Design and Development of an IoT-Enabled Health Condition Monitoring Kit

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Authors

Abstract

Present day's IoT brings the gadgets together and assumes a fundamental part in different methodologies like smart home mechanization, savvy urban areas, vehicle parking, traffic control, brilliant industries, smart environment, agribusiness fields and patient health monitoring system and so on. One of the approaches is to monitor the health state of the patient and screen it to doctors or paramedical staff through the IoT as it is hard to screen the patient for 24 hours. Health is a primary concern of every human being. Continuous health monitoring is becoming more important nowadays. But going to hospital for daily checkup can be costly and most of the time difficult for everyone. That is why a cost effective and wireless health condition monitoring system can be an effective solution. Now-a-days, health monitoring system plays the critical role by the observation of health conditions and detecting early vital sings of disease or ill-condition. In this paper, we proposed a health condition monitoring kit which is suitable with hardware implementation with the facilities of Internet of Things(IoT). The method is established on the amalgamation of Raspberry pi and firebase database. The system monitors body temperature, heartbeat, motion, galvanic skin response, blood oxygen level, blood pressure of every individual. The system is designed as user friendly with low cost and potency. Experimental studies shows the reliance and effectiveness of the proposed system with respect to existing models. In this way by utilizing this smart health monitoring system diminishes the exertion of specialists and paramedical staff to screen the patient for 24 hours and furthermore lessens the time and cost of support.

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CHAPTER 1

INTRODUCTION

Proper health monitoring is one of the basic necessities for the human beings. This chapter provides an overview of health condition monitoring kit, describes the problem statement, point out the objectives of the thesis and provides a short brief on thesis contribution along with the thesis organization.

1.1 Background

Healthcare is considered as the most important basic needs of a person. There are mainly two types of health which are considered most. They are physical and mental health. Physical health is mainly the state of being not having any diseases or injury. Physical health care plays a significant role to be free from different diseases. Different diseases causes different effects in our body. By monitoring different physical health parameters, many diseases can be detected and can be treated properly. It is considered good to do health checkup at least one time every year to make sure a person is physically fit. Applications of the Internet of Things(IoT) in healthcare have a positive impact on patients, families, physicians, hospitals, and insurance companies. A person's health can be monitored continuously even if no one is present near him/her. Doctors and nurses can also view patient health status online using an IOT system.

1.2 Problem Statement

On the report of the world health organization (WHO), health is the condition of physical and mental capability in the destitute of illness and infirmity[1]. Several life-threatening diseases can be easily monitored by IoT based systems. Nowadays routine health monitoring system has supported every community to reduce the works of doctors and nurses [2]. The use of IoT and sensor based intensive health care

systems are increasing rapidly. If any abnormalities happen in any health parameter ,then one can take immediate action without any delay[3].

Internet of Things (IoT) is now a reliable technological standard and a heavily researched field. In the recent development of IoT makes all objects interconnected and it has been recognized as next technical revolution. IoT makes our life smarter,more efficient and easier[4]. The unexpected occurance in the patients' body can be monitored using IoT.

Different health monitoring systems consist of different types of sensors to measure values of different health parameters and many health monitor kits have been developed which can expand the life quality with better health[5]. The area of health monitoring is on the basis of computer and electronics communication[6]. The ultimate goal of this activity is mainly developed using raspberry pi3 which offers a complete Linux server in a tiny platform for a very low cost. The combination of Raspberry pi and IoT becomes a new innovation technology in health care system. Raspberry Pi acts as a small clinic after connecting temperature sensor, heartbeat sensor, accelerometer sensor, gsr sensor, SpO_2 sensor and blood pressure module. However, IoT enabled wireless health condition monitoring system can be an effective solution.

1.3 Objectives of the Thesis

Health condition monitoring is a primary concern now. Daily and continuous monitoring is the main objective for every person. The main objectives of this thesis are as follows:

- Monitoring the health conditions such as body temperature, heart beat, movement of the body, sweat gland activity related to emotional arousal, blood oxygen level and blood pressure.
- Admin can see the health condition of the patient from various place from firebase database.

1.4 Scope

As it was mentioned earlier, the primary objcetive of this thesis is to develop an IoT enable portable health condition monitoring kit. By IoT based health kit, the user can detect any people's situation or any abnormalities through email notification. Person's health conditions can be observed all the time which are connected to the database . The system is a cost effective and wearable by the user while leading his daily routine without any complications.

1.5 Thesis Organization

Chapter 2 describes the literature review of the related paper and show the comparison among the existing models.

Chapter 3 describes about sytem overview and data flow of the system. The hardware implementation with sensor equipments and exprimental setup are also illustrated in this section of our system.

Chapter 4 represents the experimental analysis of our method. There is also an elaborate discussion of performance analysis in this section.

Chapter 5 draws the conclusions of our system. It also states some future works that can be done for improving the system.

CHAPTER 2

LITERATURE REVIEW

Health monitoring system is an exciting field where a lot of techniques are already available and in widespread use, but plenty of challenges still remain. This chapter provides overview some earlier health monitoring system. In this chapter some related works of the system will be discussed. It also includes brief observation on existing methods for health monitoring system and the comparison between the system and existing models.

2.1 Background Studies

Nowadays, IoT enabled health monitoring system plays the critical role by the observation of health conditions and detecting early vital signs of diseases or ill-conditions through IoT. There are some background studies needed to describe the system like the defination of IoT and importance of health condition monitoring kit.

2.1.1 Internet of Things (IoT)

The internet of things (IoT) refers to an interconnected set of computing devices that have unique identifiers on them and are able to exchange information over a network without any human intervention. It is embedded with sensors, processing ability, software and other technologies that connect and exchange data with other devices and systems over the internet or other communications networks. By means of low-cost computing, the cloud, big data, analytics and mobile technologies, physical things can share and collect data with minimal human intervention. In this hyperconnected world, digital systems can record, monitor and adjust each interaction between connected things. IoT can be used in monitoring patient's health ,for making smart house and smart city. The unexpected occurence in patient's are monitored using IoT.

2.1.2 Health Condition Monitoring Kit

A health monitoring system is a sophisticated technology and an alternative to the traditional management of patients and their health. It consists of a wearable wireless device like a bracelet with sensors that are paired with an application for a doctor to access the medical information. The health kit which is based on these electronic-based technologies and which is able to measure the patient's different physiological parameters like blood pressure, the temperature of the patient, heartbeat, pulse rate, recording of the electrical activity of the brain , electrucal activity of the muscle,changes in the sweat gland activity, the oxygen carrying molecules in the blood and then the measured result is transmitted using internert connectivity to enable health care providers far from the distance to monitor, control and analysis continuously.

2.2 Related Works

Nookhao et al. [2] discussed about a method that uses a arduino board to connect the temperature sensor and heartbeat (Easy pulse V1.1) sensor which shows the measurement on LCD display and at the same time sends them to ThingSpeak IoT platform in real time via WIFI. When both readings are uncommon,the ystem will send the notification to Line application with storing data in firebase database and showing the graph of heart rate and temperature values in real time.

Priya et al. [3] presents a project which uses pulse rate sensor,temperature sensor to measure pulse rate and body temperature which is attached to the patient's body. The pulse sensor operates on the principle of photo plethysmography (PPG) technique. From sensor data will be connected and the raspberry pi processes the data, the data is stored and updated to the database.

Kumar et al. [4] proposed a method which monitors body temperature, heart beat, respiration and accelerometer sensor using raspberry pi which is connected to the

internet to IoT website by adding with a transformer. It can be monitored in the monitor screen of the computer from anywhere.

Reddy et al. [5] proposes an IoT based health monitor system which is developed to measure body temperature and heart beat. The digital DS18B20 sensor and SEN-11574 sensor are used respectively by connectiong with raspberry pi. The measured sensor data is updated to cloud using ThingSpeak where data can be seen using graph for each person. An android application is also developed to show the data with the facility of emergency call and text message to the respected given number.

Thomas et al. [6] proposed a method which uses LM35 body temperature sensor and pulse sensor to measure body temperature and heart rate (dialostic and systolic) using arduino. Using HC-05 bluetooth module, the sensor data are sent to the android application. The temperature is shown in Fahrenheit scale and heart beat sensor measure the heart pulse in each minute which is displayed on the android.

Girhepunje et al. [8] monitored patient's body temperature using DS18B20 temperature sensor and heart beat using heart beat sensor which consists of a super bright red LED and light detector which are attached to the LPC2148 micro-controller. Bluetooth and GSM module were used because of real time wireless communication.

Ahmed et al. [9] proposed a system of patient health monitoring. The system monitors a patient's body temperature, heart beat and electrocardiography using LM-35 sensor and ECG sensor. These sensors were connected with Arduino Uno and this micro-controller was programmed to get heart rate of a patient from the electro-cardiograpgh signal obtained by ECG sensor. The collected data from the sensors processed by the micro-controller was then transferred to a physician by using wireless communication established by connecting bluetoooth HC-05 module to the Arduino.

Kumar et al. [10] uses DS18B20 body temperature sensor, pulse rate sensor, the accelerometer ADXL335 sensor and ECG module sensor to monitor the body temperature, heart beat, respiratory rate, position of the body, blood glucose of the patient connected to Arduino UNO and the detected information can be transmitted to

the server. The "ThingSpeak" named new cloud is utilized here to place the detected information into the server.

Kumar et al. [11] proposes the method to monitor the body temperature,blood pressure and heart beat of the patients by using temperature,heart beat sensor with 8051 microcontroller. Via WIFI module, the information sent to the server and checking framework by a remote gadget to measure the normality and abnormality.

Tamilselvi et al. [12] proposes a method which consists of temperature,heart beat,eye blink,SPO2, accelerometer sensor for fetching the patient's body temperature, coronary heart rate, eye movement and oxygen saturation percentage of the coma patient. It was designed by ThingSpeak which immediately triggers an alert message through the GSM device and Wi-Fi module by the use of a cloud server.

Acharya et al. [13] describes the method that uses LM35 temperature sensor, BP sensor, pulse sensor, ECG sensor (AD8232 heart rate onitor) to check the body temperature,heart beat, ECG and respiration of the patient in ICU. These sense the data from the patient's body and send towards controller and via WIFI module the doctor can track the patient from anywhere and can get a emergency alert from the web server. In the software interface , the health status is provided to the patient.

Fati et al. [14] proposes a method that uses LM35 temperature sensor, heartbeat sensor, accelerometer sensor and eye blink sensor to measure the condition of coma patient. These data are stored in the cloud which can be accessed by the patient's relatives via WIFI module and via GSM module,the alert is sent to the patient's relative if any abnormalities happen.

Puvaneshwari et al. [15] monitor the pulse rate, heart rate, temperature, oxygen saturation rate and blood pressure by using pulse sensor, heart rate sensor, temperature sensor, spo2 sensor(pulse oximetry sensor) and pressure sensor and the sensor data will be sent to the smartphones of caretaker by WSN and alert will be gone if the data is higher or lower than database.

Selvarani et al. [16] proposes a method that uses temperature sensor(LM35) and pulse sensor to monitor the body temperature and heart beat from the distance

location.The sensor data are transmitted to the programmed microcontroller (PIC16F877A) to the PC through Zigbee. The PC collects the physiological measurements and also sends SMS to the indicated mobile number through a GSM modem.

Reshma A. et al. [17] allows heart beat sensor, temperature sensor and ECG sensor to detect heart problem of the person using microcontroller and the sensor data are sent to the cloud sytem via WIFI and store on the database. By using GSM module,the system can send message to the doctor if any abnormality can recognized.

Tariq et al. [18] proposes a heart beat sensor bracelet to check the heart beat and the sensor datas are uploaded to the website which is available by the patients who are registered with a doctor-patient history updates side by side. By using the machine learning tools and techniques,linear regression algorithm (LM), classification and regression tree algorithm(CART) are used to analyze the heart beat and detection of heart rate in R language.

Warsi et al. [19] uses thermometer, electro-cardiogram sensor and sphygmomanometer attached to an arduino which transfer its data to servers using a wifi-module to measure the temperature, blood pressure and electro-cardiogram. The data could be monitprd on hand held device of the user according to date and time and alert is sent if tha datas are outside of the range.

Aziz et al. [20] implement a cloud based health care that uses DS18B20 temperature sensor and AD8232 sensor to measure the body temperature and the elecrical and muscular function of heart which sends datas to cloud server to store connected to fire base real time database. Patient's health parameter can be viewed by smart devices.

Pardeshi et al. [21] reviews a IOT based system which uses LM35 body temperature sensor,blood pressure sensor, heart beat sensor, ECG sensor to get the data of the patient's health condition using raspberry pi which can give alarms if any abnormality happens using GSM module. The data storage segment is to store the data from the sensors using IOT.

Rohit et al. [22] reviews a IOT based health monitor that proposes pulse/heart beat sensor,body temperature sensor, ECG sensor, blood pressure sensor, patient position sensor which is connected to raspberry pi to get the health condition of the patient and the sensor datas are sent to internet vnc server. The application is divided into four stages:- data acquisition,data processing,data storage and data transmission.

Chowdary et al. [23] developed to design and implement a cost effective health monitor system which is wearable and movable with the patient in his working environment. The system contains hardware and software part. The hardware part is implemented using Raspberry pi and different health parameter sensors such as pulse sensor (to measure heartbeat), temperature sensor(to measure body temperature), blood pressure sensor(to measure blood pressure). The additional fingerprint sensor is used for allowing only the respective doctor to get the measured result. The LED is used to indicate blood pressure level. The software part is implemented by using GSM module to send SMS to the doctor with patient id and Raspberry pi is used to make the webserver so that the doctor can see the sensor values through webpages.

Kamble et al. [24] explains a system for health monitoring with cloud security using the technique of Internet of Things(IOT). The system is designed to measure temperature, heartbeat, ECG and acceleration using sensors like LM-35, Heartbeat Sensor–AD8232, ECG Sensor –AD8232, Accelerometer Sensor- ADXL335 respectively. The system is implemented using Raspberry Pi B+ model to carry the measured data to a web server. An additinal ADC 0808 module is added with Raspberry Pi. The doctor can see the data using smartphone and give prescription. A database system using MySQL is developed for doctor, patients and admin of the system.

Kokalki et al. [25] intended to develop a health band along with cloud technology and android application. It is based on four tier architecture. Firstly, it uses pulse sensor and Lilypad temperature for measuring heartbeat and temperature of a patient using arduino uno along with a battery for the power of the band. Then ESP8266 Wi-Fi shield is used for connecting with cloud and interent. The data is uploaded and stored using open source cloud platform called Thingspeak. Lastly android application is developed for showing the values of the sensors along with location. Emergency notification system of the sensors data with location is developed as well.

Doss M et al. [26] describes a system of health monitoring for the children. It measures four parameters like heartbeat, temperature, respiration, type 1 diabetics. The theorem of optoelectronics with LED and microcontroller is used for heartbeat, LM35 for temperature, respiration sensor and blood gas sensor is used respectively along with Raspberry Pi 3B+ model. A IoT board is established to connect with cloud using Wi-Fi module. A Condenser Mic and a ADCis added with the system for better work.

Patil et al. [27] monitors health condition of a human being using the technology Internet of Things(IoT). The system monitors ECG, temperature, heartbeat, blood pressure and respiration using AD8232 module, DS18B20 waterproof temperature sensor probe, pulse sensor, Sound Sensor Module- MIC connected to Arduino Mega 2560 microcontroller. The 16*2 LCD display is also used in the system. ESP8266 Wi-Fi module is used to connect to the cloud which is developed using ThingSpeak cloud server.

Shaikh et al. [28] describes a health monitor system based on Internet of Things(IoT). The system measure health parameters such as temperature, heartbeat, ECG, blood pressure and body position using sensors like LM35 sensor, heart rate sensor, ECG sensor, blood pressure sensor, ADXL335 accelerometer respectively. The sensors are connected the Raspberry Pi Model B+ board where the sensor data is processed and stored in cloud. The raspberry pi also sends SMS to the respective doctor in emergency situations.

Vippalapalli et al. [29] explained in the paper monitors health condition with the Internet of Things(IoT) technology. The system measures body temperature using LM35 sensor, heartbeat using IR sensor and blood pressure using blood pressure sensor. These sensors are connected with Arduino Fio which is a Zigbee Development Platform. By connecting USB, the sensors values are recieved by using LabVIEW enabled PC by VISA (Virtual Instrumentation Software Architecture). Everytime the values are checked with threshold values for each for indicating any emergency situation. A web server is developed by LabVIEW to see the sensor values anytime from anywhere through a webpage.

Misran et al. [30] explained in this paper is based on a technology called LoRa Communication Technology for implementing IoT. There are four biomedical sensors used here which are ECG sensor, body temperature sensor, pulse rate sensor and oxygen saturation sensor. These sensors are connected with the MySignals and Arduino UNO. The measured data is sent to cloud via LoRa module and Waspmote gateway to personal computer. The LoRa module is connected to one hyper-terminal called RealTerm. The data packet is sent and recieved with a fixed baud rate.

2.3 Observation on Existing Models

A variety of health monitoring systems have been developed that use different sensors for measuring values of various health parameters. A number of health monitoring kits can facilitate better health. There have been a number of research projects and prototypes that have been developed to deal with different diseases, users, or geographical scopes of applications. In most of the existing models, the systems are faciliated with IoT technologies for data transfer and storage. IoT is mostly used because IoT makes our life smarter, more efficient and easier. Different systems measure different types of health parameters and uses different types of sensors. Most of the systems use raspberry pi and arduino uno. Some of the IoT technologies used in the systems are LoRa communication, Zigbee, WSN, GSM etc. For data storage, most of the existing systems used ThingSpeak and firebase database platform.

Table 2.1 shows the overall comparison of different existing models of health condition monitoring system. In the table, display devices used for data visualization are given. Also, the hardware components as well as whether IoT facility is provided or not are also shown in the table.

Table 2.1. Comparison between existing models.

Author	Year	Display Device	Hardware Components	IoT Enabled
Nookhao et al. [2]	2020	LCD display and computer	Temperature sensor,heart beat sensor,arduino,WIFI module	Yes
Priya et al. [3]	2019	Monitor or smartphone	Body temperature sensor,pulse rate sensor,Raspberry pi	Yes
Kumar et al. [4]	2016	Personal computer	Body temperature ,heartbeat,respiration and accelerometer sensor,raspberry pi	Yes
Reddy et al. [5]	2017	Mobile app	Temperature sensor, heartbeat sensor, Raspberry pi	Yes
Kumar et al. [10]	2017	Monitor	Body temperature ,pulse rate,accelerometer sensor,ECG module,Arduino UNO	Yes
Kumar et al. [11]	2017	Smartphone	Body temperature and heart beat sensor,8051 micro controller	Yes
V et al. [12]	2020	LCD display	Body temperature,heartbeat,eye blink,SPO2,accelerometer sensor,GSM	Yes

Acharya et al. [13]	2020	Mobile app	Body temperature sensor ,BP sensor,pulse sensor,ECG sensor,WIFI module	Yes
Fati et al. [14]	2018	PDA	Temperature sensor,heart beat sensor,accelerometer sensor,eye blink sensor,WIFI module ,GSM module	Yes
Puvaneshwari S et al. [15]	2016	Smartphone	Pulse sensor,heart rate sensor,temperature sensor,spo2 sensor,pressure sensor,WSN	No
Selvarani et al. [16]	2017	personal computer	Body temperature sensor and pulse sensor,MIcrocontroller(PIC16F877A), Zigbee	Yes
Reshma A. et al. [17]	2019	Monitor	Heart beat sensor,temperature sensor,ECG sensor,WIFI module,GSM module	Yes
Tariq et al. [18]	2019	Smartphone	Heart beat sensor	No
Warsi et al. [19]	2019	Monitor	Thermometer ,electro cardiogram sensor,sphygmomanometer sensor,Arduino.WIFI module	Yes
Aziz et al. [20]	2019	Smart device	DS18B20 temperature sensor,AD8232 sensor,	Yes

Pardeshi et al. [21]	2017	Monitor	Body temperature sensor,blood pressure sensor,heart beat sensor,ECG sensor,raspberry pi,GSM module	Yes
Rohit et al. [22]	2018	Monitor	Pulse sensor,body temperature sensor,ECG sensor,blood pressure sensor,patient position sensor,raspberry pi	Yes
Chowdary et al. [23]	2018	Monitor	Temperature sensor, pulse sensor, blood pressure sensor, Fingerprint sensor, Raspberry pi, LED, GSM module	Yes
Kamble et al. [24]	2018	Smartphone	Temperature sensor, heartbeat sensor, ECG, accelerometer, Raspberry pi b+ model, ADC 0808 module	Yes
Kokalki et al. [25]	2017	Mobile app And health band	Heartbeat sensor, temperature sensor, Arduino uno, wifi module, battery	Yes
M et al. [26]	2019	Monitor	Heartbeat sensor, temperature sensor, respiration sensor, blood gas sensor, Raspberry Pi 3B+ model, Wi-Fi module, Condenser Mic, AD converter	Yes
Patil et al. [27]	2017	Central Monitor	Heartbeat sensor, Grove - Gas Sensor (O_2), temperature sensor, ATmega328P processor, GPS Receiver, WiFi module, panic button, buzzer	Yes
Shaikh et al. [28]	2017	Monitor	Temperature sensor, blood pressure sensor, heartbeat sensor, ECG sensor, body position sensor, Raspberry Pi Model B+ board	Yes

Vippalapalli et al. [29]	2016	Monitor	Body temperature sensor, IR sensor, blood pressure sensor, Arduino Fio, USB	Yes
Misran et al. [30]	2019	Personal computer	ECG sensor, body temperature sensor, pulse rate sensor, oxygen saturation sensor, Arduino uno, LoRa module, Waspmote gateway	Yes
Kamal et al. [31]	2018	Monitor	Temperature sensor, heartbeat sensor, body motion sensor, Raspberry Pi, temperature controller and pacemaker	Yes
Patil et al. [32]	2017	Central Monitor	Heartbeat sensor, Grove - Gas Sensor (O_2), temperature sensor, ATmega328P processor, GPS Receiver, WiFi module, panic button, buzzer	Yes
Saha et al. [33]	2018	LCD screen, monitor	ECG sensor, temperature sensor, IR sensor, blood pressure sensor, Raspberry pi, transformer	Yes
Subha et al. [34]	2020	LCD display	Temperature sensor, IR sensor, accelerometer, Arduino	Yes
Mumrez et al. [35]	2019	Mobile app	Pulse sensor, temperature sensor, blood pressure sensor, Arduino Uno Rev 3 microcontroller, wifi module	Yes
Riaz et al. [36]	2017	LCD display	Heartbeat sensor, temperature sensor, ECG sensor, blood pressure sensor, Arduino uno, Zigbee S2 Module, RFID Module RMD 6300, 20*4 LCD display	Yes
Chakravorty et al. [37]	2018	Mobile app	Temperature sensor,heart beat sensor, raspberry pi, actuator	Yes

Swamy et al. [38]	2019	Mobile app	body temperature sensor, oxygen saturation (SpO2) measurement sensor, blood pressure sensor, bluetooth module HC-05, Arduino	Yes
Utekar et al. [39]	2018	Monitor	Temperature sensor,heart beat sensor, Arduino mega 2560 microcontroller, wifi module	Yes
Athira.A et al. [40]	2020	Monitor	Temperature sensor, heartbeat sensor, oxygen level sensor, ECG sensor, Arduino uno	Yes

CHAPTER 3

METHODOLOGY

In this chapter, we have discussed about the methodology implemented in our system. We have explained the system overview with proper figures. We have also discussed about the hardware implementation with core devices, sensor equipments of the system and the blood pressure module. It also includes the experimental setup of the system.

3.1 System Overview

The health condition monitoring kit which is proposed mainly developed in two parts:

a) Sensor's data acquisition.

b) Data analysis ,storage and visualization to the cloud.

At first, there are many biomedical sensors which are used to measure different health parameter like body temperature,heart beat,movement of the body, blood pressure sweat gland activity related to emotional arousal and blood oxygen level. These sensors collected data from the users. Temperature, pulse sensor, GSR sensor, accelerometer, blood pressure module and SpO_2 sensor are connected to the Arduino Uno and as the data are analog data, the Arduino is connected to raspberry pi. It is controlling the whole system. The data is updated to the Firebase database.

The blood pressure module is implemented separately as no built in sensor is available. The blood pressure module is created with the combination of a pressure sensor and different hardware device to get diastolic and systolic value of the user of the module.

The system mainly follows three tier architecture. There are three tiers in the system.

In layer 1, the sensors of the system like LM35, pulse sensor, blood pressure module, motion sensor, GSR sensor and SpO_2, collect data from users and send the data to layer 2.

In layer two, at first, the collected data is sent to Arduino Uno for processing the analog data and convert it to the digital format as the Raspberry Pi takes digital data. After processing, Arduino Uno sends the processed data to Raspberry Pi via USB cable.

Finally, in the third layer, the processed data collected by Raspberry Pi is sent to cloud. In the cloud, Firebase platform is used. In Firebase, the data is stored in Firebase database system and visualized to the user. So, the admin or user can easily login to Firebase system and can see the data from anywhere anytime by the technology of Internet of Things (IoT).

Figure 3.1 shows the flow diagram of the overall system implementation. Here, the system is designed using the three tier architecture described above. The user data is saved in the cloud database and the user can observe the abnormality of the values of the health parameter data from anywhere through the access point of the cloud.

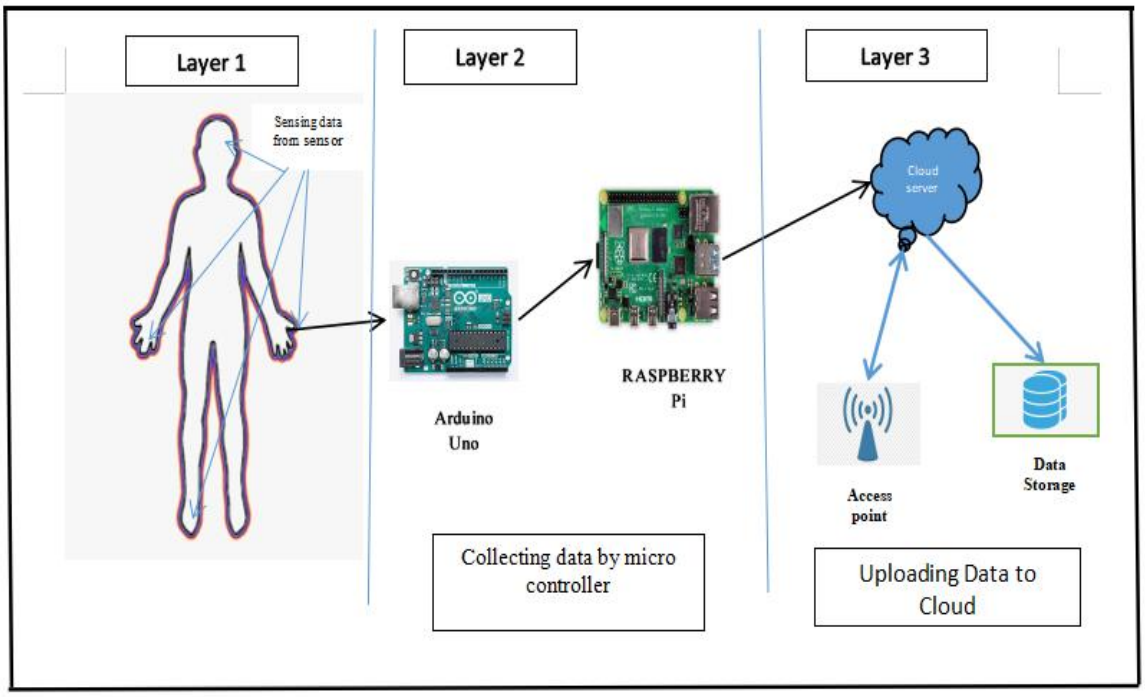

Fig. 3.1: The flow diagram of the system.

Figure 3.2 shows the data flow of the system. The system follows mainly 5 steps. The sensors collect data from the user and send the data to Arduino Uno. The collected data is processed in the Arduino Uno to send the data in Raspberry Pi which is the core of the whole system. After processing, the sensors data are sent to Raspberry pi. Raspberry Pi sends the processed data to the cloud. For the system, we used Firebase cloud system for data storage and visualization.

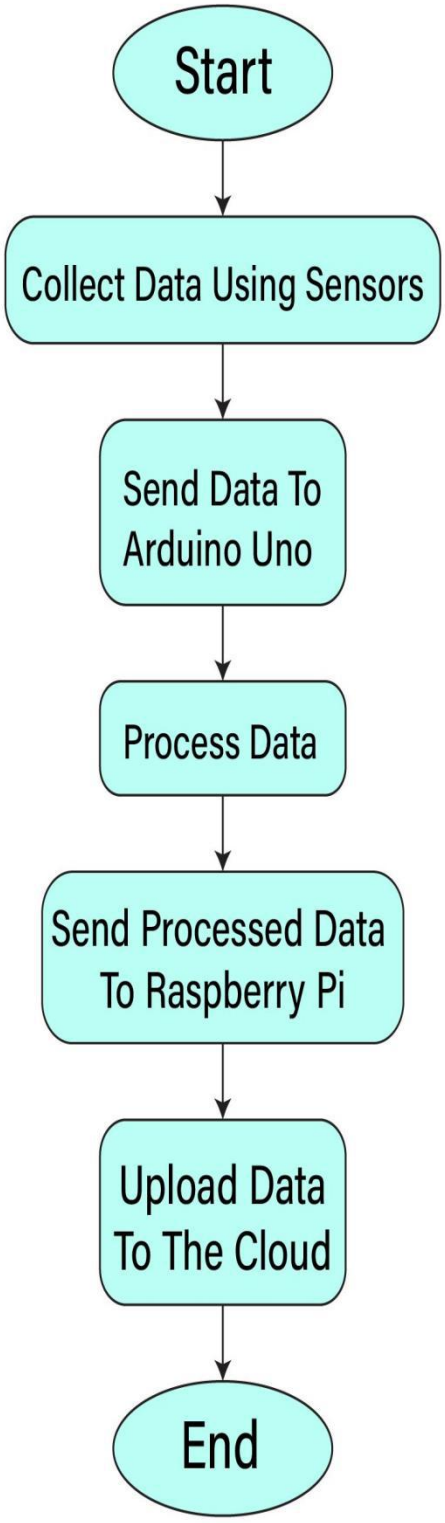

Fig. 3.2: The data flow of the system.

3.2 Hardware Implementation

The entire system can be illustrated by raspberry pi, two Arduino Uno and six sensors which are LM35 temperature sensor, pulse sensor, GSR sensor, adxsl345 accelerometer sensor, SpO_2 and pressure sensor. One core Arduino is used for collecting the data from all sensors and the other one is used for creating the blood pressure module. The other Arduino is connected with the core Arduino Uno with the serial communication. The hardware specification of the core devices of the system are discussed below:

3.2.1 Core Devices

There are some core devices which are used to combine different sensors. They mainly collect data from the the sensors and maintains the data flow of the system.

I) Raspberry Pi:

The Raspberry pi 3 model B is the third generation Raspberry Pi. This powerful credit-card sized single board computer can be used for many applications an supersedes the original Raspberry Pi Model B+ and Raspberry Pi 2 Model B. Raspberry pi 3 model comes with 64 bit quad core processor, on board WIFI and Bluetooth and USB features. The CPU of this device is considered as the brain of the device which is responsible for executing numbers of instructions based on mathematical and logical operation.

Fig. 3.3: Raspberry pi3 model.

II) Arduino Uno:

Arduino/Genuino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

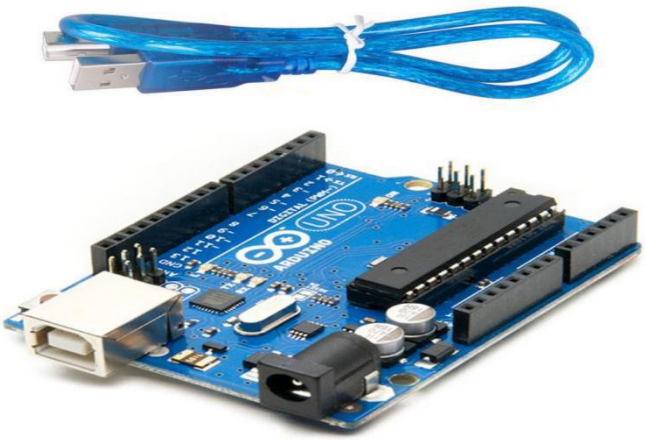

Fig. 3.4: Arduino Uno.

3.2.2 Sensor Equipments

A) LM35 temperature sensor:

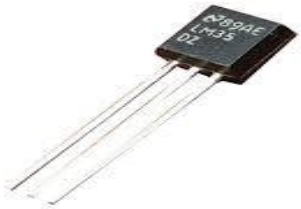

Fig. 3.5: LM35 temperature sensor.

LM35 temperature sensor is used in our project. It is placed in the user's finger for measuring the body temperature of the user. LM35 sensor's output range is -40°C to 110°C. LM35 is an integrated analog temperature sensor whose electrical output is proportional to Degree Centigrade. LM35 does not require any external calibration or trimming to provide typical accuracy.

B) Pulse sensor:

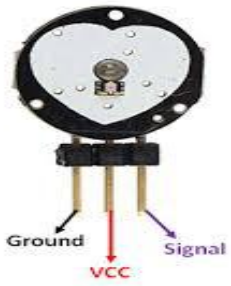

Fig. 3.6: Pulse sensor.

Heartbeat is measured using a pulse sensor. Pulse sensor is a plug-and-play heart-rate sensor for Arduino Uno. The 24'' cable on the pulse sensor is terminated with standard male headers so there's no soldering required. It measures the heartbeat of the user continuously after every 1minute. Its operating voltage is +5V or +3.3V and current consumption is 4mA.

C) GSR sensor:

Fig. 3.7: GSR sensor.

GSR is the measure of the continuous variations in the electrical characteristics of the skin for the instance the conductance caused by the variation of the human body sweating. The GSR signal is very easy to record. Two electrodes put at the second and third finger of one hard are necessary. The variation of a low voltage applied current between the two electrodes is used as measure of the EDA.

D) ADXL345 accelerometer sensor:

ADXL335 is accelerometer sensor which works on the principle of Piezoelectric effect. whenever we will tilt the sensor the ball is supposed to move in that direction because of Gravitational force. The walls are made of Piezoelectric elements. ADXl335 is a triple axis accelerometer.

Fig. 3.8: adxl345 accelerometer sensor.

E) SpO_2 Sensor:

For measuring oxygen level, the MAX30102 pulse oximeter is used. The MAX30102 is an integrated pulse oximetry and heart-rate monitor biosensor module. It includes internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection. The MAX30102 provides a complete system solution to ease the design-in process for mobile and wearable devices. It can also be used as a pulse sensor. Its operating temperature range is -40°C to +85°C.

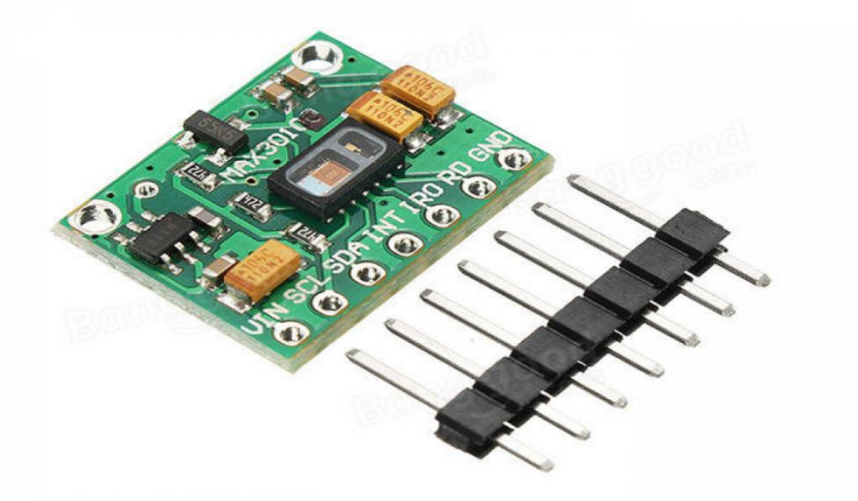

Fig. 3.9: MAX30102 pulse oximeter.

The system is developed using the communication between Raspberry Pi and Arduino Uno with serial communication as well as serial communication between two Arduino Uno. One Arduino Uno is called the sender Arduino which is used to design blood pressure module and another Arduino Uno is called the receiver which collects data from other builtin sensors as well as from sender Arduino for blood pressure value of the user. Fig. 3.10 shows the schematic circuit of the hardware system. Here, the temperature sensor, pulse sensor, accelerometer, SpO_2 sensor, GSR sensor are connected directly to the receiver Arduino which is connected to Raspberry Pi. Again, the blood pressure module is connected to the receiver Arduino Uno via the sender Arduino Uno.

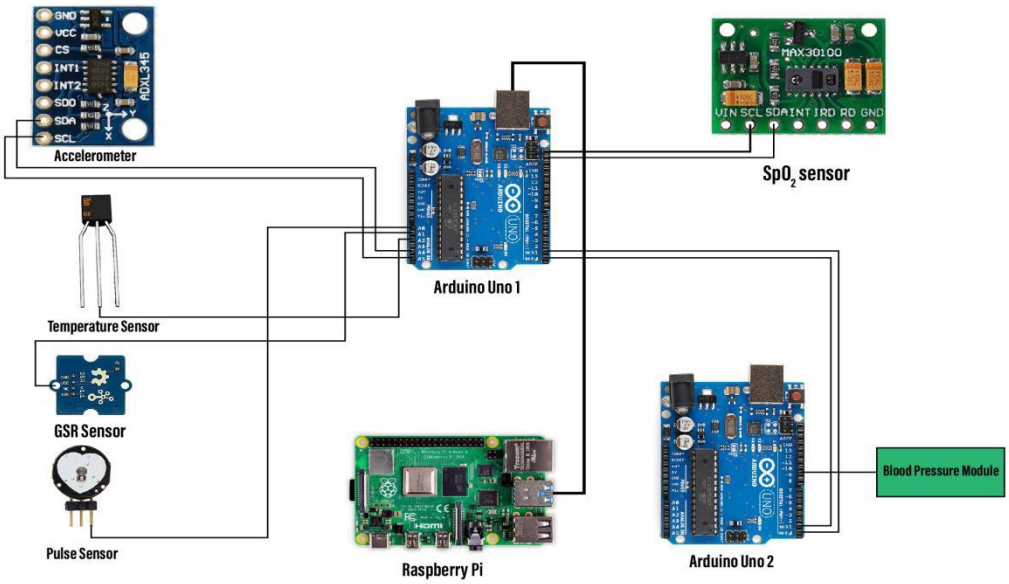

Fig. 3.10: The Schematic Circuit of the System.

3.3 Blood Pressure Module

The PB measurement platform is composed of two parts: a hardware part, which is the BP measuring circuit, and a software part, which is the Arduino code. The hardware constitutes of an Arduino board, an air pump, an air valve, an inflatable cuff, a pressure sensor and an amplifier circuit. The air pump is used to inflate the cuff and the valve is used to regulate inflation and deflation. The pressure sensor measures the pressure inside the cuff by producing a voltage signal that reflects the pressure and oscillation of the compressed artery. An operational amplifier is needed to amplify the sensor signal. The amplified signal is acquiesced by the Arduino. A software code on the Arduino processes the signal and performs basic computation to estimate the mean arterial pressure (MAP) and from its value the systolic and diastolic blood pressure values can be extracted. The MAP is defined as the average BP in a person's arteries during one cardiac cycle and is considered a better indicator of perfusion to vital organs [40]. The Arduino Uno of the module is connected with the core arduino using

serial communication. The RX and TX pin of the module's Arduino is connected to the pin TX and RX of the core Arduino respectively. Fig. 3.11 shows the serial communication between two Arduino Uno.

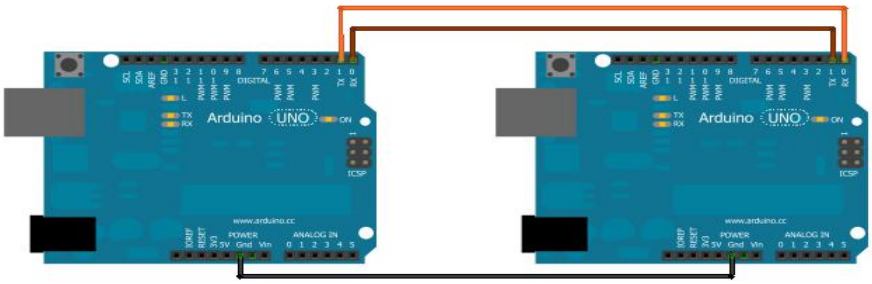

Fig. 3.11: Arduino-Arduino Serial Communication.

The hardware circuit of the implementation of the blood pressure module is shown in fig. 3.12.

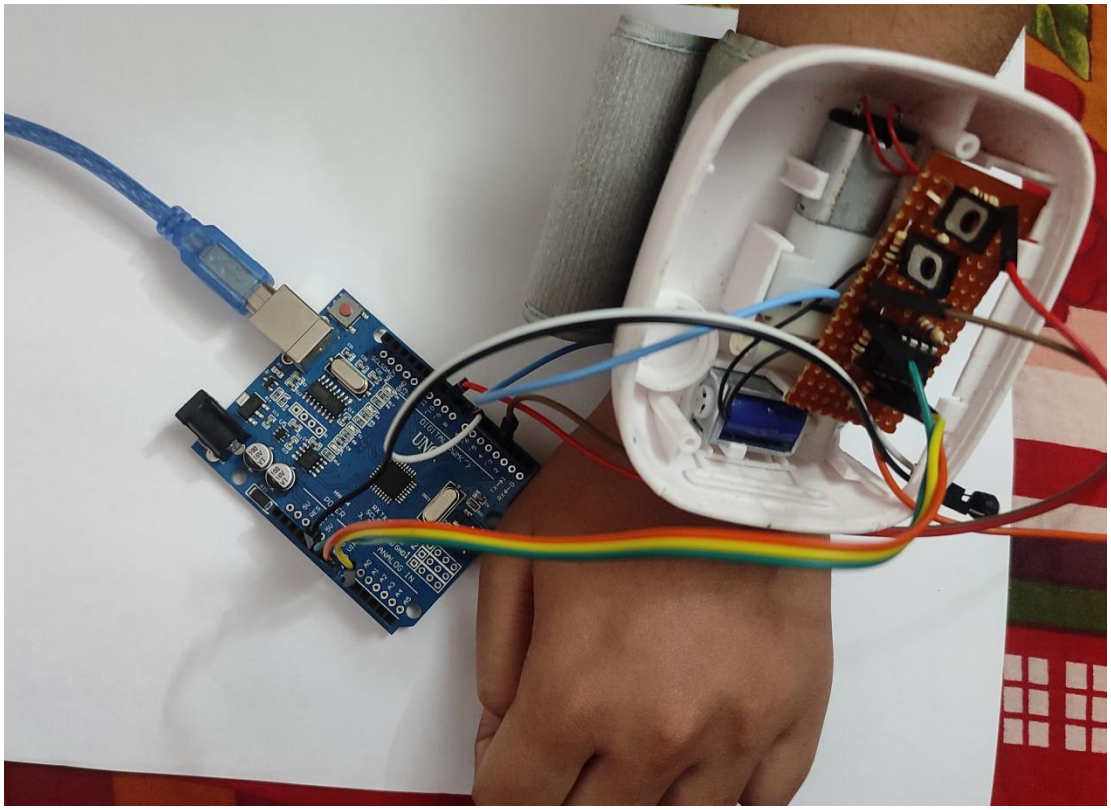

Fig. 3.12: Circuit of blood pressure module.

3.4 Temperature Module

In the system, LM35 temperature sensor is used to collect temperature of a user. LM35 sensor has three pins. Ground pin is connected to the ground and VIN is connected with VCC. The middle pin is the input pin which is connected to the Arduino analog pin A2.

3.5 Heartbeat Module

Pulse sensor is used to take the heart beat rate of a person in this system. Pulse sensor also has three pins. Ground pin and VIN pin are connected to the GRND and VCC pin respectively. The left pin is the signal pin to take heart beat value. The signal pin is connected to the Arduino analog pin A1.

3.6 Accelerometer Module

ADXL345 accelerometer sensor is used to monitor the motion of a person. In the system, the accelerometer SCL and SDA pins are connected to the Arduino analog pins A4 and A5 respectively. Similarly, the GND and VIN pin is connected to ground and VCC.

3.7 GSR Module

GSR sensor is connected to the Arduino analog pin A3. The electrodes attached with the sensors are mainly collect data from the user. The user wears the two electrodes in fingers and the value is collected through those electrodes.

3.8 SpO2 Module

MAX30102 pulse oximeter is used as a SpO2 sensor in the system. It is available, easier to use. SpO2 module is used to measure the blood oxygen level of a person. The SDA and SCL pins of the SpO2 module are connected to the Arduino SDA and SCL pins respectively.

3.9 Integrated System

The entire hardware system is developed by using a breadboard for connecting the sensors. The breadboard is connected with the Arduino Uno instead of an analog to digital converter for taking analog sensor data and the whole system is controlled using Raspberry pi. The Arduino is connected with Raspberry pi using serial communication with USB cable. The temperature sensor output pin is connected with Arduino analog PIN A2. Again, the other analog output sensors are connected with the Arduino analog pins. Such as the heartbeat sensor is connected with analog pin A1, the GSR sensor is connected with Arduino analog pin A3, the accelerometer is connected with A4 and A5, etc. The breadboard VCC and Ground are connected with the Arduino VCC and GND pin. The MAX30100 sensor is connected with the other SDA and SCL pin of the Arduino Uno. The Arduino Uno of the blood pressure module is connected with the core Arduino using serial communication. The RX and TX pin of the module's Arduino is connected to the pin TX and RX of the core Arduino respectively. Fig. 3.13 illustrates the circuit of the system.

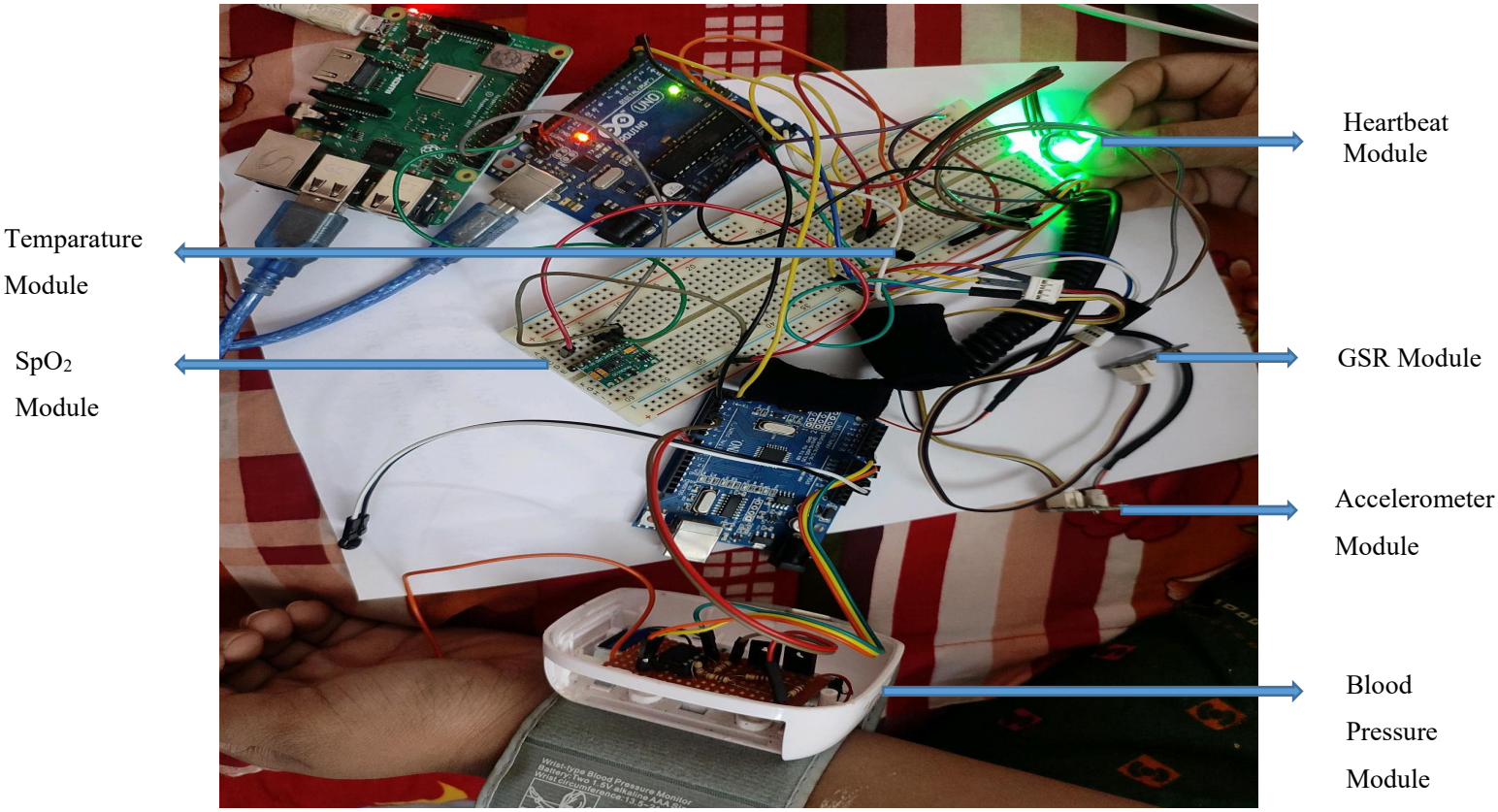

Fig. 3.13: The Circuit of the System.

CHAPTER 4

EXPERIMENTAL ANALYSIS

This chapter provides the effectiveness and performance analysis of the health monitoring system. This system is useful for every user to do continuous monitoring.

4.1 Performance Analysis

The evaluation of the research to check the performance is done by several experiments. The body temperature, heart beat, blood pressure, blood oxygen level, motion and gsr values of the patients have been monitored during the working of the projects. Several tests are done to examine the system. Patient's health parameters are shown in the evaluation of the quality of the research.

LM35 body temperature sensor measures the patient's body temperature which is shown in second column of Table 4.1. The table shows the comparison of the measured temperature by our system with the actual temperature of different users measured by using thermometer. Average accuracy is measured using (1).

$$\text{Au} = \frac{1}{n}\sum_{1}^{n}\frac{Ts}{Tt} \times 100\% \quad \text{.....(1)}$$

Here, Av= Average accuracy

n = Number of users

Ts = Temperature measured by the system

Tt = Temperature measured manually by thermometer

. **Table 4.1.** Comparison between Measured temperature and Actual temperature.

Users	Temperature using lm35, F	Temperature using thermometer, F	Average accuracy
User1	95.4	98.4	
User2	100.3	100.6	
User3	96.3	99.0	96.19%
User4	93.3	98.0	
User5	89.9	97.9	

Table 4.2. shows the data of heart beat and the comparison between the measured and actual heartbeat of five users. The data are taken using pulse sensor for the system. The average accuracy is derived using (2).

$$\text{Av} = \frac{1}{n}\sum_{1}^{n}\frac{Hs}{Hn} \times 100\% \qquad (2)$$

Here, Av= Average accuracy

n = Number of users

Hs = Heartbeat measured by the system

Hn = Normal Heartbeat

Table 4.2. Comparison between measured heartbeat and actual heartbeat.

Users	Heartbeat using pulse sensor, bpm	Normal heartbeat, bpm	Average accuracy
User1	76	78	
User2	79	82	
User3	88	89	96.77%
User4	81	84	
User5	90	95	

The accelerometer sensor is used to monitor the motion of an user by using x,y,z axis values. Table 4.3 shows the output of accelerometer of an user before motion and after motion.

Table 4.3. Accelerometer sensor value of an user.

	X axis value	Y axis value	Z axis value
Before motion	-4	25	213
Before motion	-4	25	213
After motion	62	13	204

After motion	74	12	195

In the system, we used GSR sensor to record Galvanic Skin Response based on conductivity. Table 4.4 shows the result of GSR sensor for different 5 users.

Table 4.4: GSR sensor values for different users.

User	GSR data
User1	195
User2	199
User3	201
User4	190
User5	210

In the system , we used SpO_2 sensor to monitor blood oxygen level and a blood pressure measuring module is developed for measuring systolic and diastolic pressure of different users. Table 4.5 shows the values of SpO_2 sensor and blood pressure of 5 different users.

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Table 4.5. SpO2 sensor values and blood pressure values for different users.

Users	Blood Oxygen Level(%)	Blood Pressure	
		Systolic	Diastolic
User1	95	78	125
User2	96	82	130
User3	95	85	135
User4	97	84	135
User5	96	75	120

The above results we got in our hardware circuit designed with raspberry pi 3 model.

CHAPTER 5

CONCLUSIONS

This chapter will draw a short summary of the key points of this thesis and possible future research directions based on the outcome of the present work.

5.1 Concluding Remarks

Nowadays, health treatment is very expensive and it is mandatory to do daily check-up of their health condition. Hence. health monitoring system is very important to know the health condition of the patients earlier which can reduce sufferings and medical costs. If any abnormalities are noticed,then one can take proper medication. The goal of this paper is to implement an automatic system which can measure the body temperature, heart beat, motion, Galvanic Skin Response, blood oxygen level and blood pressure of the user. There are many sensors to measure these health parameters. Our proposed system is developed using raspberry pi 3 model with LM35 Temperature Sensor, Pulse sensor, 3 axis digital accelerometer and GSR sensor connected with adc module, SpO_2 sensor and blood pressure module. The method is based on the combination of the raspberry pi with firebase database which is user friendly and easily usable.

5.2 Future Works

In future, we will try to enrich the system with proper medication arrangement and data analysis for detecting different diseases with ensuring data security. Though this method is constructive, we will try to add more sensors of monitoring health signs to the system for the betterment of detection of the health condition of every individual.

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REFERENCES

1. S. Vishnu, S. R. J. Ramson and R. Jegan, “Internet of Medical Things (IoMT) - An overview,” 5th International Conference on Devices, Circuits and Systems (ICDCS), Coimbatore, India, pp. 101-104, 2020.

2. S. Nookhao, V. Thananant and T. Khunkhao, "Development of IoT Heartbeat and Body Temperature Monitoring System for Community Health Volunteer," Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON), pp. 106-109, 2020.

3. A. D. Priya and S. Sundar, "Health Monitoring System using IoT," International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN), pp. 1-3, 2019.

4. R. Kumar and M. P. Rajasekaran, "An IoT based patient monitoring system using raspberry Pi," International Conference on Computing Technologies and Intelligent Data Engineering (ICCTIDE'16), pp. 1-4, 2016.

5. A. N. Reddy, A. M. Marks, S. R. S. Prabaharan and S. Muthulakshmi, "IoT augmented health monitoring system," International Conference on Nextgen Electronic Technologies: Silicon to Software (ICNETS2), pp. 251-254, 2017.

6. S. S. Thomas, A. Saraswat, A. Shashwat and V. Bharti, "Sensing heart beat and body temperature digitally using Arduino," International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES), pp. 1721-1724, 2016.

7. “What is IoT(Internet of Things) and How does it work?" [Online]. Available: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT.

8. V. G. Girhepunje and S. D. Chede, "Realization of low power telemedicine system to monitor temperature and heart beats," International Conference on Energy Systems and Applications, pp. 650-654, 2015.

9. S. Ahmed, S. Millat, M. A. Rahman, S. N. Alam and M. S. R. Zishan, "Wireless health monitoring system for patients," IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), pp. 164-167, 2015.

10. S. P. Kumar, V. R. R. Samson, U. B. Sai, P. L. S. D. M. Rao and K. K. Eswar, "Smart health monitoring system of patient through IoT," International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), pp. 551-556, 2017.

11. G. V. Kumar, A. Bharadwaja and N. N. Sai, "Temperature and heart beat monitoring system using IOT," International Conference on Trends in Electronics and Informatics (ICEI), pp. 692-695, 2017.

12. V. Tamilselvi, S. Sribalaji, P. Vigneshwaran, P. Vinu and J. GeethaRamani, "IoT Based Health Monitoring System," 6th International Conference on Advanced Computing and Communication Systems (ICACCS), pp. 386-389, 2020.

13. A. D. Acharya and S. N. Patil, "IoT based Health Care Monitoring Kit," Fourth International Conference on Computing Methodologies and Communication (ICCMC), pp. 363-368, 2020.

14. S. M. Fati, A. Muneer, D. Mungur and A. Badawi, "Integrated Health Monitoring System using GSM and IoT," International Conference on Smart Computing and Electronic Enterprise (ICSCEE), pp. 1-7, 2018.

15. Puvaneshwari S and Vijayashaarathi S, "Efficient Monitoring system for cardiac patients using Wireless Sensor Networks (WSN)," International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), pp. 1558-1561, 2016.

16. Selvarani, S. Josephine. "Online health monitoring system using Zigbee." International Journal on computer science and engineering 3.4, pp. 1578-1583, 2011.

17. M. B. Reshma A.B., N. Rejee W.H., S. Revathy and J. Jabez, "Recommendation of Nearest Heart care Center during Emergency using IoT," International Conference on Intelligent Computing and Control Systems (ICCS), pp. 1056-1060, 2019.

18. T. Tariq, R. M. A. Latif, M. Farhan, A. Abbas and F. Ijaz, "A Smart Heart Beat Analytics System Using Wearable Device," 2nd International Conference on Communication, Computing and Digital systems (C-CODE), pp. 137-142, 2019.

19. G. G. Warsi, K. Hans and S. K. Khatri, "IOT Based Remote Patient Health Monitoring System," International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon), pp. 295-299, 2019.

20. H. B. Aziz, S. Sharmin and T. Ahammad, "Cloud Based Remote Healthcare Monitoring System Using IoT," International Conference on Sustainable Technologies for Industry 4.0 (STI), pp. 1-5, 2019.

21. V. Pardeshi, S. Sagar, S. Murmurwar and P. Hage, "Health monitoring systems using IoT and Raspberry Pi — A review," International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), pp. 134-137, 2017.

22. S. L. Rohit and B. V. Tank, "Iot Based Health Monitoring System Using Raspberry PI - Review," Second International Conference on Inventive Communication and Computational Technologies (ICICCT), pp. 997-1002, 2018.

23. K. C. Chowdary, K. Lokesh Krishna, K. L. Prasad and K. Thejesh, "An Efficient Wireless Health Monitoring System," 2nd International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), pp. 373-377, 2018.

24. A. Kamble and S. Bhutad, "IOT based Patient Health Monitoring System with Nested Cloud Security," 4th International Conference on Computing Communication and Automation (ICCCA), pp. 1-5, 2018.

25. S. A. Kokalki, A. R. Mali, P. A. Mundada and R. H. Sontakke, "Smart health band using IoT," IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), pp. 1683-1687, 2017.

26. P. D. M., S. N. Siva and M. Sudhan, "Non invasive health monitoring system for infant using IOT," 1st International Conference on Innovations in Information and Communication Technology (ICIICT), pp. 1-3, 2019.

27. V. Patil, S. S. Thakur and V. Kshirsagar, "Health Monitoring System Using Internet of Things," Second International Conference on Intelligent Computing and Control Systems (ICICCS), pp. 1523-1525, 2018.

28. S. Shaikh and V. Chitre, "Healthcare monitoring system using IoT," International Conference on Trends in Electronics and Informatics (ICEI), pp. 374-377, 2017.

29. V. Vippalapalli and S. Ananthula, "Internet of things (IoT) based smart health care system," International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES), pp. 1229-1233, 2016.

30. N. Misran, M. S. Islam, G. K. Beng, N. Amin and M. T. Islam, "IoT Based Health Monitoring System with LoRa Communication Technology," International Conference on Electrical Engineering and Informatics (ICEEI), pp. 514-517, 2019.

31. N. Kamal and P. Ghosal, "Three Tier Architecture for IoT Driven Health Monitoring System Using Raspberry Pi," IEEE International Symposium on Smart Electronic Systems (iSES) (Formerly iNiS), pp. 167-170, 2018.

32. N. Patii and B. Iyer, "Health monitoring and tracking system for soldiers using Internet of Things(IoT)," International Conference on Computing, Communication and Automation (ICCCA), pp. 1347-1352, 2017.

33. J. Saha et al., "Advanced IOT based combined remote health monitoring, home automation and alarm system," IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC), pp. 602-606, 2018.

34. R. Subha, M. Haritha, B. Nithishna and S. G. Monisha, "Coma Patient Health Monitoring System Using IOT," 6th International Conference on Advanced Computing and Communication Systems (ICACCS), pp. 1454-1457, 2020.

35. A. Mumrez, H. Tariq, U. Ajmal and M. Abrar, "IOT- Based Framework for E-Health Monitoring System," International Conference on Green and Human Information Technology (ICGHIT), pp. 113-115, 2019.

36. M. H. Riaz, U. Rashid, M. Ali and L. Li, "Internet of Things Based Wireless Patient Body Area Monitoring Network," IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), pp. 970-973, 2017.

37. D. Chakravorty, S. Islam and T. K. Rana, "IoT Based Patient Guidance System using Raspberrypi," 2nd International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech), pp. 1-4, 2018.

38. T. J. Swamy and T. N. Murthy, "eSmart: An IoT based Intelligent Health Monitoring and Management System for Mankind," International Conference on Computer Communication and Informatics (ICCCI), pp. 1-5, 2019.

39. R. G. Utekar and J. S. Umale, "Automated IoT Based Healthcare System for Monitoring of Remotely Located Patients," Fourth International Conference on Computing Communication Control and Automation (ICCUBEA), pp. 1-5, 2018.

40. A. Athira, T. D. Devika, K. R. Varsha and S. S. Bose S., "Design and Development of IOT Based Multi-Parameter Patient Monitoring System," 6th International Conference on Advanced Computing and Communication Systems (ICACCS), pp. 862-866, 2020.

41. "How Do Automatic Blood Pressure Cuffs Work?." [Online]. Available: https://rk.md/2017/automatic-blood-pressure-cuffswork/?fbclid=IwAR2sij6GUVDACAW8lNO1GNQiPAzprf3R McwORyHawRtC2iJFFs4mgihE6I.