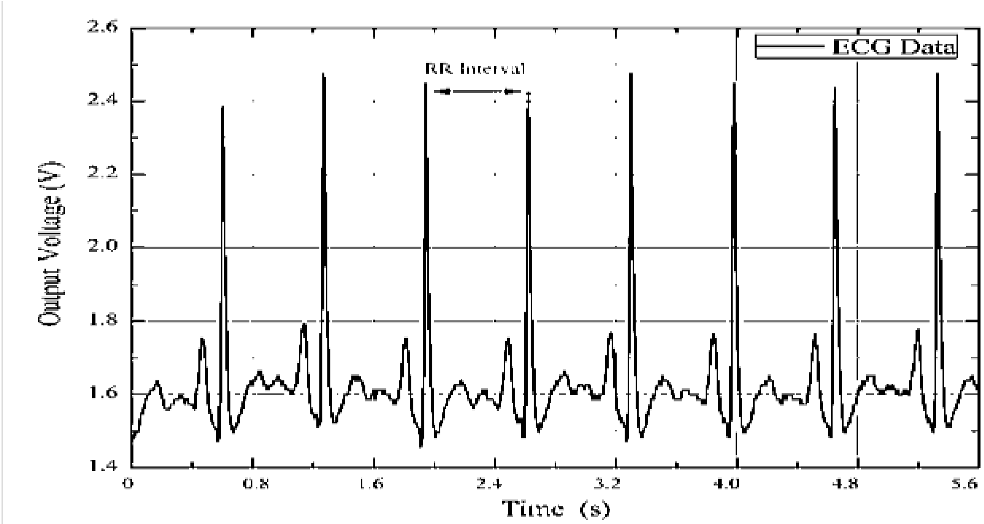


Figure 5.4: Real time ECG signal from a healthy volunteer.

In order to analyze the key features of the measured ECG signal, two cycles of the signal are chosen as examples, which are shown in Figure- 5.5.

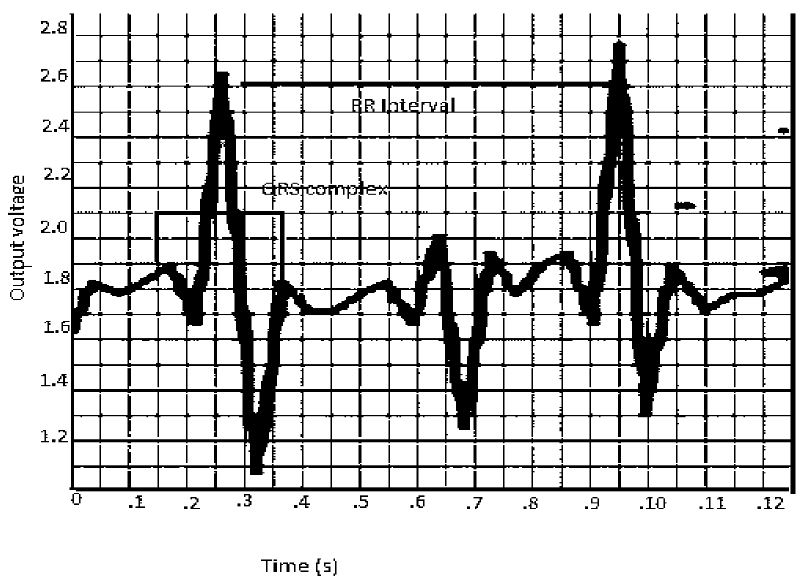


Figure 5.5: Key features of measured ECG Signal.

In Figure 5.5, it can be observed that, QRS complex is also regular indicating no abnormality in the processes of ventricular depolarization and repolarization. QT interval is also normal. Finally, the PR interval is also within the normal range, which implies that the process of atria depolarization is normal as well. So this person is not suffering from any heart diseases.

The performance of the device in generating waveforms and heart rates are tested against the reading of 12-lead ECG machine. This system is also able to detect irregular ECG conditions such as Tachycardia, Bradycardia and asystole. Statistical tools have been used to t-test with a sample size of 10 and $\alpha = 0.05$ [70], percent difference and percent reliability. Alpha (α) is the cut off value for identifying the difference between two sample sets [71]. This value has been used to comparison testing between the results of ECG machine used in hospitals and the prototype device. The t-value is computed using the following Equation 1.

$$t = \frac{\overline{X} - \mu}{\frac{s}{\sqrt{n}}} \quad (1)$$

Where, $\overline{X}$ = Sample Mean

μ = hypothesized population mean

s = sample standard deviation

n = sample size

Degrees of freedom = n -1

For medical application percent difference should be less than 1 %. The following Equation (2) is used to determine the relative difference between 12-lead and 3-lead ECG samples.

$$\% \text{ difference} = \left| \frac{Expected - Actual}{\frac{Expected + Actual}{2}} \right| \quad (2)$$

Where, Expected = ECG value gained from 12-lead ECG machine and Actual = ECG value gained from ECG device prototype.

Table 5.2. Summary of Mean Percent Difference of ECG Parameters

ECG Parameter	**Data of 12 lead ECG Device**	**Data of 3 lead ECG Prototype Device**	**Percentage Difference (%)**
RR Interval	0.7709	0.7785	0.98
PR Interval	0.1232	0.1544	20.2
QT Interval	0.3496	0.3507	0.31
QRS Complex	0.0959	0.1040	8.104

From the Table III, we can observe that, the value of our prototype is quite similar with expected value collected from 12-lead ECG device.

To determine the efficiency rate of the device "Equation 3" is used to test the number of successful attempts vs. the total number of attempts.

$$\% \text{ reliability} = \left| \frac{Number\ of\ successfull\ attempts}{Total\ no\ of\ attempts} \right| \qquad (3)$$

The performance of ECG monitoring system in generating heart rates and also ECG wave shapes were tested against Bio care, 12-channel ECG machine. The prototype device has been tested on 10 patients at the cardiology department of Delta Medical College and Hospital 80% efficiency came out in detecting ECG conditions. From the samples collected from our prototype three trials (4, 8, and 9) did not match with the 12-lead machine. The results have been shown below in Table IV.

Table 5.3 Tabulated Summary of Comparison between Two ECG Devices

Trial	Trial 12-lead ECG Device	Trial 3-lead ECG Device
1	Normal Sinus Rhythm	Normal Sinus Rhythm
2	Normal Sinus Rhythm	Normal Sinus Rhythm
3	Normal Sinus Rhythm	Normal Sinus Rhythm
4	Normal Sinus Rhythm	Sinus Bradycardia
5	Normal Sinus Rhythm	Normal Sinus Rhythm
6	Normal Sinus Rhythm	Normal Sinus Rhythm
7	Normal Sinus Rhythm	Normal Sinus Rhythm
8	Normal Sinus Rhythm	Sinus Bradycardia
9	Sinus Bradycardia	Normal Sinus Rhythm
10	Normal Sinus Rhythm	Normal Sinus Rhythm

5.3 Pulse Rate, Oxygen saturation Level and Temperature Analysis

From this prototype, we can also detect pulse rate, oxygen saturation level, the motion of the patient, body temperature to detect the actual condition of a patient. A threshold value has been added to the IoT cloud for temperature, pulse rate, and oxygen saturation level. When the threshold value exceeds an emergency mail will be sent to the connected doctors and patients' relatives. So, by using this system elderly patients can get emergency help whenever needed.

Table 5.4 shows, the primary standard data for pulse rate and temperature measurement of a patient's body. If the above conditions are not fulfilled then automatic mail will be sent to the users for further treatment. Heart rate monitoring is an important component, especially in cardiovascular assessment and training programs. Cardiovascular diseases are the main cause of mortality among elderly people, they can also get paralyzed due to sudden heart failure. The pulse rate collected from patients' bodies can also help him or her to decide whether he can be able to go for exercise or not. Thus, sudden death during exercise and recovery time can be minimized. From this system, motion can also be detected by the video camera connected with the server.

Table 5.4. Reference Data for Pulse Rate, Blood Oxygen Level and Temperature Detection

Parameters	Data	Data	Data
Parameters/age	18-35	36-64	Above 64
Normal heart rate	72–75 (BPM)	76–79 (BPM)	70–73 (BPM)
Bradycardia	Heart Rate ≤ 55	Heart Rate ≤ 60	Heart Rate ≤ 65
Tachycardia	Heart Rate ≥ 110	Heart Rate ≥ 120	Heart Rate ≥ 100
Fever	Temperature ≥ 37.2°C	Temperature ≥ 37.5°C	Temperature ≥ 36.9°C
Hypothermia	Temperature < 35.5°C	Temperature < 35.1°C	Temperature < 35.0°C
Blood Oxygen Level (Normal Level)	95%- 100%	95%- 100%	95%- 100%
Hypoxemia (Below Normal Level)	< 95 %	< 95 %	< 95 %
ABG (Above Normal)	>100%	>100%	>100%

From this prototype, we can detect several diseases such as high fever, hypothermia, and patients' normal heart rate, Bradycardia, and Tachycardia due to abnormal heart rates.

The measurement of blood oxygen is called oxygen saturation level. In this prototype, a pulse oximeter has been used to check the blood oxygen saturation level (SpO2). A normal blood oxygen level for healthy lungs falls between 80 and 100 millimeters of mercury (mm Hg). If a pulse oximeter measured blood oxygen level (SpO2), normal reading will fall within 95 percent to 100 percent. However, for COPD or other severe lugs disease, these ranges may not apply. In that case, doctors will advise the patients about their specific blood oxygen levels. A below-normal blood oxygen level is called hypoxemia. Hypoxemia is often caused for concern. The lower the oxygen level, the more severe the hypoxemia. This can lead to complications in body tissue and organs.

Normally, a reading below 80 mm Hg or a pulse oximeter (SpO2) reading below 95 percent is considered low. When a patient's breathing is unassisted, it's difficult for oxygen levels to be too high. In most cases, high oxygen levels occur in people who use supplemental oxygen. This can be detected on an ABG.

From this prototype, it can be easily checked the oxygen saturation level from a patient's body from where we get to know about his or her lugs condition which is a very essential parameter for observing the people are affected or not in a worldwide pandemic COVID-19.

This device has been tested against healthy volunteers and it shows efficiency to detect the condition of a patient's body.

5.3.1 Pulse Rate and Oxygen Saturation Level Analysis

Pulse oximeter is noninvasive and painless test that measures oxygen saturation level in the blood. It can quickly detect how efficiently oxygen is being carried extremities furthest from the heart including the legs and arms.

Pulse oximeter works by emitting infrared and red light and having it passes through the tissue bed which includes pulsatile blood flow .The infrared and red light pass through the tissue bed over through a receiver. As the red and infrared light passes through the tissue bed the completed saturated and de saturated hemoglobin will absorb different spectrums and different amount of light. Fully saturated hemoglobin absorbs infrared light and de saturated hemoglobin absorbs red light by passing this information about how much light is absorbed of infrared and red light the machine will be able to calculates percentage of fully saturated hemoglobin in blood.

Pulse oximeter basically has an LED on one side and a photo detector on another side. The light emitted from one side of the finger travels through the tissue bed and venous blood and atrial blood is collected from the photodetector. The flow of the blood induced heartbeat. Oxyhemoglobin (HbO2) absorbs visible and infrared (IR) light differently than deoxyhemoglobin (Hb), and appears bright red as opposed to the darker brown Hb. Absorption in the atrial blood flow is represented by an AC signal and and DC signal represented the absorption of venous blood flow. The AC signal is superimposed on a DC signal. Cardiac-synchronized AC signal is approximately 1% of the DC level. This is referred to as the perfusion index %. The ratio 'R' is approximated in Equation (4). % SpO2 is calculated as follows:

$$R = (\text{ACrms of Red} / \text{DC of Red}) / (\text{ACrms of IR} / \text{DC of IR}) \quad (4)$$

The standard model of finding SpO2 is shown in Equation (5).

$$\%\ SpO2 = 110 - 25 \times R \quad (5)$$

The test results aims to determine the accuracy value of the prototype device by comparing the measurement results of device with Jumper Pulse Oximeter (JPD-500D OLED Edition). The comparison is shown as a percentage error in the table below by comparing different measurements

(Δbpm) with BPM measurements in pulse oximeter and the prototype as shown in the following formula.

$$\% \text{ error} = \left(\frac{\Delta\text{bpm}}{oxbpm}\right) \times 100\ \% \tag{6}$$

$$\% \text{ error} = \left(\frac{\Delta\text{SpO2}}{ox\text{SpO2}}\right) \times 100\ \% \tag{7}$$

The results of the test are written in the table below:

Table 5.5. Comparison of Heartbeat Rate and Oxygen Saturation Level measurement result with oximeter

SL No	Gender /Age	BPM Prototype Value	BPM Oximeter value	Error Rate %	Oxygen Saturation Level Prototype Value	Oxygen Saturation Level Oximeter Value	Error Rate %
1	Male/24	76	76	0	100	100	0
2	Male/26	80	81	1.23	98	98	0
3	Female/26	90	90	0	96	97	1.03
4	Female/30	79	79	0	98	98	0
5	Female/55	81	82	1.21	101	103	1.94
6	Male/57	98	100	2	98	99	1.01
7	Female/45	99	99	0	96	96	0
8	Female/29	111	111	0	100	100	0
9	Male/48	100	100	0	97	97	0
10	Male/45	79	79	0	99	99	0
Average Error Rate for BPM (%)				1.48			
Average Error Rate for Oxygen Saturation Level (%)							1.32

Table 5.5. Summarizes the results of measurements of bpm and oxygen saturation level for ten respondents. In calculating BPM the average error rate is 1.48 % and Oxygen Saturation Level the average error rate is 1.32 % which is almost ignorable.

5.3.2 Temperature Analysis

The DS18B20 is one type of temperature sensor and it supplies 9-bit to 12-bit readings of temperature. These values show the temperature of a particular device. The communication of this sensor can be done through a one-wire bus protocol which uses one data line to communicate with an inner microprocessor. The test results aims to determine the accuracy value of the prototype device by comparing the measurement results of device with Toshiba Thermometer. The comparison will be displayed as a percentage error by comparing the different temperature measurements (Δtemp) with the measurement of a digital thermometer (temp) as shown in the following formula:

$$\% \text{ error} = \left(\frac{\Delta temp}{thermometertemp}\right) \times 100\ \% \quad (8)$$

Table 5.6. Temperature Measurement result compared with a thermometer

SL No	Gender /Age	Prototype temp. Value in Fahrenheit	Public thermometer value in Fahrenheit	% of Error Rate
1	Male/24	96	96	0
2	Male/26	98	98	0
3	Female/26	99	99	0
4	Female/30	100	100	0
5	Female/55	98	99	1.01
6	Male/57	99	99	0
7	Female/45	98.7	100	1.3
8	Female/29	101	101	0
9	Male/48	98	98	0
10	Male/45	100	100	0
Average Error Rate (%)				1.15

Table 5.6. Summarizes that the data collected from the prototype and thermometer for ten respondents and the error rate is very minimal only 1.15 %.

5.4 Server

In order to view, real time data from sensor a live server with a database is needed. Initially a local server has been created to test the prototype device. For this, XAMPP is being used which is as Apache distribution containing pearl, PHP and MariaDB. XAMPP acts as a local server which allows to create database with phpMyadmin and operate the MySQL database [31]. After testing everything in local host the PHP file has been uploaded to the domain hosting website and created a server for health monitoring service for elderly patients. Figure 5.6 shown below, is showing the home page of the website.

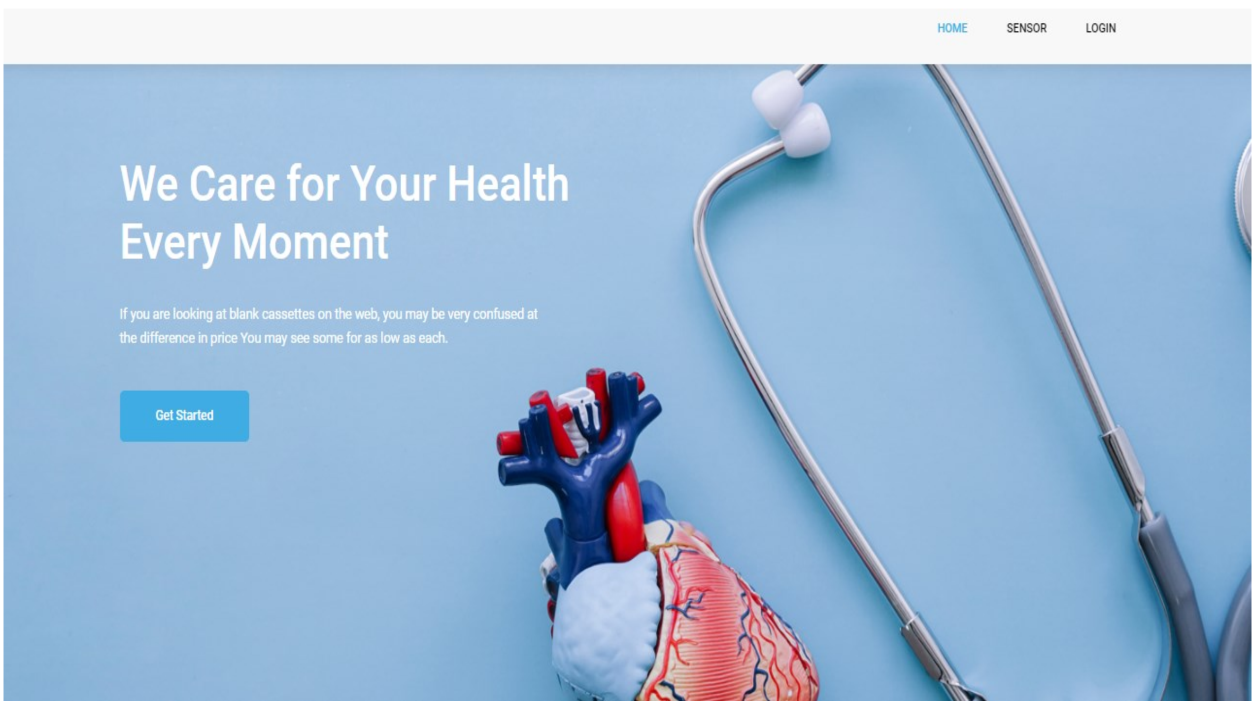


Figure 5.6: Home Page of health care monitoring system for elderly people

5.4.1 Database Table

The name of the prototype system database is healthba_registration. There are several tables, such as user, user details, chat, ecg, heat_rate and temp_sensor. In the following figure-5.7, there is all the tables' structure which shows all the attributes.

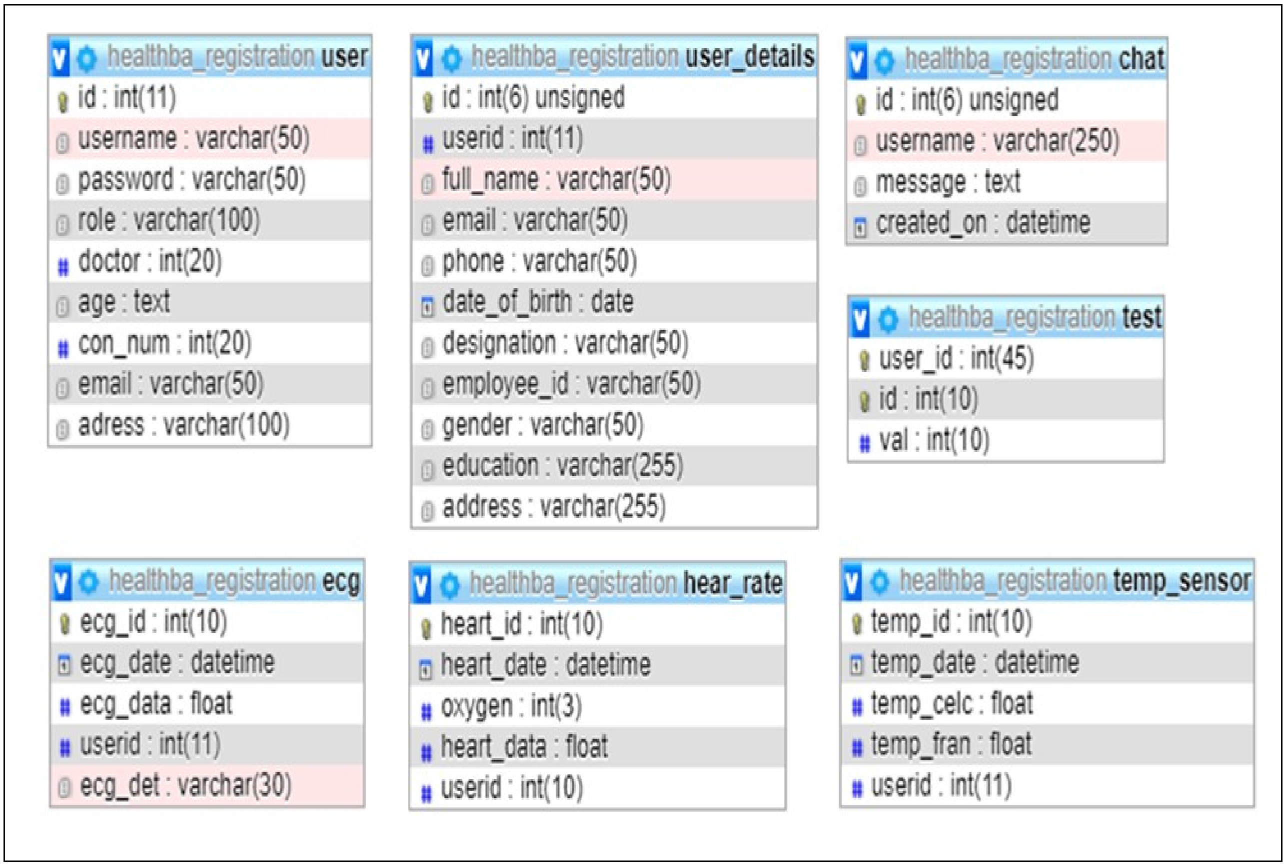


Figure 5.7: Database Table Structure.

In the database, there is a table named "user". This table contains all the information about patients and connected doctors. The main purpose of this table is to save data of registered people and help users to log in to account. The data of users saved using some personal information such as ID, user name, email, role, doctor, age, contact number, and address. The following figure 5.8 shows, the user table with necessary information.

Browse | Structure | SQL | Search | Insert | Export | Import | Operations | Triggers

+ Options

	id	username	password	role	doctor	age	con_num	email	adress
Edit Copy Delete	1	user	12345	user	3	33	1724694273	user.m@gmail.com	Badhan-01,Kadirabad Housing,Mohammadpur,Dhaka-1207
Edit Copy Delete	2	admin	12345	admin	-1	31	1717414265	admin.m@gmail.com	T-15, Noorjahan Road, Mohammadpur, Dhaka-1207.
Edit Copy Delete	3	doctor	12345	Doctor	-1	58	1921439822	doctor.m@gmail.com	House 71/A, Road 5/A, Dhanmondi R/A, Dhaka-1209
Edit Copy Delete	4	Habibur Rahman	user1	user	5	23	1719914365	habib.rahman@gmail.com	House-142, Block- H, Road-62, Gulshan, Dhaka-1212
Edit Copy Delete	5	Dr. Nusaiba Jesmine	12345	Doctor	-1	32	1707586912	nusaiba@yahoo.com	House-2, Block- Z, Road-172, Gulshan, Dhaka-1212.
Edit Copy Delete	6	Abeda Ahmed	12345	user	3	60	1747222444	ahmedabeda@yahoo.com	House-132, Block- I, Road-12, Bashudhura Dhaka
Edit Copy Delete	7	Aisha Siddika	47695	user	5	29	1700221234	aisha124@yahoo.com	House-12, Block- G, Road-2, Gulshan,Dhaka-1212
Edit Copy Delete	8	Dr. Jamil Mahmud	12345	Doctor	-1	49	1711584739	Jamil_mahmud@gmail.com	R-19,Tajmahal Road,Mohammadpur,Dhaka-1207.
Edit Copy Delete	9	Polok Rahman	1234	user	8	42	1729356859	polok.rahman@yahoo.com	House-6, Block- E, Road-132, Gulshan Dhaka-1212.
Edit Copy Delete	10	Jamal Chowdhury	1234	user	3	50	1727343669	jamal431@yahoo.com	House-12, Block- G, Road-132, Gulshan, Dhaka-1212....
Edit Copy Delete	11	Dr. Abdul Kader	doctor2	Doctor	-1	56	1516125462	kader_abdul@gmail.com	21-T, Salimullah Road, Mohammadpur, Dhaka-1207.
Edit Copy Delete	12	Raza Mahmud	9876	user	5	55	1341904321	mahmud_raza@gmail.com	P-19, Noorjahan Road, Mohammadpur, Dhaka-1207.
Edit Copy Delete	13	Dr. Mirza Kabir	kabir21	Doctor	-1	55	1617414265	kabir_mirza@yahoo.com	T-17, Shia Mosque, Mohammadpur, Dhaka-1207.
Edit Copy Delete	14	Shamoli Karim	4321	user	8	47	1719124375	shamoli_k@gmail.com	Flat No-08, Japan Garden City, Mohammadpur, Dhaka-...
Edit Copy Delete	15	Nayan Rahman	2941	user	11	38	1715247156	rahman_nayan@gmail.com	House 12/B, Shamoli , Mohammadpur, Dhaka-1207.
Edit Copy Delete	16	Md.Fazlul Bari	bari21	user	13	31	1724515234	bari.fazlul@yahoo.com	Flat 41/C, Japan Garden City, Mohammadpur,Dhaka-12...
Edit Copy Delete	24	mukur ali	12345	user	11	26	1303542120	tasnim.mukur@gmail.com	mohommadpurr

Check all With selected: Edit Copy Delete Export

Figure 5.8: User Table with data

This table contains information about patients' vital signs. The columns contains name of the patients and doctors, their ID, age, phone numbers and addresses. Here the column named ID will actually indicate the unique id of each device that distinguishes one patient from another. Whenever a patient record data, the data immediately store in this table.

5.4.2. Registration and Login

Primarily a patient needs to create an account. For this, the patient needs to register for an account providing necessary information such as username, password, email address, mobile number, age and address. After completing the registration patient can log in to the account by using only the user name and password. In the same process, a doctor can also be registered on the website by providing some basic information. An admin panel or authorized personnel is also connected in this website who can access all the information and can also add new users as both doctors and patients from the admin panel dashboard. Figure 5.10 shows, the user login and registration interface and figure 5.11 shows that, there are five doctors and twelve patients. The patients are registered under specific doctors and a doctor will only be able to check the health conditions of those patients' who are registered under his or her assistance.

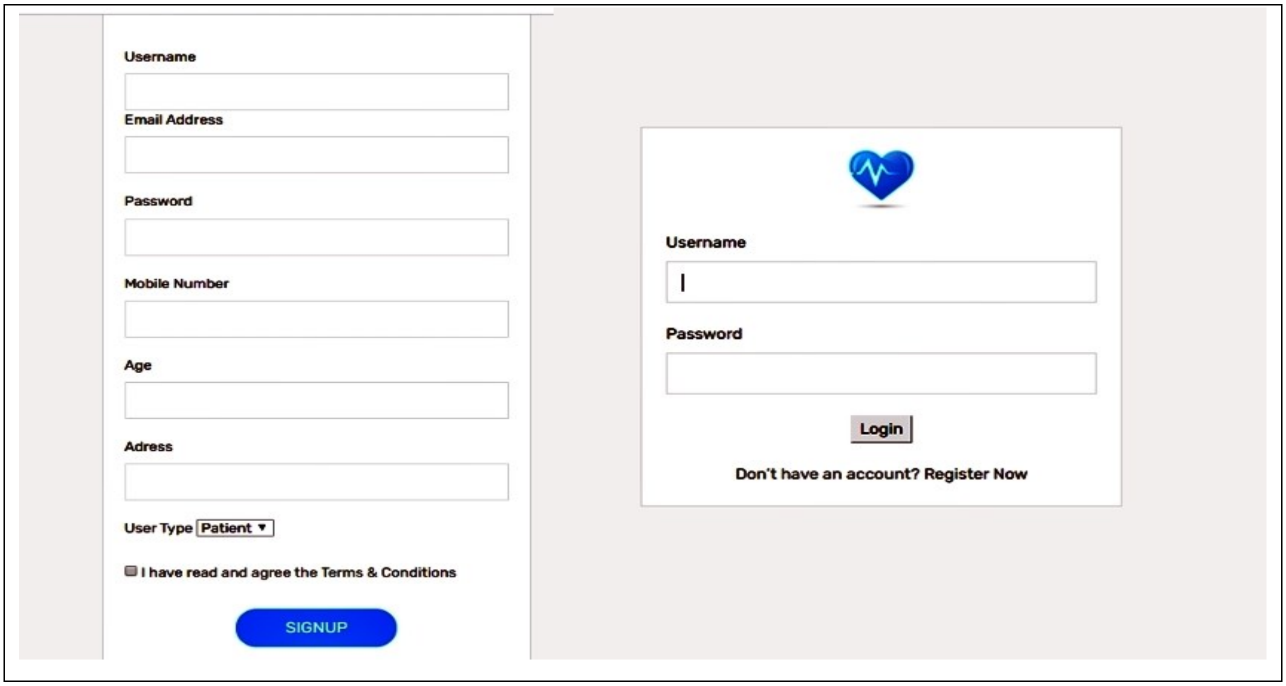


Figure 5.9: User Login and Registration Interface

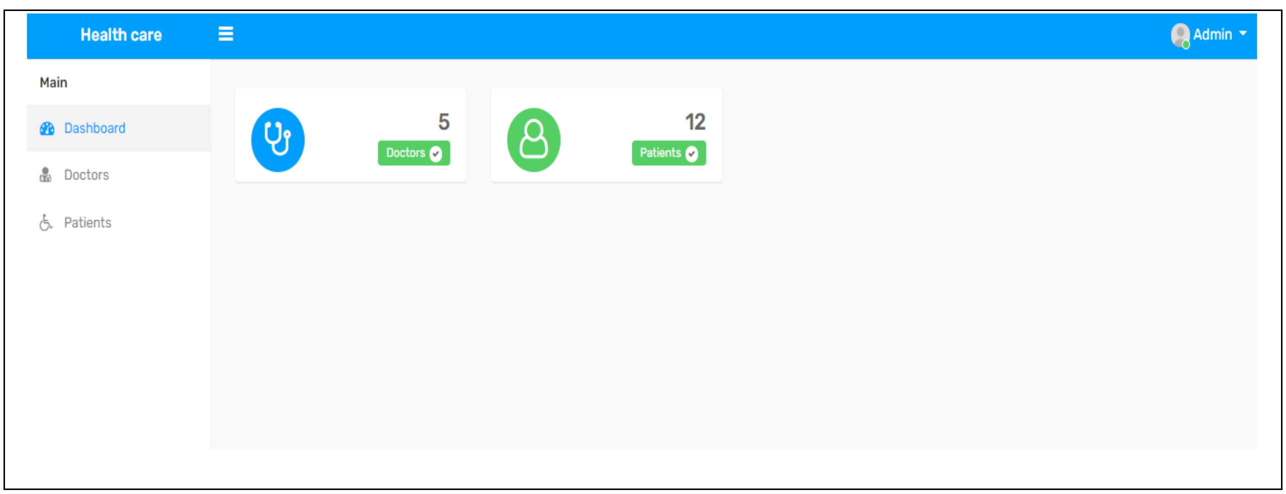
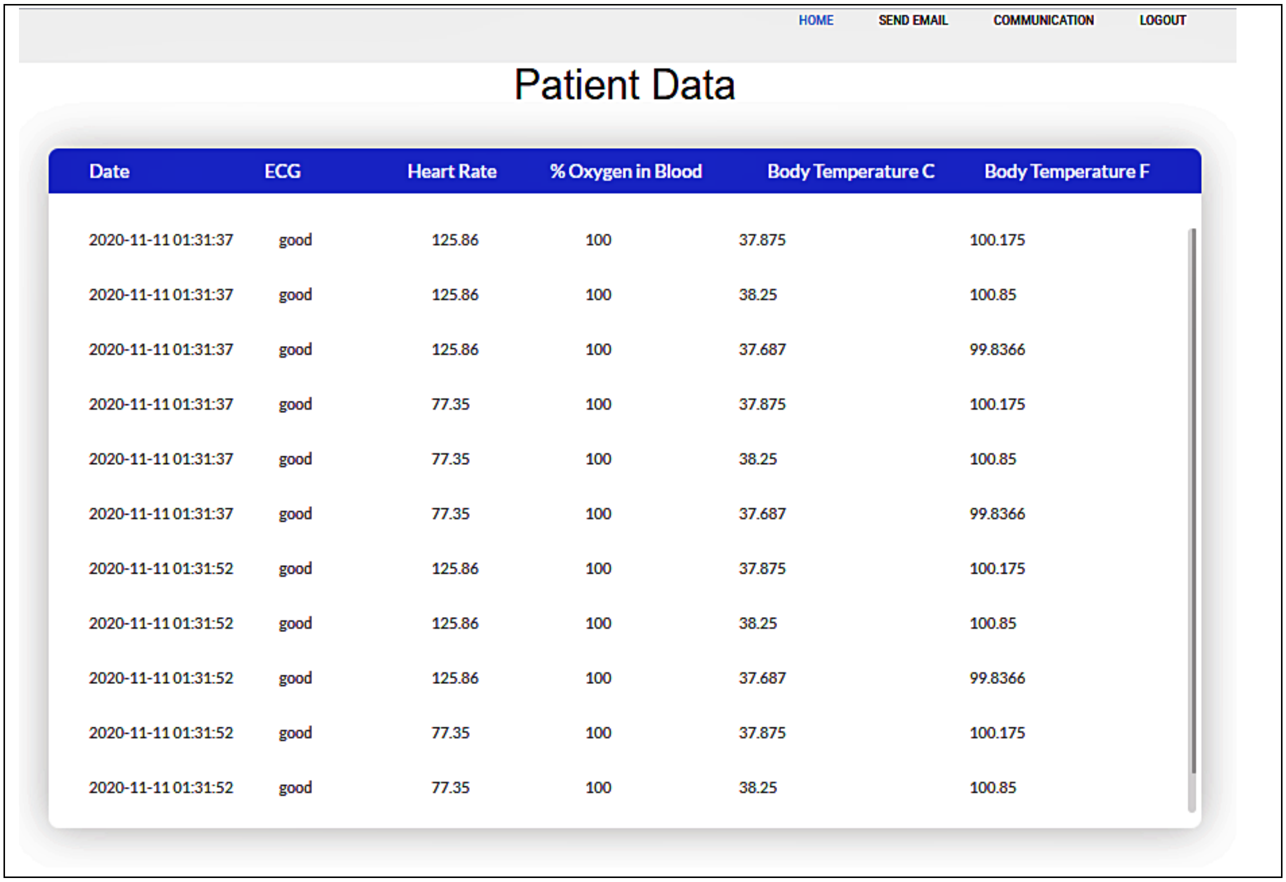


Figure 5.10: Admin Panel Dashboard

The following two figures 5.12 and 5.13 is the data showing in website after collecting all the data from a patients' body from the device using different sensors such as –ECG sensor, Temperature sensor, Pulse Oximeter sensor.



HOME SEND EMAIL COMMUNICATION LOGOUT

Patient Data

Date	ECG	Heart Rate	% Oxygen in Blood	Body Temperature C	Body Temperature F
2020-11-11 01:31:37	good	125.86	100	37.875	100.175
2020-11-11 01:31:37	good	125.86	100	38.25	100.85
2020-11-11 01:31:37	good	125.86	100	37.687	99.8366
2020-11-11 01:31:37	good	77.35	100	37.875	100.175
2020-11-11 01:31:37	good	77.35	100	38.25	100.85
2020-11-11 01:31:37	good	77.35	100	37.687	99.8366
2020-11-11 01:31:52	good	125.86	100	37.875	100.175
2020-11-11 01:31:52	good	125.86	100	38.25	100.85
2020-11-11 01:31:52	good	125.86	100	37.687	99.8366
2020-11-11 01:31:52	good	77.35	100	37.875	100.175
2020-11-11 01:31:52	good	77.35	100	38.25	100.85

Figure 5.11. Patient's Health Related Data Collected from Website

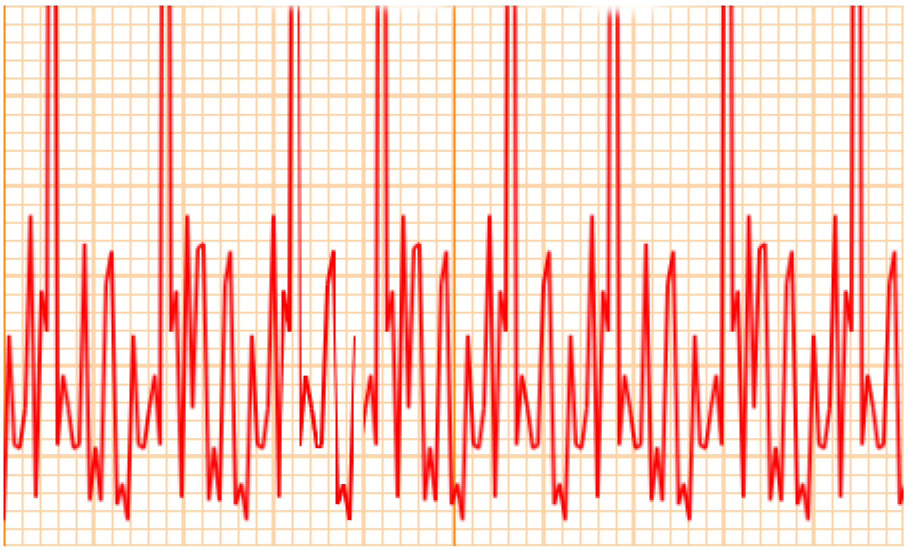


Figure 5.12: ECG data Collected from website

In emergency cases, it can automatically send an email to doctors and users of the device and they can be able to take necessary precautions in case of health service. And both doctors and patients can also communicate with each other via live chat.

There is also an application in this system that it can send automated and manual email to the patients' and doctors for abnormal temperature, heart rate and blood oxygen level. In the case of ECG user can send direct email from the website to the doctors for their expert assistance. Figure 5.13: shows the email notification sent to both patients in their connected email address. Thus patients' can get emergency services whenever they needed without visiting the hospitals regularly and this type of application is very much needed in a pandemic situations like COVID-19. So patients' can regularly get monitored by staying their home.

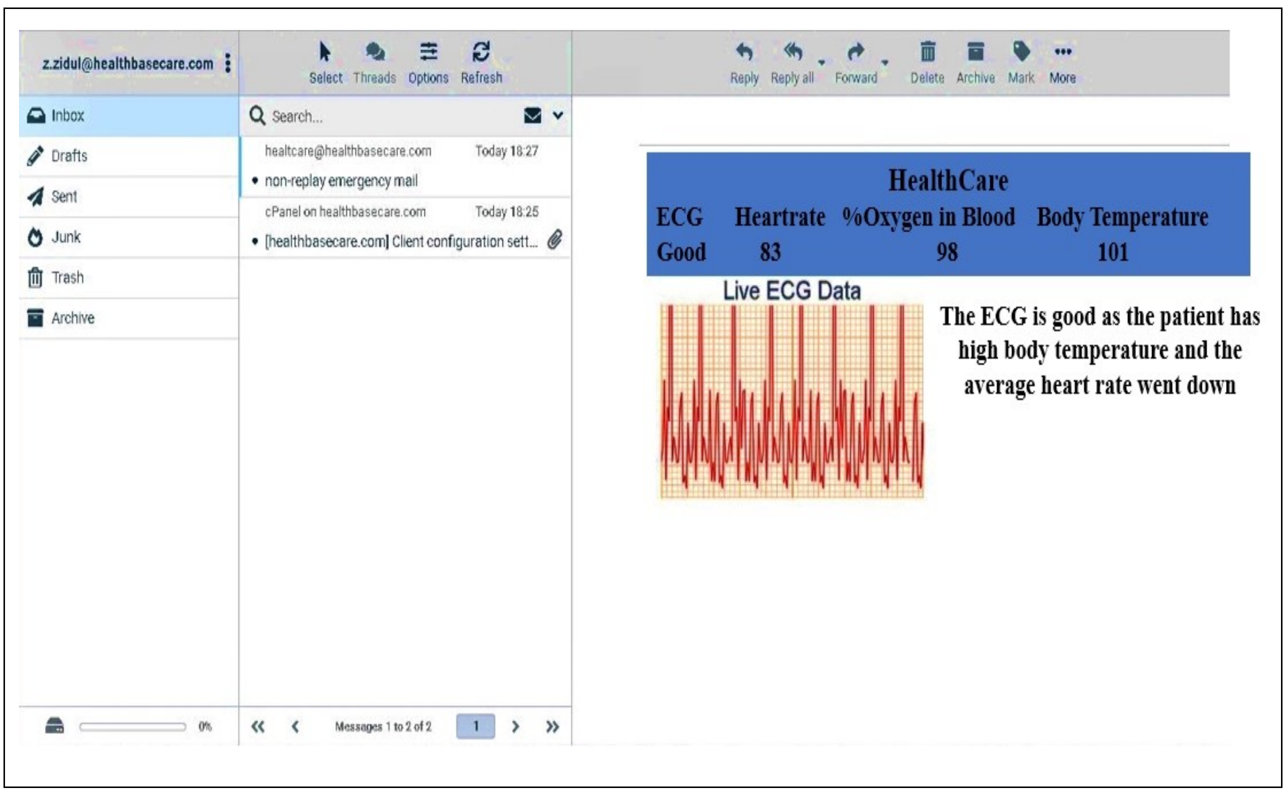


Figure 5.14: Email Notification

The prototype has been tested on several healthy volunteers to detect the primary health conditions of a patient. The prototype device on 10 patients at the cardiology department of Delta Medical College and Hospital and we got 80% efficiency in detecting ECG conditions and this prototype has also been tested in the emergency department and the other results show approximately 99.4% efficient to detect primary health diseases of an elderly patient.

5.5 Feasibility Analysis

The scalability of the systems depends much on the essential bandwidth of each individual system. The number of systems asked for the availability of the communication infrastructure in a certain area. The proposed system and prototype is independent and easy to use as it can easily be used in both homes and hospitals. It shows more than 80% efficiency compared with the devices used in hospitals. This porotype is very cost-efficient for a developing country like ours.

5.6 Cost Analysis

In this total research area of implementing a health monitoring system for elderly patients the goal is to minimize the cost, so that this device can be affordable for all in developing countries for both rural and urban areas. In table 5.1 all the components are listed used in the prototype with their market prices. The total cost of the health monitoring system for elderly people device will be 192 USD approximately.

Table 5.6. Cost Analysis of Health Monitoring Device

Equipment List	Unit	Model	Price in USD
Raspberry Pi 3	1	Model B	45
Heart Rate Monitoring Sensor	1	AD8232	11
Raspberry Pi camera	1	V2.1 8MP Night Vision	30
5 Inch HDMI TFT RPI Display	1	800×480 megapixel	44
4 Channel ADC Module	1	ADS1115 16-Bit	5
Waterproof Digital temperature sensor	1	DS18B20	1.5
Pulse Oximeter Sensor	1	MAX30100	7
Raspberry Pi OS	1	Raspbian Buster with desktop (32GB)	10
Arduino Uno	1	ATMEGA328P Microcontroller	2.5
400 Tie Points Breadboard White	1	Solderless	3.5
Male-Female Jumper Wires	20	n/a	1
Acrylic sheet (2x2)	1	n/a	9.5
Domain Hosting	5 GB	n/a	22

5.5 Chapter Summary

In this chapter results has been discussed using different sensors like ECG Sensor (to detect ECG data, Pulse Rate), temperature, pulse oximeter (blood oxygen saturation level) and motion of a patient using video surveillance camera from the prototype and the website. In this chapter we have also evaluated the performance analysis between medical equipment and the prototype built for this research and this porotype proves an efficient one to use in medical purpose.

Chapter 6

Conclusion and Future Work

The objective of the thesis is to understand the key requirements of a remote health monitoring System and use technology for mankind. Based on these knowledge, the thesis proposed an architecture that efficiently delivers healthcare data to the servers for further processing.

6.1 Conclusion

In this research, a prototype has been proposed and built an IoT-based health monitoring model for elderly care for assisted living by offering email notification to doctors and relatives of the patients. The most demanding feature of our system that, the health condition of the patient could be monitored from home and necessary precautions can be taken for emergency purposes. As it is a sensor-based implemented system, it can be reduced human-made errors. We have built a prototype to evaluate the performance and efficiency of our device. It is a low-cost device and can be used reliably at home for remote health monitoring. Now-a -days in a global pandemic such as COVID-19 this device can easily be used and patients' health data such as ECG, temperature, pulse rate, oxygen saturation level can easily be monitored without visiting the hospitals regularly. This type of application will be really helpful for developing countries like ours for the detection of cardiovascular diseases, lung problems which can be helpful to prevent severe and sudden damages to elderly patients.

6.2 Future Scope

- The future work will be included blood pressure monitoring, glucose level monitoring system, respiratory rate calculation in case of health monitoring.
- For further reliability and security purpose, adding a fingerprint sensor, face recognition for individual patient's registration can be done.
- By using this method I am also continuing my research in detecting different kinds of skin diseases like – measles, leprosy, chickenpox etc.
- A mobile application can also be built for the system where anyone who have a smart phone with internet connection can easily check his/her current health conditions and take medicine in proper time.
- It can also be compacted as a smart watch.
- Finally, I am trying to use artificial intelligence here in this prototype thus the system does not need any doctors to detect the health condition of the patients. The device will be useful enough to detect the condition of a patient and prescription can be auto generated.

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