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Project Report on

IOT Based Health Monitoring System

Project by

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TOWARDS THE PARTIAL FULFILLMENT FOR

THE DEGREE OF

M.Sc. (PHYSICS)

UNDER THE GUIDANCE OF

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DEPARTMENT OF PHYSICS

Post-Graduate Section

CERTIFICATE

This is to certify that, **Pratik Nitin Kadam (Examination No:- 2103869)** of M.Sc. (Physics), Semester IV has satisfactorily completed the project titled "**IoT based health monitoring system"** for the partial fulfillment of M.Sc. (Physics) degree of Savitribai Phule Pune University during the academic year 2022-23.

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CERTIFICATE OF THE GUIDE

This is to certify that the report entitled **"IoT Based health monitoring system"** submitted by **Pratik Nitin Kadam** for the partial fulfillment of M.Sc. Degree in Physics at the Department of Physics, Modern College of Arts, Commerce and Science (Autonomous), Shivajinagar, Pune 05 has been carried out by him under my supervision and guidance. He had carried out his project work at Department of Physics, Modern College of Arts, Commerce and Science (Autonomous), Shivajinagar, Pune 05.

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Abstract

The Internet of Things (IoT) concepts have been widely used to interconnect the available medical resources and offer smart, reliable, and effective healthcare service to the patients. Health monitoring for active and assisted living is one of the paradigms that can use the IoT advantages to improve the patient's lifestyle. In this project, I have presented an IoT architecture customized for healthcare applications.

The aim of the project was to come up with a Healthcare Monitoring System that can be made with locally available sensors with a view to making it affordable if it were to be mass produced. Hence the proposed architecture collects the sensor data through ESP 32 and relays it to the cloud where it is processed and analyzed for viewing purpose. Feedback actions based on the analyzed data can be sent back to the doctor or guardian through SMS alerts in case of any emergencies

[Keyword: IoT-Internet of Things]

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Chapter 1 Introduction

1.1 Literature Study

A literature review of IoT-based health monitoring systems can reveal a lot about the current state of the technology, the challenges faced, and potential areas for future research. Here are some key findings from recent studies:

IoT-based health monitoring systems can improve patient outcomes and reduce healthcare costs. A study found that such systems can provide real-time data to healthcare providers, enabling them to monitor patients more effectively and intervene before complications arise.

Wearable devices and sensors are key components of IoT-based health monitoring systems. According to a study by Dina A. Alabbad et al. (2020) [1], wearable devices such as smartwatches and fitness trackers can collect vital signs data, while sensors can monitor environmental factors such as temperature and humidity.

IoT-based health monitoring systems can face challenges related to data privacy and security. A study by Mohammed Salih Mahdi et al. (2020) [2] highlighted the need for secure communication protocols and encryption to protect sensitive patient data.

Machine learning algorithms can be used to analyse data collected by IoT-based health monitoring systems. According to a study by Alshahrani et al. (2020), machine learning algorithms can help predict patient outcomes and identify early warning signs of health issues.

IoT-based health monitoring systems can be used to monitor chronic conditions such as diabetes and hypertension. A study by Ghafourian et al. (2020) [3] found that such systems can help patients better manage their conditions and reduce the risk of complications.

Overall, the literature suggests that IoT-based health monitoring systems have the potential to revolutionize healthcare by enabling more effective and personalized monitoring and treatment. However, more research is needed to address the challenges related to data privacy and security and to develop more sophisticated machine learning algorithms.

1.2 IoT

Internet of Things (IoT) driven health and wellness monitoring system enables remote and continuous monitoring of people, with applications in chronic conditions, such as obesity, hypertension, diabetes, heart failure, stress, preventive care and wellness. Medical care and healthcare represent one of the most attractive application areas for the IoT. Digitization and the increasing connectivity between devices, citizens and their meaningful way. Smart manufacturing becomes the norm in industry 4.0, where intelligent machines are network so they can exchange and respond to data to independently manage industrial production. The internet of things is a transformational concept. In 1999, Kevin Ashton, co-founder of the Auto-ID Centre at the Science Institute of Technology, envisioned an Internet of Things based on RIFD chips that could enable “things” to communicate with each other. IoT breaks the confines of traditional computer networks and establishes connections directly with objects in the physical world. The core concept of this phenomenon is that IoT allows for “things” to connect to the Internet, ranging from the significant –airplanes, elevators, solar panels, medical equipment-to the mandate-toys, soap dispensers and porch lights.

The IoT paradigms can play a significant role in improving the health and wellness of subjects by increasing the availability and quality of care, and grammatically lowering the treatment costs and frequent travel. The IoT driven healthcare system employs networked by biosensors to simultaneously collect multiple physiological signals and wireless connectivity to share or send gathered signals directly to the cloud diagnostic server and the caregivers for further analysis and clinical review. Further, the IoT enabled remote monitoring applications can significantly reduce travel, cost and time in long term monitoring applications.[4]

IoT applications of healthcare

Infirmity/Condition	Sensors used/Operations
1. Diabetes	A non-invasive opto-physiological sensors.
2. Wound analysis for advanced diabetes patients	A smartphone camera: image decompression and segmentation.
3.Heart rate monitoring	An optical heart rate sensor measures pulse waves, An optical heart rate sensor measures pulse wave.
4. BP monitoring	A wearable BP sensor: Oscillo-metric and automation inflation and measurements
5. Body temperature monitoring	Wearable body temperature sensor; Which detect temperature of the body.
6. Cough detection	A built-in microphone audio system in the smartphone

1.3 Background of the study

What is a Health Monitoring System?

A remote health monitoring system is an extension of a hospital medical system where a patient's vital body state can be monitored. Traditionally the detection systems were only found in hospitals and were characterized by huge and complex circuitry which required high power consumption. Continuous advances in the semiconductor technology industry have led to sensors and microcontrollers that are smaller in size, faster in operation, low in power consumption and affordable in cost.

This has further seen development in the remote monitoring of vital life signs of patients especially the elderly. The remote health monitoring system can be applied in the following scenarios:

i. A patient is known to have a medical condition with unstable regulatory body system. This is in cases where a new drug is being introduced to a patient.
ii. A patient is prone to heart attacks or may have suffered one before. The vitals may be monitored to predict and alert in advance any indication of the body status.
iii. Critical body organ situation
iv. The situation leading to the development of a risky life-threatening condition. This is for people at an advanced age and maybe having failing health conditions.
v. Athletes during training. To know which training regimes will produce better results.

In recent times, several systems have come up to address the issue of remote health monitoring. The systems have a wireless detection system that sends the sensor information wirelessly to a remote server. Some even adopted a service model that requires one to pay a subscription fee. In developing countries, this is a hindrance as some people cannot use them due to cost issue involved. There is also the issue of internet connectivity where some systems to operate, good quality internet for a real-time remote connection is required. Internet penetration is still a problem in developing countries.

Many of the systems were introduced in the developed countries where the infrastructure is working perfectly. In most cases, the systems are adapted to work in developing countries. To reduce some of these problems there is need to approach the remote detection from a ground-up approach to suit the basic minimal conditions presently available in developing countries.

1.4 Purpose of the study

To design a Patient Health Monitoring System (PHMS) which has heartbeat detection system, temperature detection system and ECG detection system. A doctor or health specialist can use the system to monitor remotely of all vital health parameters of the patient or person of interest. An attempt at designing a healthcare system made with locally available components.

i. Heartbeat detection system, temperature detection system.
ii. A simple cloud server was hosted with a database for all the vital data to be accessed remotely whenever required.

1.5 Objective of the study

Here the main objective is to design a PHMS to diagnose the health condition of the patients. Giving care and health assistance to the bedridden patients at critical stage with advanced medical facilities have become one of the major problems in the modern hectic world. In hospitals where many patients whose physical conditions must be monitored frequently as a part of a diagnostic procedure, the need for a cost-effective and fast responding alert mechanism is inevitable. Proper implementation of such systems can provide timely warnings to the medical staffs and doctors and their service can be activated in case of medical emergencies. Present-day systems use sensors that are hardwired to a PC next to the bed.

The use of sensors detects the conditions of the patient and the data is collected and transferred using a microcontroller. Doctors and nurses need to visit the patient frequently to examine his/her current condition. In addition to this, use of multiple microcontrollers based intelligent system provides high-level applicability in hospitals where many patients must be frequently monitored. For this, here we use the idea of network technology with wireless applicability, providing each patient a unique ID by which the doctor can easily identify the patient and his/her status of health parameters. Using the proposed system, data can be sent wirelessly to the Patient Monitoring System, allowing continuous monitoring of the patient. Contributing accuracy in measurements and providing security in proper alert mechanism give this system a higher level of customer satisfaction and low-cost implementation in hospitals. Thus, the patient can engage in his daily activities in a comfortable atmosphere where distractions of hardwired sensors are not present. Physiological monitoring hardware can be easily implemented using simple interfaces of the sensors with a Microcontroller and can effectively be used for healthcare monitoring. This will allow development of such low-cost devices based on natural human-computer interfaces. The system we proposed here is efficient in monitoring the different physical parameters of many numbers of bedridden patients and then in alerting the concerned medical authorities if these parameters bounce above its predefined critical values. Thus, remote monitoring and control refer to a field of industrial automation that is entering a new era with the development of wireless sensing devices.

The Internet of Things (IoT) platform offers a promising technology to achieve the healthcare services, and can further improve the medical service systems. IoT wearable platforms can be used to collect the needed information of the user and its ambient environment and communicate such information wirelessly, where it is processed or stored for tracking the history of the user. Such a connectivity with external devices and services will allow for taking preventive measure (e.g., upon foreseeing an upcoming heart stroke).

1.6 Intelligent wireless mobile patient monitoring system

Nowadays, Heart-related diseases are on the rise. Cardiac arrest is quoted as the major contributor to the sudden and unexpected death rate in the modern stress filled lifestyle around the globe. A system that warns the person about the onset of the disease earlier automatically will be a boon to the society. This is achievable by deploying advances in wireless technology to the existing patient monitoring system. This paper proposes the development of a module that provides mobility to the doctor and the patient, by adopting a simple and popular technique, detecting the abnormalities in the bio signal of the patient in advance and sending an SMS alert to the doctor through Global System for Mobile (GSM) thereby taking suitable precautionary measures thus reducing the critical level of the patient.

Worldwide surveys conducted by World Health Organization (WHO) have confirmed that the heart-related diseases are on the rise. Many of the cardiac-related problems are attributed to the modern lifestyles, food habits, obesity, smoking, tobacco chewing and lack of physical exercises etc. The post-operative patients can develop complications once they are discharged from the hospital. In some patients, the cardiac problems may reoccur, when they start doing their routine work. Hence the ECG of such patients needs to be monitored for some time after their treatment. This helps in diagnosing the improper functioning of the heart and take precautions. Some of these lives can often be saved if acute care and cardiac surgery is provided within the so-called golden hour. So, the need for advice on first-hand medical attention and promotion of good health by patient monitoring and follow-up becomes inevitable. Hence, patients who are at risk require that their cardiac health to be monitored frequently whether they are indoors or outdoors so that emergency treatment is possible. Telemedicine is widely considered to be part of the inevitable future of the modern practice of medicine.

1.7 Challenges of IoT in healthcare

Maintaining privacy and security is one of the most significant challenges of IoT in healthcare. Other than that, overloading of data is another issue as storing and maintaining a huge pile of patient data is a cumbersome process. Interpreting such a huge amount of data can further lead to decision fatigue and inaccurate diagnosis.

Chapter 2 Proposed System

2.1 Proposed System

In the existing system, we use active network technology to network various sensors to a single patient healthcare monitor system. Patients' various critical parameters are continuously monitored via single patient healthcare monitor system and reported to the Doctors or Nurses in attendance for timely response in case of critical situations. The sensors are attached to the body of the patients without causing any discomfort to them. In this patient healthcare monitor system monitor the important physical parameters like body temperature, ECG, heart beat rate and blood pressure using the sensors which are readily available. Thus, the analog values that are sensed by the different sensors are then given to a microcontroller attached to it. The microcontroller processes these analog signal values of health parameters separately and converts it to digital values using ADC converter.

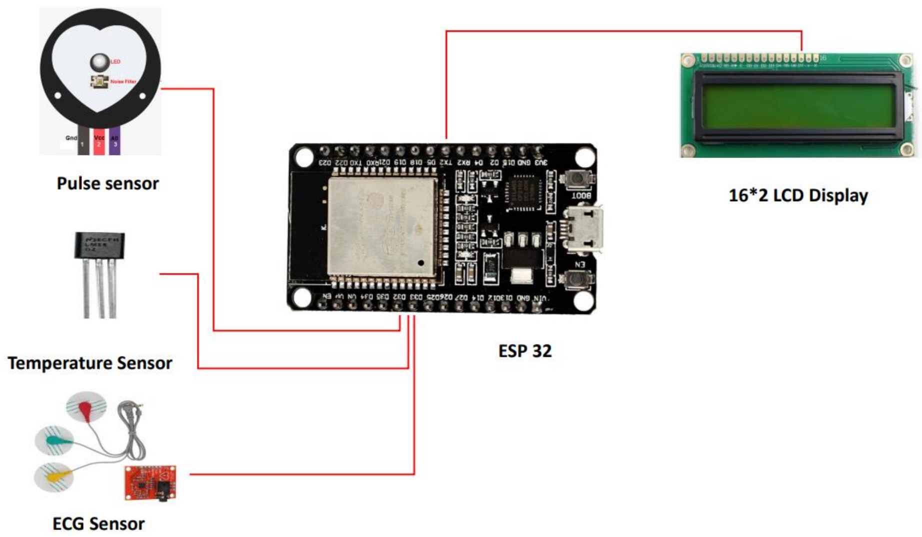

Figure 2.1: Proposed System

At any time, any of the doctors or nurses can check the history of the observed critical parameters of any of the patient attached to the network. In case of a critical situation which requires the immediate attention of the doctors or nurses for any of the patients, through the ESP32 module the SMS will be sent to the doctor. The SMS also consists of a status of the patient's physical condition. With the help of that information of the patient, the doctor can easily attend to the patient situation.

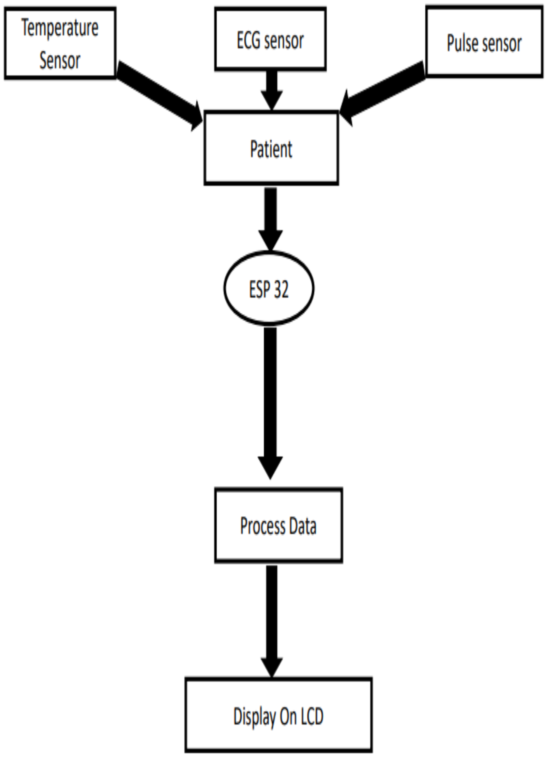

Figure 2.2: Flowchart of Proposed System

2.2 Requirement

Requirement Analysis is the first and important phase of the software developing activity in developing any kind of project effectively. I started to list out all the functionalities that my application should provide. There have been some minor changes with respect to the functionalities over the course of development.

2.3 Software Specifications

• Operating System: Windows 7 or higher

• Platform: IoT Cloud

• IDE: Arduino 2.0.3

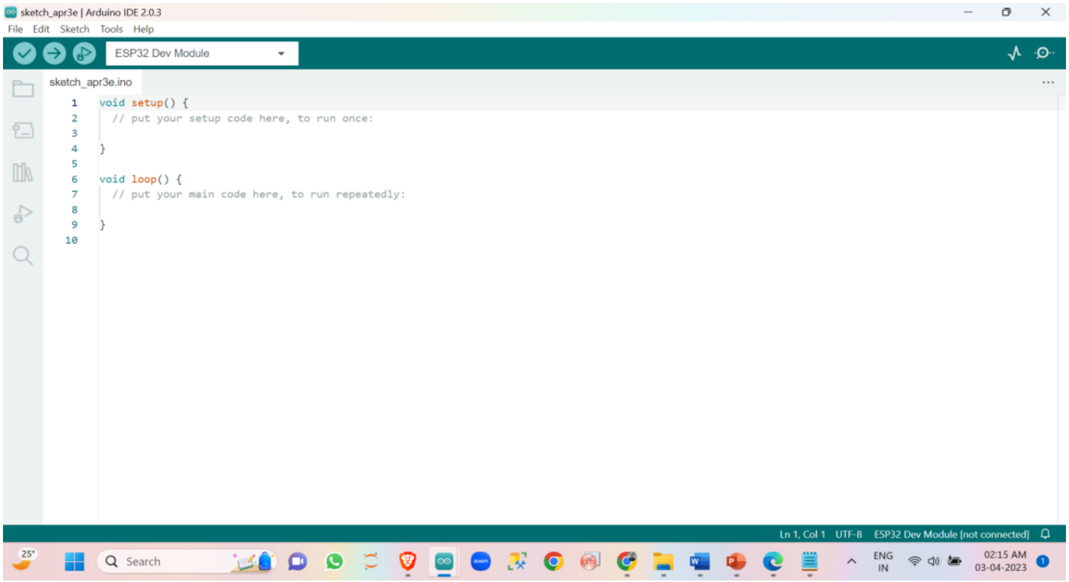

Figure 2.3: Interface of Arduino IDE 2.0.3

2.4 Hardware Specifications

ESP 32 Module (extrasensory perception)

LCD display

Sensors:

1] Temperature (LM35)
2] Pulse sensor
3] ECG

2.4.1 ESP 32

It is a less-cost, little power system on a chip microcontroller with included Wi-Fi and dual mode Bluetooth. The ESP32 is the heart of the project. It is a microcontroller board used to connect all the sensors. The board is programmed with the source code in order to perform the operations of the project. The source code is stored in the on-chip memory available on the ESP32. This block can be considered as an interface between the programmer and the user. So, it is considered as the heart of the project. The ESP32 operating voltage range is 2.2 to 3.6V. Under normal operation the ESP32 thing will power the chip at 3.3V.

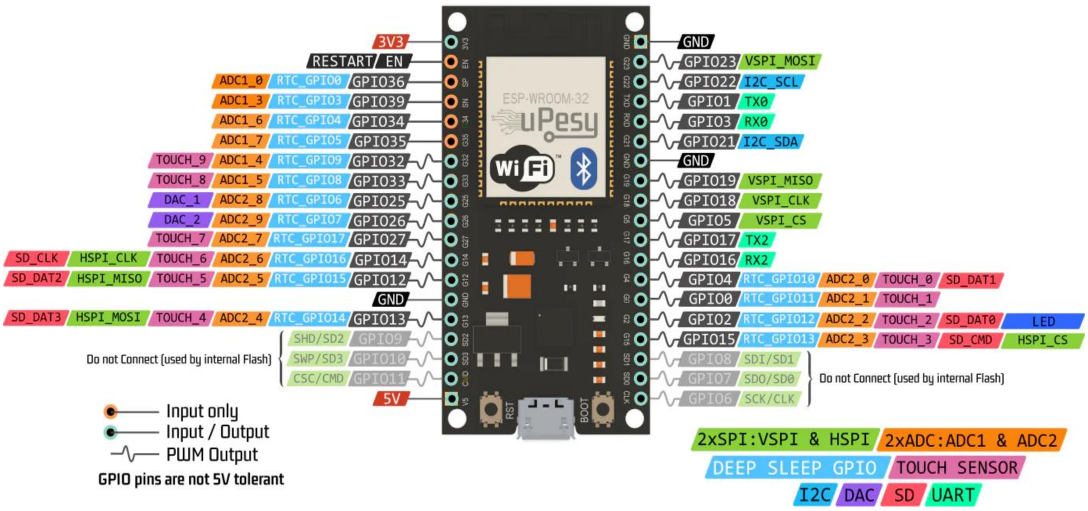

Figure 2.4: ESP Pin Configuration **[5]**

2.4.2 LCD display

- **Pin1 (Ground/Source Pin):** This is a GND pin of display, used to connect the GND terminal of the microcontroller unit or power source.
- **Pin2 (VCC/Source Pin**): This is the voltage supply pin of the display, used to connect the supply pin of the power source.
- **Pin3 (V0/VEE/Control Pin):** This pin regulates the difference of the display, used to connect a changeable POT that can supply 0 to 5V.
- **Pin4 (Register Select/Control Pin**): This pin toggles among command or data register, used to connect a microcontroller unit pin and obtains either 0 or 1(0 = data mode, and 1 = command mode).
- **Pin5 (Read/Write/Control Pin):** This pin toggles the display among the read or writes operation, and it is connected to a microcontroller unit pin to get either 0 or 1 (0 = Write Operation, and 1 = Read Operation).
- **Pin 6 (Enable/Control Pin):** This pin should be held high to execute Read/Write process, and it is connected to the microcontroller unit & constantly held high.
- **Pins 7-14 (Data Pins):** These pins are used to send data to the display. These pins are connected in two-wire modes like 4-wire mode and 8-wire mode. In 4-wire mode, only four pins are connected to the microcontroller unit like 0 to 3, whereas in 8-wire mode, 8-pins are connected to microcontroller unit like 0 to 7.
- **Pin15 (+ pin of the LED):** This pin is connected to +5V
- **Pin 16 (- pin of the LED):** This pin is connected to GND.

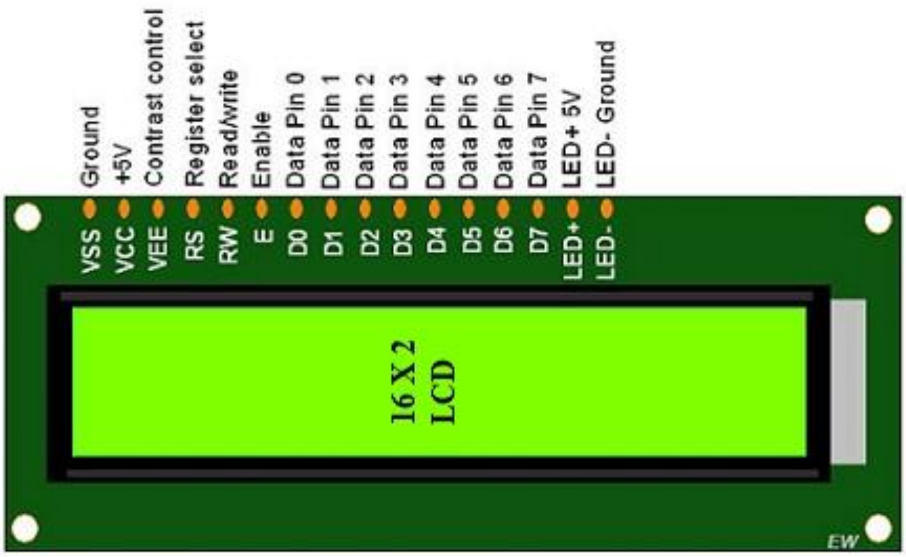

Figure 2.5: LCD display **[6]**

2.4.3 I2C Module

The I2C, 16×2 is used as communication interface between ESP 32 and LCD Screen. It is able to display 16×2 characters on 2 lines, white characters on blue background.

This display overcomes the drawback of LCD 16x2 Parallel LCD Display in which you'll waste about 8 Pins on your ESP 32 for the display to get working. Luckily in this product, an I2C adapter is directly soldered right onto the pins of the display. So, all you need is to connect are the I2C pins, which shows a good library and little of coding.

The I2C is a type of serial bus developed by Philips, which uses two bidirectional lines, called SDA (Serial Data Line) and SCL (Serial Clock Line). Both must be connected via pulled-up resistors. The usage voltages are standard as 5V and 3.3V. If you already have the I2C adapter soldered onto the board like in this product, the wiring is quite easy. You should usually have only four pins to hook up. VCC and GND of course. The LCD display works with 5 Volts. So, we go for the 5V Pin.

The values shown on the display can be either a simple text or numerical values read by the sensors, such as temperature or pressure, or even the number of cycles that the ESP 32 is performing.

Figure 2.6: Pinout of I2C module **[7]**

Pins for the LCD display:

Pin Details:
VCC
i) GND
ii) SDA (Serial Data Pin)
iii) SCL (Serial Clock Pin)

Specification and futures:

- Compatible with Arduino UNO, Nano, ESP 32
- I2C Address: 0x20-0x27(0x20 default)
- Back lit (Blue with white char colour)
- Supply voltage: 5V
- Adjustable contrast
- Size: 82 x 35 x 18 mm (3.2×1.4×0.7 in)
- Interface Address: 0x27
- Character Colour: White

Interface Between I2C module and LCD display:

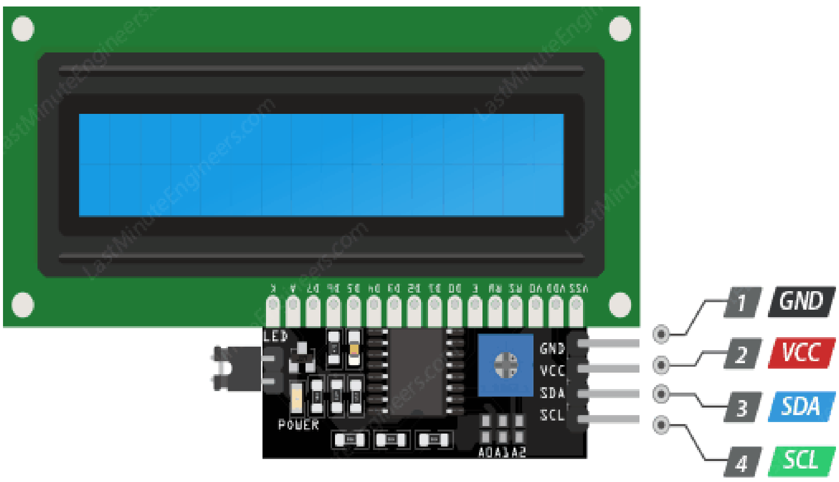

Figure 2.7: Interface Between I2C module and LCD display **[8]**

2.4.4 Temperature Sensor

Temperature sensor is a device which is designed specifically to measure the hotness or coldness of an object. LM35 is a precision IC temperature sensor with its output proportional to the temperature (in °C). With LM35, the temperature can be measured more accurately than with a thermistor. It also possesses low self-heating and does not cause more than 0.1 °C temperature rise in still air. The operating temperature range is from -55°C to 150°C.The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy.

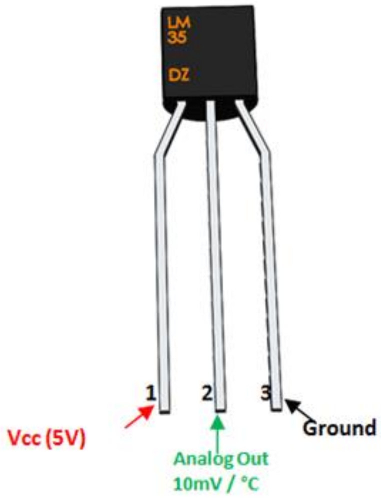

Figure 2.8: a) Temperature Sensor (LM 35) **[9]**

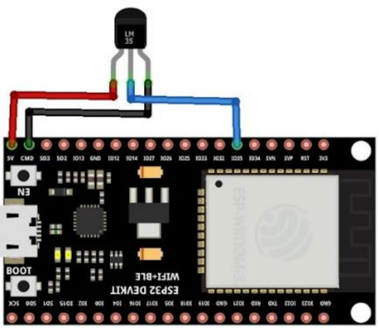

Figure 8: b) Interface between ESP32 and Pulse sensor

Features of LM35:

- Calibrated Directly in Celsius (Centigrade)
- Output proportional to °C
- Linear + 10-mV/°C Scale Factor
- Operates From 4 V to 30 V
- Less Than 60 μA Current Drain
- Low-Impedance Output, 0.1 Ω for 1 mA Load
- Low-Cost Due to Wafer-Level Trimming
- Accuracy 0.5°C (at 25°C)
- LM35 range temperature −55°C to 150°
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical

2.4.5 Heartbeat Sensor

Heartbeat sensor provides a simple way to study the function of the heart which can be measured based on the principle of psycho-physiological signal used as a stimulus for the virtual reality system. The amount of the blood in the finger changes with respect to time. The sensor shines a light lobe (a small very bright LED) and measures the light that gets transmitted to the Light Dependent Resistor. The amplified signal gets inverted and filtered, in the Circuit. In order heart beat sensor calculate the heart rate based on the blood flow to the fingertip.

Figure 2.9: a) Pulse/Heartbeat sensor

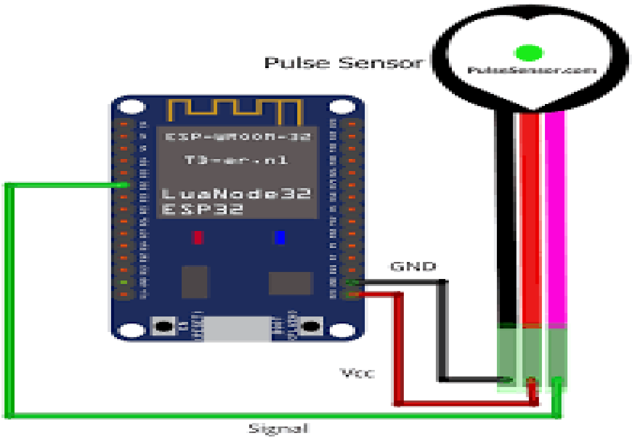

Figure 2.9: b) Interface Between ESP32 and Pulse sensor **[10]**

2.4.6 ECG

ECG records the electrical activity generated by heart muscle depolarizations, which propagate in pulsating electrical waves towards the skin. Although the electricity amount is in fact very small, it can be picked up reliably with ECG electrodes attached to the skin. The full ECG setup comprises at least four electrodes which are placed on the chest or at the four extremities according to standard nomenclature (RA = right arm; LA = left arm; RL = right leg; LL = left leg). Of course, variations of this setup exist to allow more flexible and less intrusive recordings, for example, by attaching the electrodes to the forearms and legs. ECG electrodes are typically wet sensors, requiring the use of a conductive gel to increase conductivity between skin and electrodes.

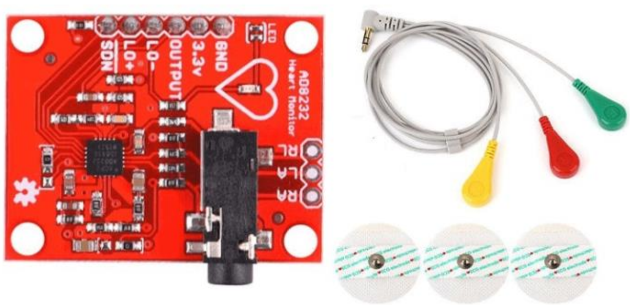

Figure 2.10: a) ECG Sensor **[11]**

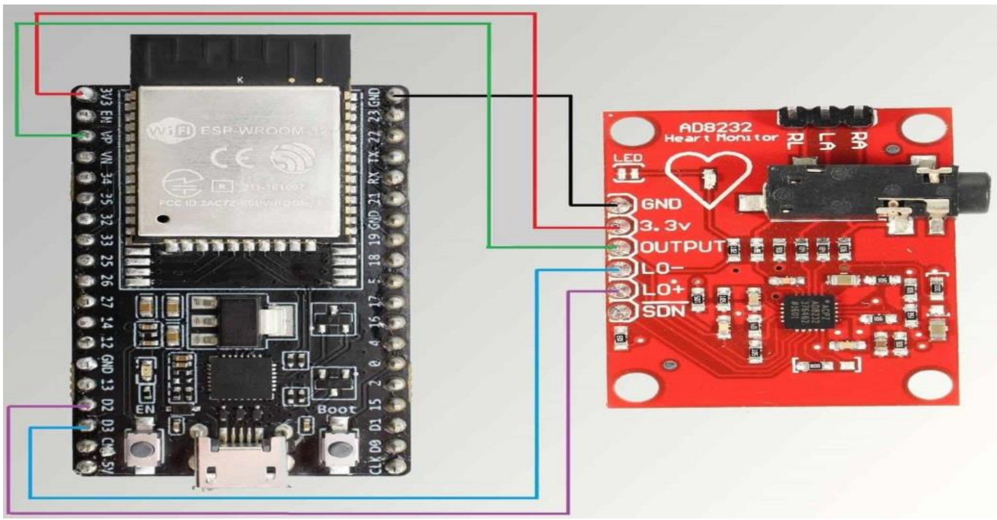

Figure 2.10: b) Interface between ESP32 and ECG sensor AD8232 **[12]**

Chapter 3 Result

A health monitoring system using an ESP32 microcontroller and temperature and pulse sensors can be used to measure and record vital signs such as body temperature and heart rate.

The ESP32 can read the analog output signals of the temperature and pulse sensors and convert them into digital signals. The data can then be processed and displayed on the LCD (16*2 display) With the collected data, the system can provide real-time monitoring.

To implement such a system, you would need to select appropriate sensors, such as the LM 35 temperature sensor and MAX30102 pulse sensor, and write code to read the sensor data and displayed on the LCD display.

Chapter 4 Conclusion and Future work

In this report, I have presented the prototype for an automatic system that guarantees a constant monitoring of various health parameters and prediction of any kind of disease or disorder that prevents the patient from the pain of paying frequent visits to the hospitals. The proposed system can be set-up in the hospitals and massive amount of data can be obtained and stored in the online database. Even the results can be made to be accessed from mobile through an application.

<u>There are some limitations of the project:</u>

The scope of the project was limited to temperature, heartbeat collected data from a single patient. Here, the most important specification considered was that they should be safe to use and accurate. This is because the physiological information being detected determines the severity of a critical life-threatening situation.

The LM35 temperature sensor should be replaced with much reliable and accurate temperature sensors. The temperature output of the LM35 temperature sensor is not reliable since the outputs of the sensor fluctuates a lot during the experiment. As a result, false alarms may be triggered from time to time which reduces the reliability and efficiency of the health monitoring system.

<u>Future Work:</u>

Moreover, other medical sensors such as ECG sensors and blood pressure sensors can be added into the system to improve the functionality of the system and can be used as all in one device. The user will be able to track their health conditions better if the system is capable of tracking more other health data accurately.

The system can be further improved by adding artificial intelligence system components to facilitate the doctors and the patients. The data, consisting medical history of many patients' parameters and corresponding results, can be explored using data mining, in search of consistent patterns and systematic relationships in the disease. For instance, if a patient's health parameters are changing in the same pattern as those of a previous patient in the database, the consequences can also be estimated. If the similar patterns are found repeatedly, it would be easier for the doctors and medical researchers to find a remedy for the problem.

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Appendix

Code for Temperature Sensor (LM35):

```
// Define the LM35 temperature sensor pin
int sensorPin =26;

void setup() {
  Serial.begin(9600); // Initialize serial communication
}

void loop() {
  // Read the voltage value from the LM35 temperature sensor
  int sensorValue = analogRead(sensorPin);

  // Convert the voltage value to temperature in degrees
Celsius
  float temperature = (sensorValue * 5.0 / 1024.0) * 100.0;

  // Print the temperature value to the serial monitor
  Serial.print("Temperature: ");
  Serial.print(temperature);
  Serial.println("Fahrenheit");

  delay(1000); // Wait for 1 second before taking another
reading
}
```

Output of LM35 Sensor:

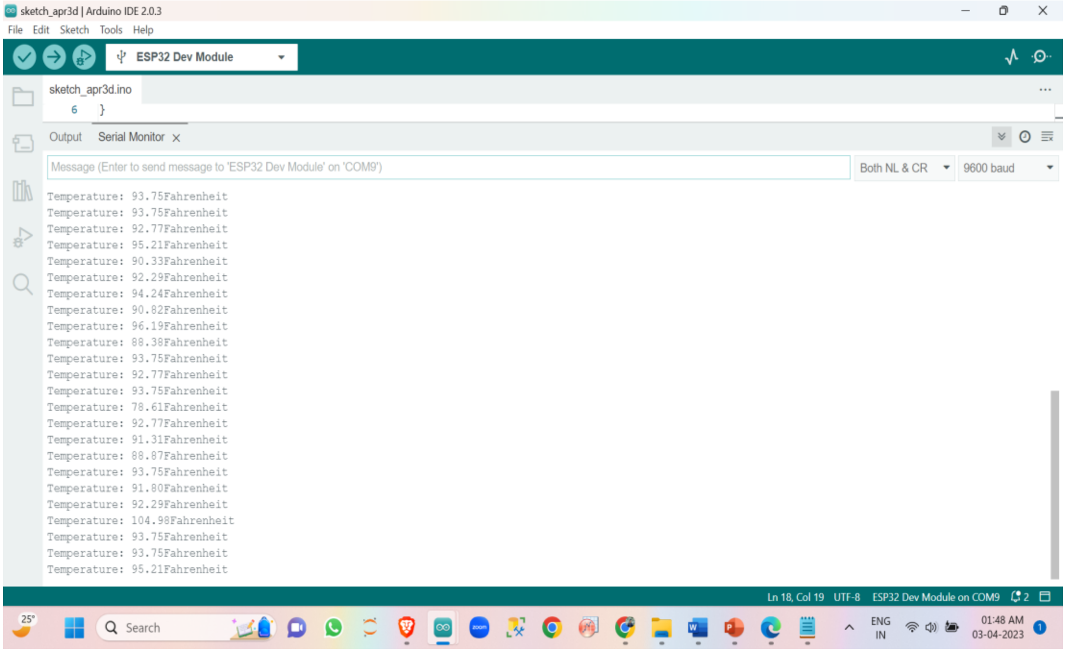

Figure 3: Output of LM35 Sensor

Code For Pulse/Heartbeat Sensor:

```
#define PULSE_SENSOR_PIN 34  // Pulse sensor signal pin
#define THRESHOLD 500       // Threshold for detecting pulse
#define INTERVAL 1000       // Time interval for calculating
pulse rate

int pulseValue;             // Pulse sensor value
int pulseCount = 0;         // Pulse count
unsigned long previousMillis = 0;  // Time of the last pulse

void setup() {
  Serial.begin(9600);
  pinMode(PULSE_SENSOR_PIN, INPUT);
}

void loop() {
  // Read pulse sensor value
  pulseValue = analogRead(PULSE_SENSOR_PIN);

  // Check if a pulse is detected
  if (pulseValue > THRESHOLD) {
    // Increase pulse count
    pulseCount++;

    // Calculate pulse rate every interval
    unsigned long currentMillis = millis();
    if (currentMillis - previousMillis >= INTERVAL) {
      float pulseRate = (float)pulseCount / ((float)INTERVAL /
1000.0);
      Serial.print("Pulse rate = ");
      Serial.print(pulseRate);
      Serial.println(" BPM");
      previousMillis = currentMillis;
      pulseCount = 0;
    }
  }

  delay(10);
}
```

Output Of Pulse/Heartbeat Sensor:

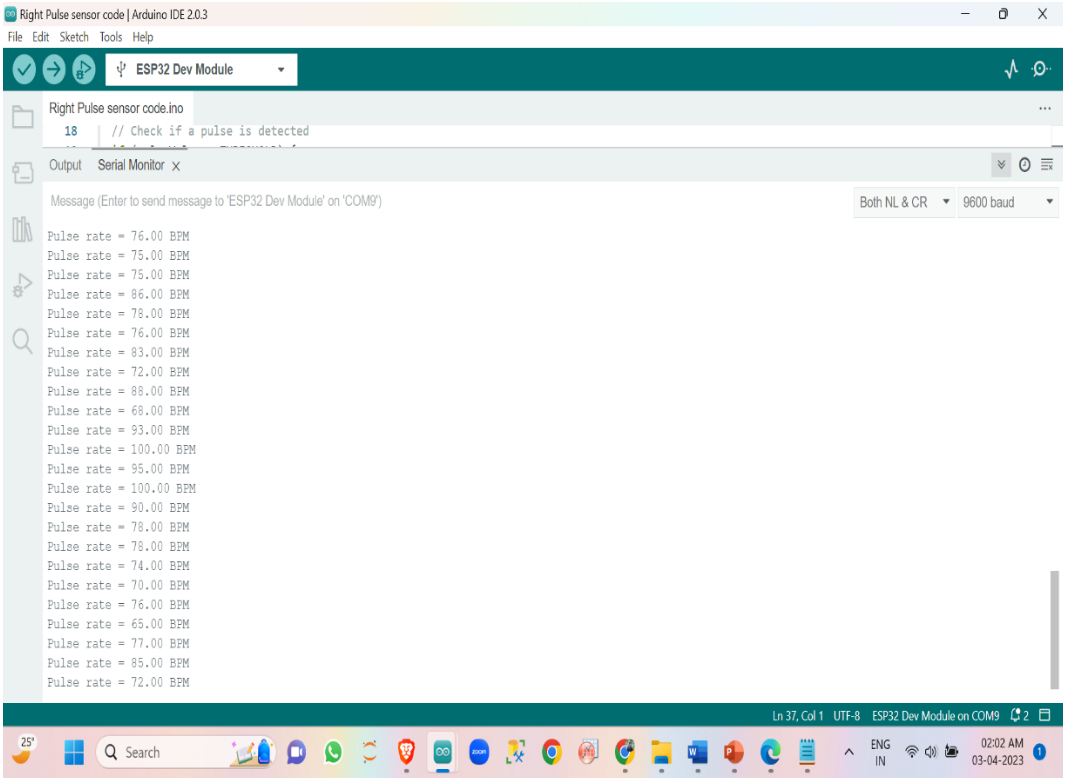

Figure 4: Output of Pulse/Heartbeat Sensor

Code for Temperature & Heartbeat sensor:

```
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 16, 2);

#define PULSE_SENSOR_PIN 34  // Pulse sensor signal pin
#define THRESHOLD 500       // Threshold for detecting pulse
#define INTERVAL 10       // Time interval for calculating
pulse rate

int pulseValue;             // Pulse sensor value
int pulseCount = 0;         // Pulse count
unsigned long previousMillis = 0;  // Time of the last pulse
int sensorPin = 26;//LM35 pin

void setup() {
  pinMode(PULSE_SENSOR_PIN, INPUT);
    // initialize LCD
  lcd.init();
  // turn on LCD backlight
  lcd.backlight();
}

void loop() {
  // Read pulse sensor value
  pulseValue = analogRead(PULSE_SENSOR_PIN);
  int sensorValue = analogRead(sensorPin);

  float pulseRate =00;

  // Check if a pulse is detected
  if (pulseValue > THRESHOLD) {
    // Increase pulse count
    pulseCount++;

    // Calculate pulse rate every interval
    unsigned long currentMillis = millis();
    if (currentMillis - previousMillis >= INTERVAL) {
       pulseRate = (float)pulseCount / ((float)INTERVAL /
1000.0);

      previousMillis = currentMillis;
      pulseCount = 0;
    }
  }
```

```
  delay(10);

float temperature = (sensorValue * 5.0 / 1024.0) * 100.0;
  // set cursor to first column, first row
  display(temperature,pulseRate);



}
void display(float temperature,float pulseRate){
  lcd.setCursor(0,0);
  // print message
  lcd.print("Temp:");
  lcd.print(temperature);
  lcd.print(" F");

  lcd.setCursor(0,1);
  // print message
  lcd.print("BPM:");
  lcd.print(pulseRate);
  //lcd.print("BPM");
  delay(1000);
}
```

Code for ECG sensor:

```
#include <SPI.h>


const int ECG_DATA_PIN = 19; // data pin for ECG sensor
const int ECG_CLK_PIN = 18; // clock pin for ECG sensor

void setup() {
  Serial.begin(115200);
  SPI.begin(ECG_CLK_PIN,ECG_CS_PIN); // initialize SPI interface
}

void loop() {
  int ecgValue = readECG(); // read ECG value from sensor
  Serial.println(ecgValue); // print ECG value to serial monitor
  delay(10); // wait 10 milliseconds before reading again
}

int readECG() {
  byte data[3];
  SPI.beginTransaction(SPISettings(500000, MSBFIRST, SPI_MODE1)); // set
SPI settings
  digitalWrite(ECG_CS_PIN, LOW); // select ECG sensor
  SPI.transfer(0x81); // send start bit
  for (int i = 0; i < 3; i++) {
    data[i] = SPI.transfer(0x00); // read 3 bytes of data
  }
  digitalWrite(ECG_CS_PIN, HIGH); // deselect ECG sensor
  SPI.endTransaction(); // end SPI transaction
  int ecgValue = ((data[0] << 8) | data[1]) & 0x3FFF; // combine data
bytes and mask out unwanted bits
  return ecgValue;
}
```