Health Monitoring System

A **mini-project** Report submitted

for

IoT based System (UEC715)

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ABSTRACT

The project focuses on the development of an IoT-based health monitoring system integrated with machine learning (ML) and deep learning (DL) models for analyzing heart rate and oxygen levels. The system aims to provide a cost-effective, real-time, and reliable solution for tracking vital health parameters, enhancing patient care and remote health management.

The system captures raw physiological data through sensors like PulseMax and heart rate monitors, then sends it to the cloud for processing. A curated dataset with heart rate and oxygen levels would be used to train a deep learning model to predict potential abnormalities and patient health trends. It uses advanced architectures for the accuracy and reliability of predictions.

IoT infrastructure can provide data acquisition, storage, and visualization with an easy-to-use interface for patients and healthcare providers. This system can enhance early detection of such problems in cardiac and respiratory health and help in adopting preventive healthcare measures and subsequently decreasing visits to hospitals. With the added feasibility of scalability and adaptation according to the needs for diverse healthcare requirements, it focuses on a smarter and healthier future.

LIST OF FIGURES

LIST OF ABBREVIATIONS

TIET	Thapar Institute of Engineering and Technology
ECED	Electronics and Communication Engineering Department
ML	Machine learning
DL	Deep learning
AI	Artificial intelligence
IoT	Internet Of Things
OLED	Organic Light-Emitting Diode

CHAPTER 1

INTRODUCTION

Health monitoring is essential for managing and preventing a variety of conditions, particularly those related to cardiovascular and respiratory health. However, traditional approaches often rely on periodic check-ups and diagnostic tests, which can be time-consuming, expensive, and inaccessible to people in remote or underserved areas. The rapid advancement of technology offers a promising alternative through systems that leverage the Internet of Things (IoT) and artificial intelligence (AI) to deliver real-time, continuous health monitoring.

Continuous health monitoring has gained significant attention as it allows for the early detection of abnormalities and trends that might not be caught during infrequent check-ups.Technologies such as wearable sensors and Internet of Things (IoT) devices have revolutionized this field, enabling individuals to monitor vital health parameters from the comfort of their homes. This shift not only allows individuals to manage their health more effectively but also relieves the pressure on healthcare systems by reducing the frequency of in-person visits and consultations.

1.1 PROJECT OVERVIEW

The hardware aspect of our system incorporates a Pulse Sensor for real-time health monitoring, coupled with an OLED display to provide immediate feedback to users. This setup ensures that users can view vital parameters such as heart rate and oxygen levels directly on the display, enhancing accessibility and convenience.

The system is designed for robust performance and efficient resource utilization. It includes a dynamic communication mechanism where data from the sensor is processed and displayed locally, while advanced insights can be transmitted to a remote server if required. For communication, the system can seamlessly transition between Bluetooth (for short-range connectivity) and Wi-Fi modules, ensuring reliable data transmission under varying conditions.

The OLED display is a critical feature that eliminates the dependency on external devices like smartphones or computers for immediate health parameter feedback. By incorporating the Pulse Sensor and OLED display with the ability to adapt to various scenarios, the system ensures a user-friendly, efficient, and accessible health monitoring experience.

1.2 MOTIVATION

The motivation for this project arises from the need for accessible and reliable health monitoring solutions. Traditional healthcare often relies on periodic check-ups, which may miss early signs of health issues, especially in remote or underserved areas. With the rise of lifestyle-related disorders and cardiovascular diseases, continuous monitoring has become crucial for early detection and intervention.

By leveraging IoT, wearable technologies, and AI, this system empowers individuals to monitor vital parameters conveniently and proactively. It reduces dependency on in-person visits, enhances access to healthcare, and alleviates the strain on overburdened healthcare systems. This project aims to make healthcare more efficient, personalized, and accessible, improving overall health outcome

1.3 NOVELTY OF WORK

The proposed IoT-based health monitoring system stands out due to its comprehensive integration of physiological, contextual, and behavioral parameters. Unlike conventional health monitoring systems that focus on isolated metrics such as heart rate or oxygen saturation, this system incorporates additional factors like age, stress levels, body temperature, and physical activity. This holistic approach enables a more accurate and personalized understanding of an individual’s health status.

The novelty lies in its use of advanced machine learning (ML) and deep learning (DL) techniques to analyze the interplay between these diverse parameters, providing actionable insights and early detection of potential health risks. By combining IoT-enabled real-time data collection with intelligent predictive algorithms, the system ensures timely intervention and supports preventive healthcare. Furthermore, it emphasizes remote health monitoring, making quality healthcare accessible to individuals in remote or underserved regions, addressing a critical gap in modern healthcare systems.

Additionally, the system's adaptability and scalability to diverse healthcare needs, its user-friendly interface for data visualization, and its integration of stress and lifestyle metrics to cater to modern healthcare challenges are distinctive features that differentiate it from existing solutions. These innovations collectively enhance the system's ability to deliver proactive, personalized, and accessible health monitoring, establishing it as a significant advancement in the field of digital healthcare.

CHAPTER 2

PROBLEM FORMULATION AND OBJECTIVES

2.1 PROBLEM DEFINITION

Rapidly advancing healthcare technologies revolutionized traditional medical practices but considerably fell short in ensuring timely and accessible care for acutely or chronically ill patients. Conditions, largely cardiovascular and respiratory in nature, have continued to be among the leading causes of morbidity and mortality worldwide. Had early detection and monitoring of vital signs such as heart rate, pulse rate, and SpO2 been conducted, many adverse health outcomes might have been avoided.

Traditional healthcare relies on periodic hospital visits, causing delays in addressing urgent conditions, especially in underserved areas. Real-time monitoring for abnormalities like hypoxemia or tachycardia is often limited due to expensive, non-portable devices requiring specialized training. Overburdened healthcare facilities further compromise care quality. While IoT devices collect health data, few leverage machine learning for real-time risk prediction. An IoT-enabled health monitoring system addresses these challenges by offering affordable, portable, and user-friendly real-time monitoring with predictive analytics, enhancing healthcare accessibility and effectiveness.

2.2 OBJECTIVES

- **Data Acquisition**

Hardware System Design: Using IoT sensors, e.g., MAX30100 for pulse oximetry measurement, measure vital parameters such as pulse, heart rate, and SpO2 in real time.

All the sensor data must be brought to the processing unit via a valid communication protocol, such as serial communication with Arduino.

- **Data Storage**

Store data in a format that can be analyzed and be compatible with the machine learning pipeline.

- **Interconnection with the System**

  Integrating IoT hardware with a machine learning model to enable real-time predictions. Develop data pipeline for preprocessing data from sensors and feeding into a model, retrieved as real time predictions

- **Mobility and Cost effectiveness**

  Cost-effective components to make it affordable and accessible to a wide range of users.

- **Machine Learning-Based Prediction**

  Data Preparation: Propose a machine learning model that can predict the health condition (e.g., Healthy, Hypoxemia, Tachycardia) based on the gathered parameters.

CHAPTER 3

PROJECT DESIGN, RESULTS AND DESCRIPTION

3.1 PROJECT DESIGN AND DESCRIPTION

Our project aims to design a portable, easy to use Health monitoring system using optical pulse detection technique termed as Photoplethysmogram. Wifi communication, application real time prediction. This integration ensures real-time health monitoring with online application with machine learning model. The focus is on early detection of severe disease easy to use, low power consumption, and online data availablility.

Hardware Components and Communication Infrastructure

The hardware infrastructure of the system includes OLED display, pulse sensor, MAX30102 heart rate sensor module. These components are used to measure heart beat and oxygen level in the blood.

- **Pulse sensor:**

  The Pulse Sensor is a well-designed low-power plug-and-play heart-rate sensor for the Arduino. The front of the sensor, with the heart logo, is where you put your finger. You'll also notice a tiny circular opening through which the Kingbright's reverse mounted green LED shines.

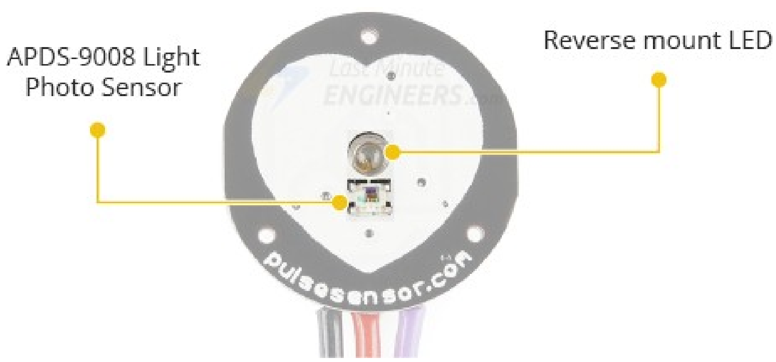

fig 3.1 pulse sensor

Just beneath the circular opening is a small ambient light photo sensor – APDS-9008 from Avago. This sensor is similar to the ones used in cell phones, tablets, and laptops to adjust the screen's brightness based on the ambient lighting conditions.

On the back of the module are an MCP6001 Op-Amp from Microchip and a few resistors and capacitors that make up the R/C filter network. Additionally, there is a reverse protection diode to prevent damage in the event that the power leads are accidentally reversed.

- **MAX30102 Heart rate sensor:**

The MAX30102 pulse oximeter and heart rate sensor is an I2C-based low-power plug-and-play biometric sensor. It can be used by students, hobbyists, engineers, manufacturers, and game & mobile developers who want to incorporate live heart-rate data into their projects.
The module features the MAX30102 – a modern (the successor to the MAX30100), integrated pulse oximeter and heart rate sensor IC, from Analog Devices. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry (SpO2) and heart rate (HR) signals.

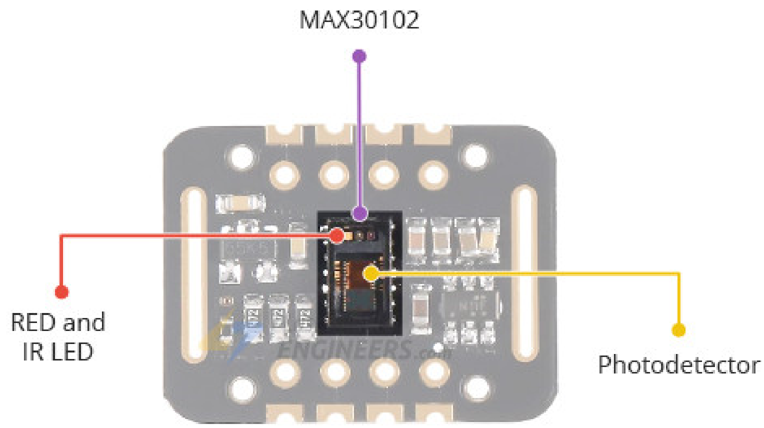

fig 3.2(a) MAX30102 sensor

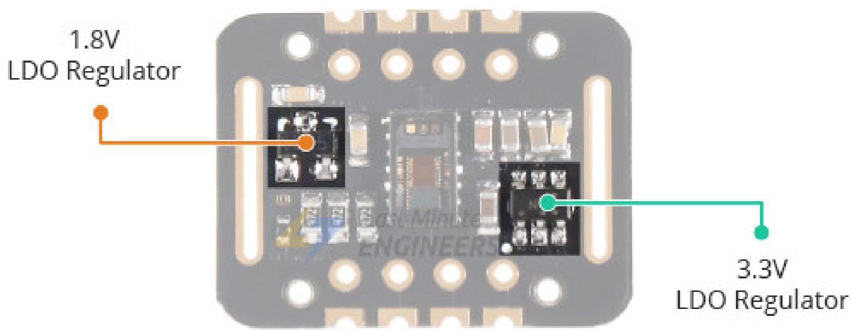

fig 3.2(b) LDO regulator 1.8 and 3.3v

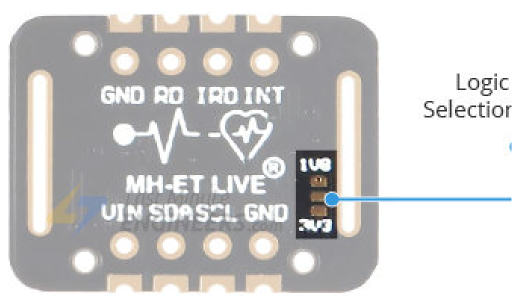

fig 3.2(c) logic selector of sensor

- **ThingSpeak Cloud Integration for Data Management**

  Our system is using ThingSpeak cloud integration for the data management for health parameters, which provides real time data integration.

- **Data Transmission to ThingSpeak**:

  With Wifi ability of ESP32 module, it sends health data to the to ThingSpeak using HTTP GET requests. ThingSpeak stores the incoming data in real-time streams, which can be accessed later by the Streamlit application.

- **Fetching Data from ThingSpeak:**

  The Streamlit application fetches data from ThingSpeak using HTTP GET requests. Thus we can see the health parameters in real time on application and use model to predict condition.

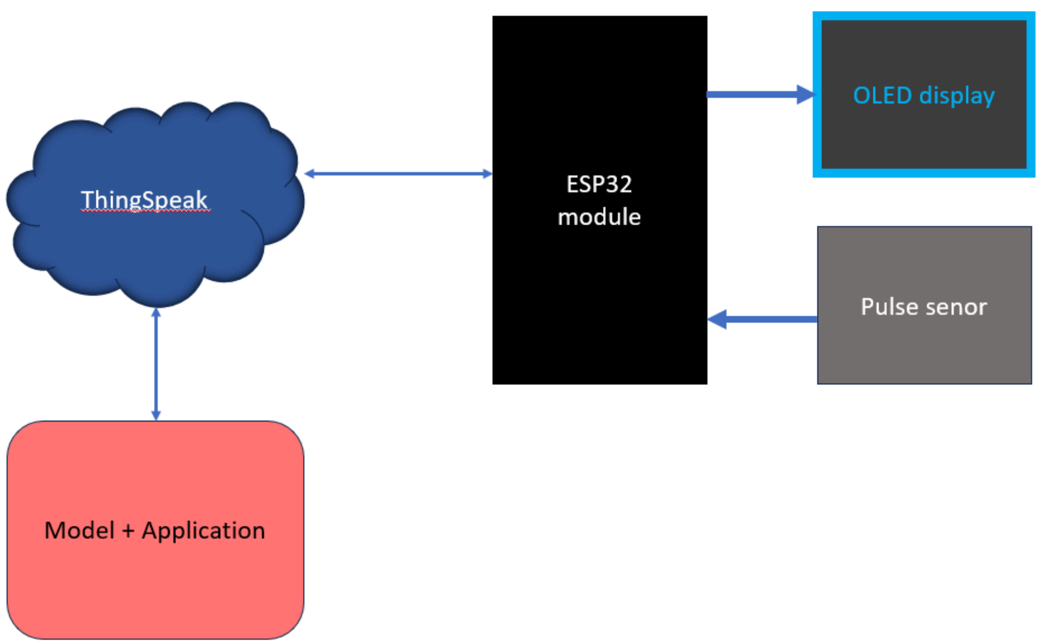

Fig 3.3 A High-Level architecture of the various components and endpoints involved in the implementation of a Health Monitoring system

3.2 RESULTS

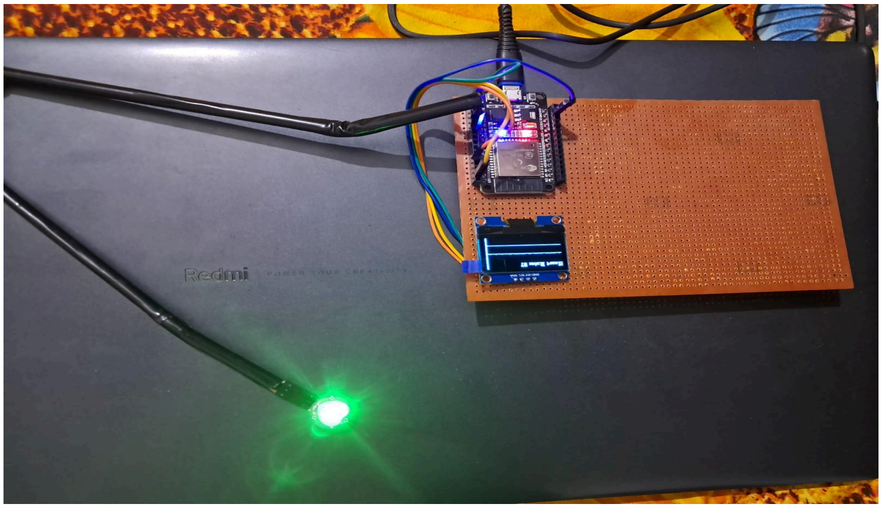

Fig 3.4 Circuit view

```
♥ A Heartbeat Happened!
BPM: 238
♥ A Heartbeat Happened!
BPM: 238
♥ A Heartbeat Happened!
BPM: 161
♥ A Heartbeat Happened!
BPM: 128
♥ A Heartbeat Happened!
BPM: 96
```

Fig 3.5 serial monitor output

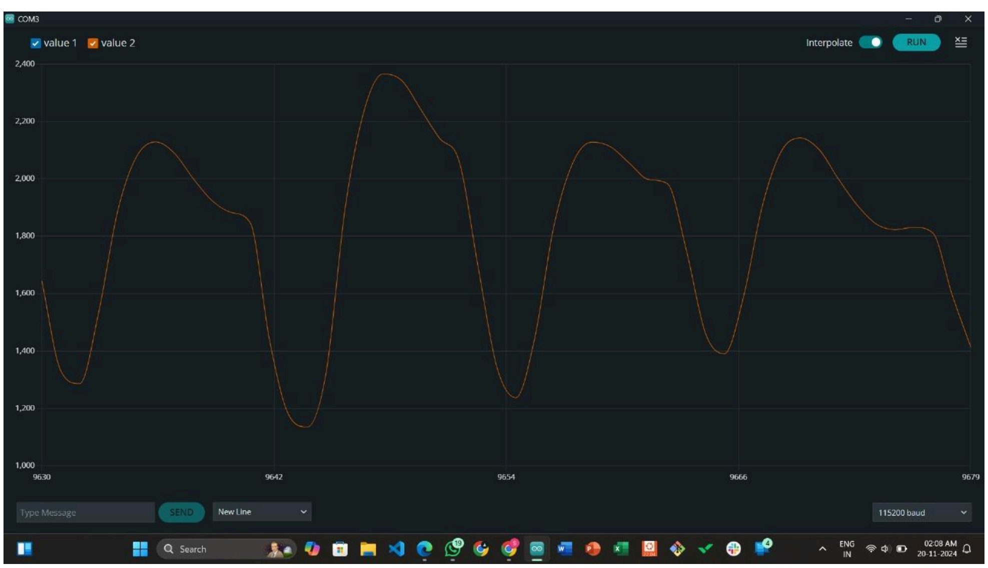

Fig 3.6 Pulse rate serial plot

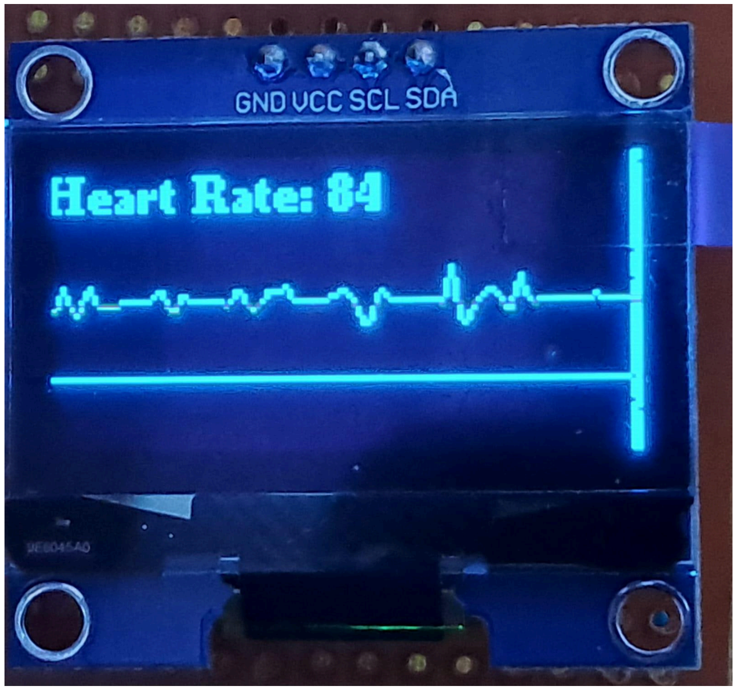

Fig 3.7 Heart rate oled display

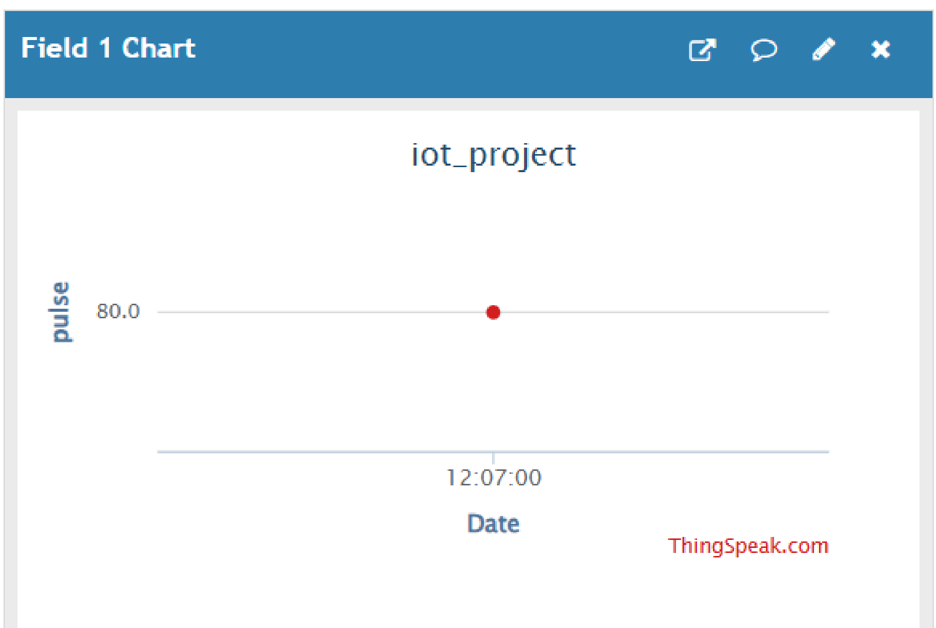

Fig 3.8 Pulse data on ThingSpeak

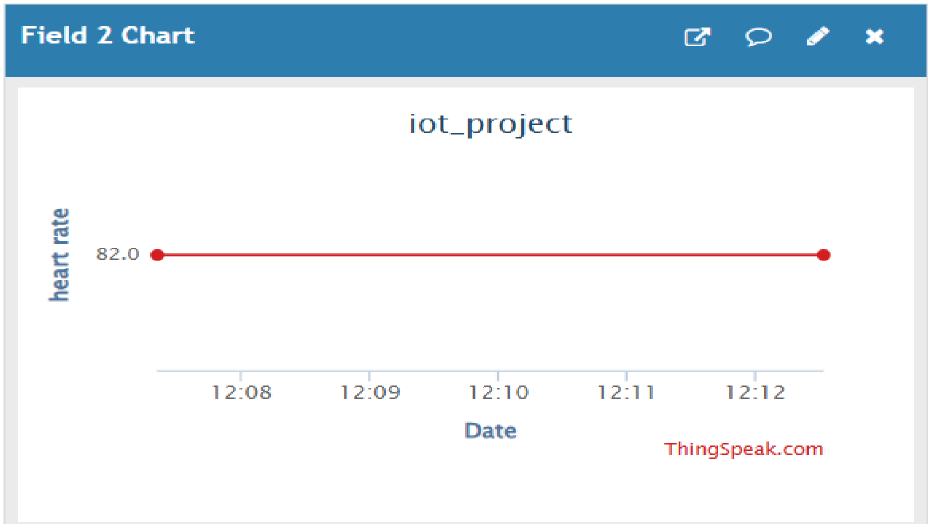

Fig 3.9 Heart rate data on ThingSpeak

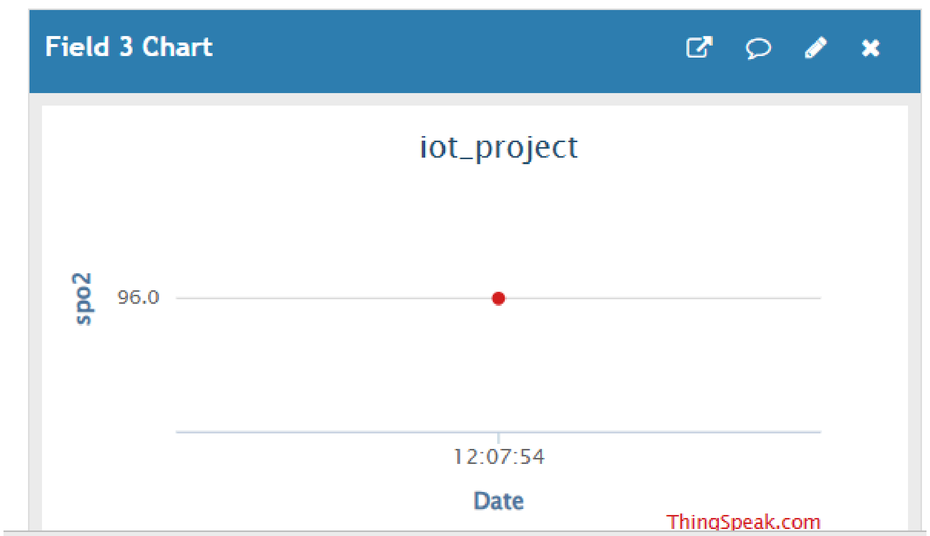

Fig 3.10 SpO2 data on ThingSpeak

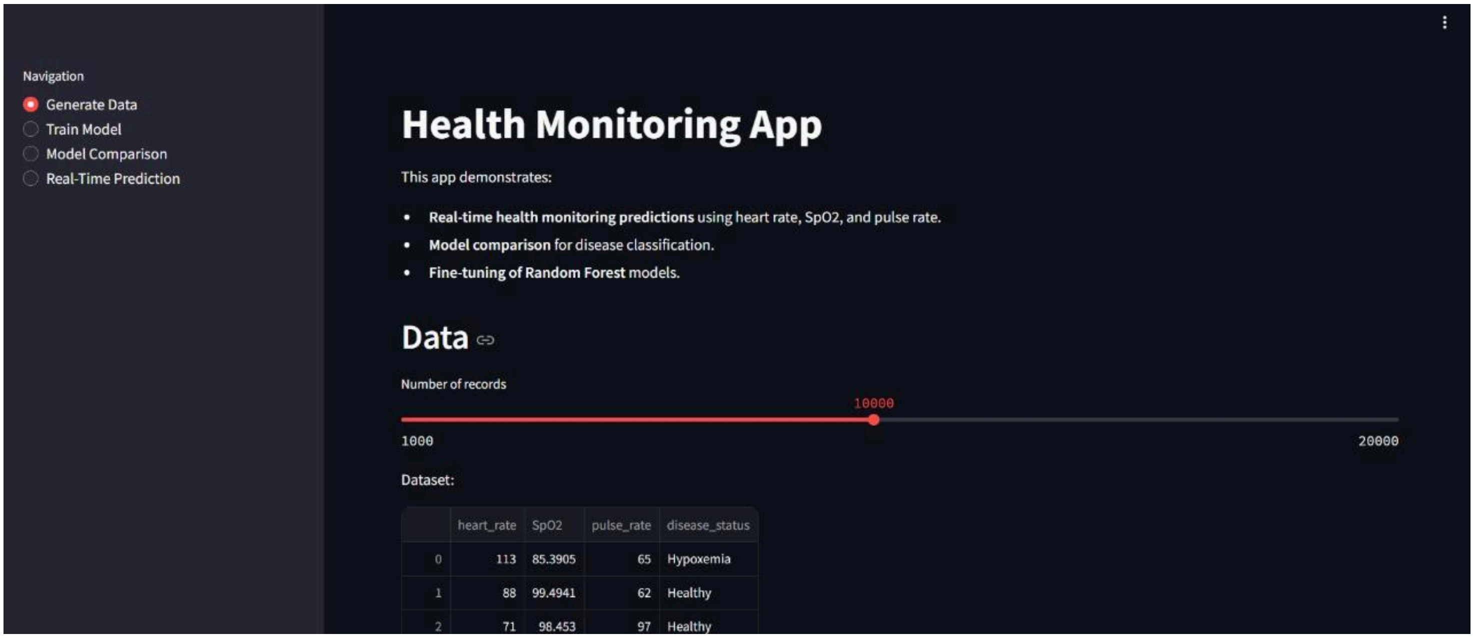

Fig 3.11 Online application

CHAPTER 4
OUTCOME AND PROSPECTIVE LEARNING

4.1 SCOPE AND OUTCOMES

The project focuses on developing an IoT-enabled health monitoring system for real-time tracking of vital signs like heart rate and pulse. It integrates affordable sensors with machine learning models for predictive analytics, providing alerts for abnormalities. Designed to be portable and user-friendly, it aims to enhance healthcare access, especially in underserved areas.

- **Real-time Health Monitoring**

  The real-time health monitoring feature enables continuous tracking of vital signs, such as heart rate and pulse, using connected sensors and IoT technology. This ensures that health data is collected and analyzed instantly, providing immediate feedback and alerts if any abnormalities are detected. This real-time insight allows for timely intervention, making it especially valuable for users in remote or resource-limited areas who may not have immediate access to healthcare facilities.

- **Random Forest(Predictive Analysis)**

  The Random Forest algorithm was used in this project to enable predictive analysis by identifying patterns and trends in health data, such as heart rate and pulse fluctuations. By training the model on historical health data, it can classify potential health risks and provide early warnings, supporting preventive care measures. This enhances the system's ability to alert users of potential issues before they become critical, adding an essential layer of proactive health monitoring.
- **Predictive Alerts and Decision Support**: The Random Forest model analyzes historical and real-time data to predict possible health risks, sending alerts when an anomaly is detected. These predictions help in early diagnosis and intervention, which can prevent critical health episodes.

- **Integration with Other Devices**

  The system can be expanded by adding more sensors for monitoring additional health parameters, such as temperature, blood oxygen levels, or blood pressure, offering a comprehensive health tracking system.

4.2 PROSPECTIVE LEARNINGS

1.Wired Communication Technologies

Our project focuses on wired communication for real-time data transmission between sensors and processing units. Key learnings include:

- **Serial Communication (UART)**: Understanding the basics of UART for transmitting health data from the Arduino to the processing unit and configuring optimal baud rates for efficient communication.
- **I2C Protocol**: Learning how I2C allows multiple sensors like MAX30100 to communicate with a microcontroller using minimal pins and addressing challenges like device synchronization and noise handling.

2.Ethical and Security Considerations

- **Data Integrity and Privacy:** Ensuring the accuracy and security of health data during transmission and storage.
- **Ethical Use of Data:** Gaining awareness of best practices for handling sensitive health data responsibly.

3.Machine Learning and Real-Time Integration

- **Predictive Models:** Training and fine-tuning machine learning models like Random Forest to classify health conditions.
- **Real-Time Predictions:** Integrating live sensor data with the trained model and ensuring accurate, low-latency predictions.

4.System Reliability and Scalability

- **Error Handling:** Addressing challenges like noise and signal degradation in wired communication.
- **Scalability:** Building a modular system that can easily incorporate additional sensors or features in the future.

5.Future Business Models

- **Remote Health Monitoring:**
  - Scaling the system for use in local clinics or community health centers to monitor multiple patients simultaneously using wired setups.
- **Home Healthcare Solutions:**
  - Developing affordable home-based health monitoring kits with USB or Ethernet connectivity for individuals requiring continuous health supervision.
- **Integration with Hospital Systems:**
  - Connecting the system to existing hospital networks via wired connections, enabling seamless data transfer and integration with electronic health records.

CHAPTER 5

CONCLUSION

In conclusion, therefore, the development of a portable health monitoring system utilizing the Pulse Sensor, MAX30102 sensor, and OLED display, with machine learning, represents a significant step forward in personalized healthcare. This means that real-time monitoring of vital signs like heart rate and blood oxygen level is possible and offers the great advantage of compact efficiency for individual or healthcare provider use. Integration of a machine learning model would further enhance the functionality of this application by enabling predictive analysis, anomaly detection, and personalized health insights, thus allowing users to take proactive measures for their health.

Thus, it also shows the feasibility of applying low-power, accurate sensors with advanced computational models and further potential for scaling remote health monitoring applications into telemedicine and fitness tracking. The device is portable, hence accessible, but its customizability will allow new breakthroughs to pop up, such as multi-parameter tracking of health and integration into IoT ecosystems for seamless data sharing and remote diagnostics.

Not only does this system facilitate successful implementation but, further, lays the foundation for investigating deeper issues of medical technology in advanced signal processing, data security, and the ethical considerations of health data management. This project stands for the harmony that exists between innovations in hardware and machine learning.

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