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Final Project Report

Section: B1 Group: 04

IoT Sleep Monitoring and Safety System

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Academic Honesty Statement:

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1 Abstract

The project titled "IoT Sleep Monitoring and Safety System" is a well-rounded initiative aimed at improving the quality of sleep and guaranteeing safety by incorporating a range of sensors. Leveraging modern technology, the system combines a combination of heart rate and oximeter sensors, humidity and temperature sensors, gas leakage detection sensors, and sound sensors to monitor and analyse sleep parameters of a person. All these sensors were incorporated and data was extracted using ESP32 microcontroller. Moreover, these parameters are then transferred to “Thingspeak” IoT platform to remotely monitor a person’s sleep condition and analysed the quality of sleep using machine learning. This ingenious system tackles crucial elements of sleep well-being and security by offering live information on essential indications, surroundings, and possible risks.

The inclusion of heart rate and oximeter sensors enhances the health monitoring feature, enabling users to monitor their physiological metrics as they sleep. Concurrently, sensors for humidity and temperature assess the surrounding variables to establish an ideal sleep setting. By incorporating gas leakage detection sensors, safety is heightened as they instantly detect and notify users of any gas dangers. In addition, sound sensors are in place to detect any abnormal sounds, providing valuable information on disruptions that could impact the quality of sleep. The IoT platform enables to remotely observe any patient’s sleep condition. Finally, the machine learning algorithm can determine whether a person’s sleep quality is good or bad. The integration of these sensors is enabled using an Internet of Things (IoT) framework (Thingspeak), providing smooth communication between the devices and a centralized system. Through this connectivity, users may tap into live data and get notifications via an intuitive interface, encouraging well-informed choices about sleep routines and safety precautions.

Within this study, we explore the intricacies of the design, execution, and operation of the IoT Sleep Monitoring and Safety System. Besides, we will discuss about the machine learning algorithm we used to determine the sleep quality and how it creates positive impact on user’s lifestyle. Moreover, We will delve into the project's architecture, sensor technologies, data processing techniques, and user interface in great detail, emphasizing the system's capability and the potential it holds in improving sleep quality and guaranteeing user safety. The forthcoming presentation will showcase the outcomes of the system's performance and user input, illustrating the efficacy of this inventive approach in tackling the various dimensions of sleep well-being and security.

2 Introduction

In an era distinguished by rapid technological breakthroughs and an increasing emphasis on holistic well-being, the convergence of health and innovation has opened the way for transformative solutions. Sleep, a key pillar of human health, plays a pivotal function in physical and mental well-being. As society grapples with the challenges of modern living, there is an increasing realization of the necessity for complete sleep monitoring systems that not only check vital signs but also protect the safety of individuals during their resting hours.

The "IoT Sleep Monitoring and Safety System" develops as a response to this requirement, merging cutting-edge Internet of Things (IoT) technology and an array of sensors to build a sophisticated platform for monitoring sleep conditions. This project integrates heart rate and oximeter sensors, humidity and temperature sensors, gas leakage detection sensors, and sound sensors into a unified

framework. The synergy of these sensors provides a holistic approach to sleep monitoring, including physiological well-being, ambient factors, and potential safety hazards.
As sleep disorders continue to afflict a major section of the global population, there is a rising need for accessible and user-friendly solutions that enable individuals to take charge of their sleep health. Furthermore, safety hazards within sleeping spaces, such as gas leakages and unexpected disturbances, demand continuous monitoring and early intervention. The IoT Sleep Monitoring and Safety System strives to address these difficulties, giving a comprehensive and intelligent solution that not only monitors but also increases the quality of sleep while emphasizing user safety.This study details the design, development, and implementation of the IoT Sleep Monitoring and Safety System. It investigates the underlying technology, the integration of diverse sensors, the data processing processes, and the user interface. Through this exploration, we hope to give a full knowledge of the system's capabilities, its potential impact on sleep health and safety, and the broader implications of leveraging IoT for personalized well-being solutions. The succeeding sections will delve into the approach, design considerations, and consequences of the project, providing a full description of the IoT Sleep Monitoring and Safety System's functionality and efficacy.

3 Design

3.1 Problem Formulation

Getting enough sleep is crucial for general health and wellbeing. Because sleep disorders and insufficient sleep are so common in both adults and children, they pose a threat to public health, especially since inadequate sleep is linked to negative health consequences. Recent research has shown that healthy sleep can be impacted by environmental elements in the home and community. Research has demonstrated that social characteristics of surroundings, family, social cohesiveness, safety, noise, and disorder in the neighborhood can all influence and/or form sleep patterns. Additionally, physical characteristics like light, noise, traffic, pollution, and walkability can affect sleep and are linked to sleep disorders in both adults and children. So it is very important to keep the sleeping environment favorable to ensure a good sleep. Our use of electric illumination at night is one of the primary offenders for sleep deprivation. According to a US study, residents of places with greater outdoor lighting at night (such as cities) are more likely to report experiencing sleep problems, such as shorter sleep durations, difficulty waking up in the middle of the night, and daytime weariness. This is due to the fact that prolonged exposure to light throws off our body's circadian rhythm, also known as the sleep-wake cycle or internal clock, which indicates when it is appropriate for us to feel alert or sleepy. Although all types of light have the potential to disrupt our sleep-wake cycle, blue light is the one we should be especially cautious of. Regretfully, it originates from the devices we use most frequently: televisions, laptops, tablets, and cellphones. As technology continues to progress at a rapid pace, our dependence on modern electronic devices such as smartphones and laptops is increasing day by day. Unfortunately, this overreliance on electronic devices has a downside. According to a recent study, over 40% of adults use these devices right before going to bed, which can significantly hamper the quality of their sleep. The blue light emitted by these devices can disrupt our circadian rhythm, making it harder for our bodies to recognize when it's time to sleep. Additionally, the radiation emitted from these devices can reduce the amount of melatonin, a hormone that helps regulate sleep, in our bodies. Consequently, we may struggle to fall asleep or wake up feeling groggy and tired, which can negatively impact our overall health and well-being. It is found out that people who suffer from insufficient sleep are more likely to die from coronary heart disease. Here is a graph which shows the trend where people who sleeps less than 7 hours daily have higher rate of stroke, depression and diabetes. We frequently believe that lack of sleep has an impact solely on an individual's health and well-being. In reality, though, its impact on society as a whole—including traffic fatalities—is significantly more extensive. Drunk driving is less safe since it impairs cognitive abilities like judgment and reaction times. However, a lot of us continue to drive. According to a survey, 1 in 25 adult drivers reported dozing off while operating a vehicle in the 30 days before to reporting. Contrary to popular belief, getting less sleep does not mean having more time to accomplish more. In actuality, it lowers our productivity, and economies suffer as a result.

According to one study, sleeplessness costs the US economy $63 billion annually. However, this isn't because those who don't get enough sleep miss work. They were actually there for about the same number of days as the people who slept well. The problem was that they performed their duties with less effectiveness. Additionally, workers are losing out on 11.3 days of production annually, or around $2,280, as a result of this.

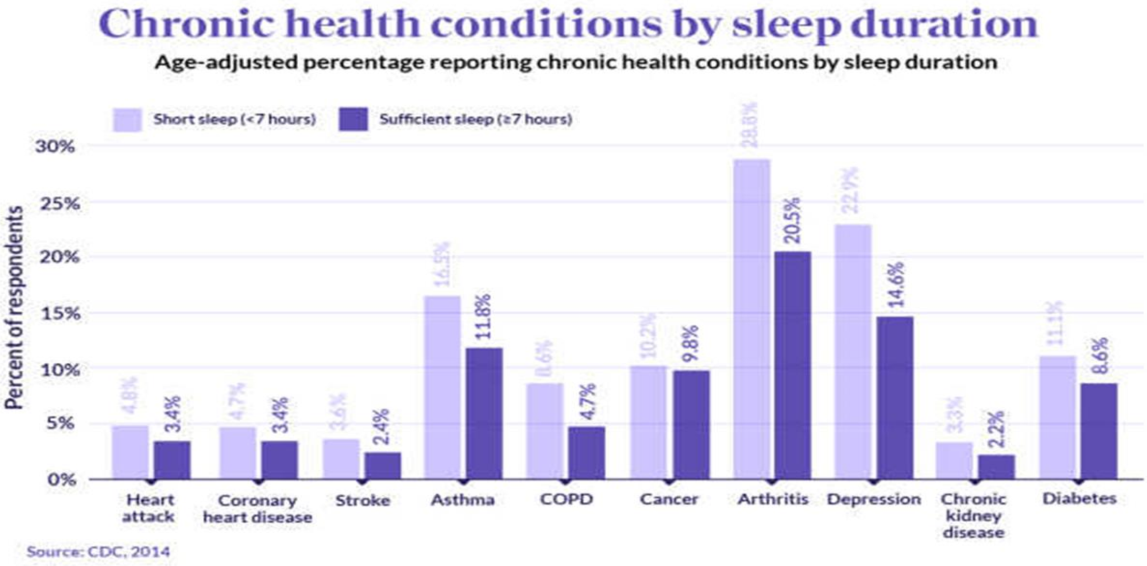


Fig 1: Chronic health conditions according to sleep duration

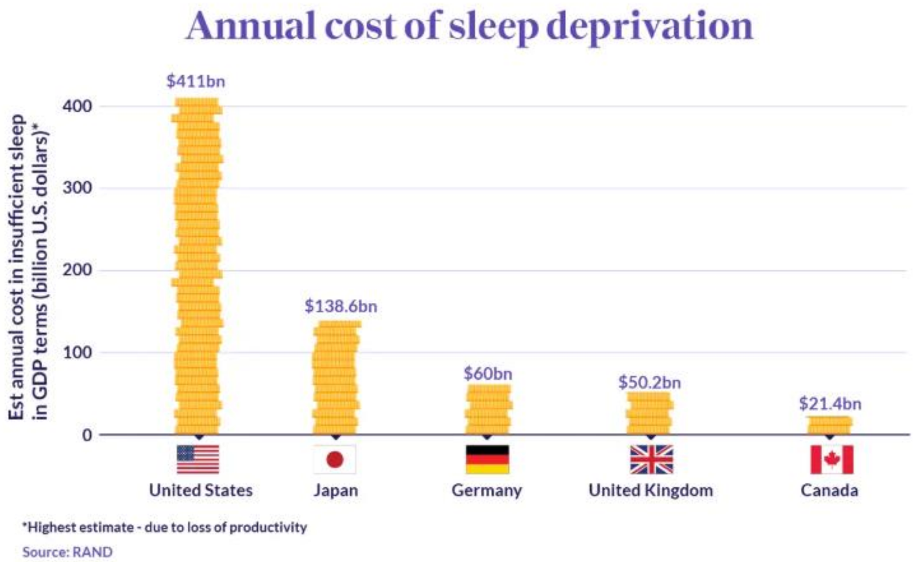


Fig 2: Cost of sleep deprivation for different countries in terms of nominal GDP

This far we only discussed about the effect of environmental parameter effect on sleep quality. However the main factor which is inevitable for good sleep quality is physical condition including heart rate, oxygen saturation level etc. Generally speaking, the heart rate drops as you sleep compared to other periods of the day. A healthy and fit individual has a lower heart rate during the sleeping phase, typically in the range of 50–60 bpm. An average person's heart rate during sleep is typically between 60 and 80 bpm. A peculiar variation in heart rate is among the indications of sleep apnea. A shortage of oxygen in the body might cause a decreased heart rate. It might occur if someone's respiration stopped for any strange reason. Another effect of sleep apnea is an elevated heart rate. Stress and hypertension can both induce an increase in heart rate. And it typically interferes with a person's regular sleep. It's one of the primary causes of heart failure at night.

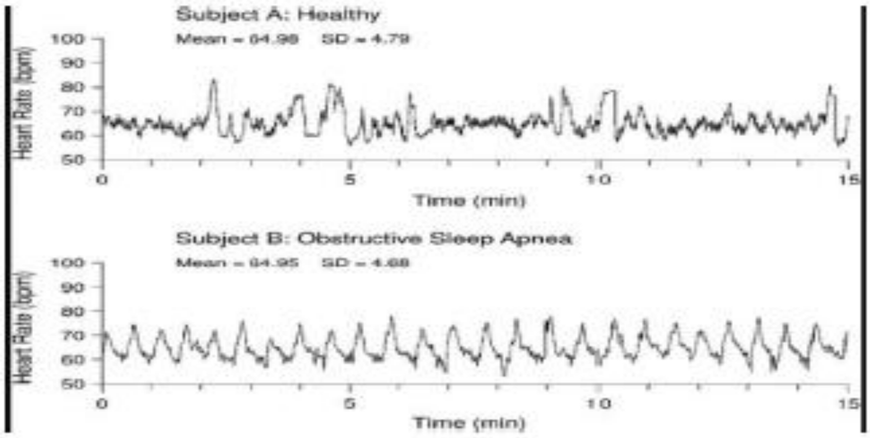


Fig 3: Heart rate during sleep

The term "blood oxygen level" refers to the quantity of oxygen circulating in the blood. The distribution of oxygen in the body can be used to distinguish between healthy and diseased bodies. How evenly oxygen is delivered throughout the body—from the lungs to the cells—is shown by the blood oxygen level, also known as the oxygen saturation level. One of the main causes of low oxygen saturation is lung issues. Low oxygen levels in the body and lungs can result from breathing issues. The respiratory rate often decreases during OSA. The body receives less oxygen as a result. The blood's oxygen saturation rate is impacted by such alteration. An individual in good health has an oxygen saturation (SpO2) of 95% or above. An individual with sleep apnea typically has a reduced SpO2 level, typically around 90%. Hypoxemia may result from low SpO2. It also suggests lung illness that is ongoing. In the event that the oxygen saturation values drop below these threshold levels, patients require external oxygen delivery.

So the main objective in this project is mainly to detect if there are any unfavorable environmental and physical condition. We will detect some environmental parameters like humidity, temperature, smoke, sound of surroundings and physical parameters like heart rate and oxygen saturation level using sensors. We will collect these data and upload in an IoT platform. By analyzing these data we will predict the sleep quality. We will classify sleep quality as high, medium and low.

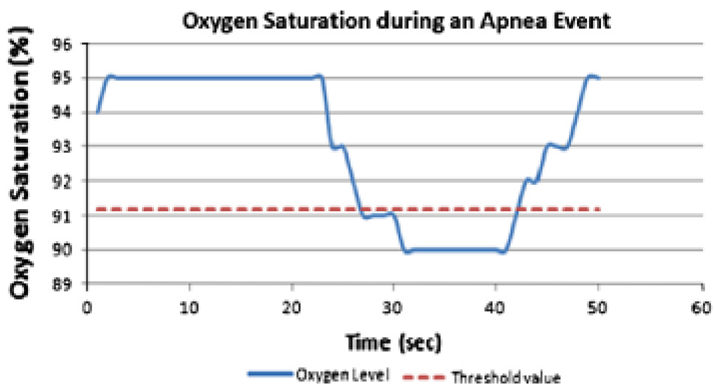


Fig 4: Oxygen saturation level

3.1.1 Identification of Scope

We see that the problem of sleep deprivation can cause various diseases and cost a lot of work hours. It even affects our economy, causing a huge loss in GDP. If we can use the outcome of our project in greater extent then it will be a lot of help to overcome these problem. Our innovative project outcome serves as an efficient tool to monitor the duration of sleep and to detect the quality of sleep through different stages. We will predict sleep quality based on three classes - high, medium, and low. To delve deeper into the structure of sleep, we'll keep track of how long each stage lasts and how frequently we switch between them. Moreover, we'll keep a vigilant eye out for symptoms of sleep disorders such as irregular breathing patterns, slumbering motions, or breaks in regularity. To evaluate the impact of surrounding factors like light, temperature, and noise levels on sleep, we'll analyze the environment. By doing this, we can help people optimize their sleeping environment to improve the quality of their sleep. Our recommendations will be used to improve sleep hygiene based on individual sleep patterns and behaviors. Importantly, we'll monitor how sleep habits change over time to identify trends and patterns that can help determine whether therapies are working or to flag possible health issues. For better prediction and smarter applications we used machine learning algorithms which will help us to take decision about sleep quality more accurately and efficiently. As we analyzed the sleep data through various steps, we will be able to get a clear idea about our sleep pattern. However if it is possible to make the good use of our project outcome in commercial level then we can hope to reduce the sleep disorder in mass level.

3.1.2 Literature Review

Research on improving sleep quality is a popular topic with noteworthy contributions.

Clinical Applications of Mobile Health Wearable–Based Sleep Monitoring: Systematic Review: The paper reviewed the literature, including feasibility studies and clinical trials, with the goal of better understanding the clinical uses of wearable-based sleep monitoring for this study. Through June 2019, the authors conducted searches on PubMed, PsycINFO, ScienceDirect, the Cochrane Library, Scopus, and the Web of Science. Wearables and sleep are the two domains on which they based their keyword list creation. The main criterion for selection was the publication of clinical trials involving wearable technology to record adult sleep. 645 articles were found in the first search; 19 of those that met the inclusion criteria were included in the analysis that was conducted in the end. Four categories total for the chosen articles were displayed. Out of the 19 research included in the review, 11/19 (58%) compared the findings to the gold standard, 4/19 (21%), studied feasibility, 3/19 (15%), and 1/19 (5%), evaluated the effects of sleep disorders in the clinic. The samples varied widely in size, with 1 to 15,839 patients included. This analysis demonstrates the viability of wearable, mobile health (mHealth) technology for sleep monitoring. When compared to polysomnography, they did find several significant limitations to the dependability of wearable-based monitoring techniques. This review demonstrated that wearables offer passable sleep tracking but lack consistency. Wearable mHealth technology, however, seems to be a viable instrument for ecological monitoring.

Recent Developments in Home Sleep-Monitoring Devices: The polysomnogram (PSG) is a widely used test to assess sleep physiology both in healthy individuals and those with sleep disorders. Although it is the gold standard, issues of cost and inconvenience have led to the development of portable devices capable of evaluating sleep at home. Longitudinal home monitoring offers the potential to provide a more realistic platform for sleep data. This paper reviews recent developments in the area of devices that can be used for home-based sleep assessment. The devices are grouped into categories based on the type of data collected, and the key features are evaluated including the availability of published validation studies. Finally, a research agenda for the field of home-based sleep monitoring is discussed.

Non-invasive Techniques for Monitoring Different Aspects of Sleep: A Comprehensive Review: Obtaining high-quality sleep is a fundamental aspect of maintaining a healthy lifestyle. Unfortunately, a significant portion of the global population does not get enough sleep, which can have serious negative consequences for their overall well-being. In response, researchers are exploring methods to monitor sleep patterns and gain a better understanding of sleep behaviors. Currently, the gold standard for sleep analysis is polysomnography, but its cost and complexity make it less than ideal for long-term use. Thanks to recent advancements in sensor technology and the availability of off-the-shelf technologies, unobtrusive solutions for in-home sleep monitoring are becoming increasingly popular. Both wearable and non-wearable methods have been proposed as inexpensive and user-friendly alternatives for sleep monitoring. In this comprehensive survey, we examine the latest research conducted after 2015 in various categories of sleep monitoring, including sleep stage classification, sleep posture recognition, sleep disorders detection, and vital signs monitoring. We explore the latest non-invasive research efforts, covering both wearable and non-wearable methods, and discuss the design approaches and key attributes of the work presented. Our analysis is based on ten key factors, with the aim of providing a comprehensive overview of recent developments and trends in all four categories of sleep monitoring. Additionally, we collect publicly available datasets for different categories of sleep monitoring to facilitate further research. Finally, we discuss several open issues and future directions for research in the area of sleep monitoring.

Promises and Challenges in the Use of Consumer-Grade Devices for Sleep Monitoring: The market for smartphones, smartwatches, and wearable devices has seen a significant surge in demand in recent years. These devices have been utilized by both individuals and researchers as supplementary tools to monitor and track sleep patterns, physical activity, and behavior. Incorporating these commercial devices in sleep research and clinical applications can help overcome the limitations of polysomnography, which is currently considered the gold standard. However, the use of consumer-grade devices for large-scale sleep studies poses certain challenges. To address these challenges, this paper presents an in-depth review of sleep monitoring systems and the techniques used in their development. The study also assesses their performance in terms of reliability and validity, and considers the needs and expectations of different user groups, including experts, patients, and the general public. Through this comprehensive review, we highlight a number of challenges faced by current studies, such as the absence of standard evaluation methods for consumer-grade devices, limitations in the populations studied, consumer expectations of monitoring devices, and constraints related to the resources of consumer-grade devices, such as power consumption.

Consumer Sleep Technologies: A Review of the Landscape: In this research paper, the authors delved into various digital libraries to review publications related to sleep technology. They specifically looked into publications from the Association for Computing Machinery, Institute of Electrical and Electronics Engineers, and PubMed. Additionally, we examined publications from consumer technology websites and mobile device app marketplaces. The search terms included "sleep technology," "sleep app," and "sleep monitoring." It was found that consumer sleep technologies can be classified based on the delivery platform. These platforms may include mobile device apps that are integrated with a mobile operating system, wearable devices that can be worn on the body or attached to clothing, embedded devices that are integrated into furniture or other fixtures in the sleep environment, accessory appliances, and conventional desktop or website resources. The primary objectives of consumer sleep technologies vary widely and are aimed at facilitating sleep induction or wakening, self-guided sleep assessment, entertainment, social connection, information sharing, and sleep education. It is important to note that while consumer sleep technologies have the potential to improve sleep health and clinical sleep medicine, they can also have negative effects if not implemented correctly. Overall, consumer sleep technologies are changing the way the paper approach sleep health and clinical sleep medicine. It is essential to be aware of their potential benefits and drawbacks when considering their use.

Recent advances in wearable sensors and portable electronics for sleep monitoring: This review aims to highlight the latest technology updates in wearable sensors and integrated portable electronics for sleep monitoring applications. The advancements made in recent times have enabled at-home sleep monitoring by overcoming the limitations of standard PSGs. These advancements have led to the development of systems that are more user-friendly, unobtrusive, and easy to use. Many of the new systems have incorporated miniaturized low-profile sensors within a single device platform to enable portable, accurate, and comprehensive sleep monitoring. Additionally, non-standard body locations have been taken into account while measuring different signals for sleep monitoring. These measures have been validated through comparison with standard methods. Moreover, new types of physiological signal measurement, such as EDA, are being explored in sleep monitoring to provide unique perspectives for evaluating sleep. Advanced signal-processing methods such as machine learning can be applied to analyzing measured sleep signals to automatically assess sleep quality and detect any sleep disorders with high accuracy. Though these mobile sleep monitoring devices still lack an independent validation process, their clinical applications related to sleep health have been studied, providing promising results. Efforts have been made to develop non-wearable sleep monitoring systems to minimize the interruption with the user's natural sleep behavior, which suffers from limited information and sleep assessment accuracy. Two of the most prominent examples in the market are Beddit from Apple and S+ from ResMed. However, there are still some challenges faced by wearable sleep monitoring systems. Our weak understanding of sleep and lack of precise assessment methods poses a significant challenge in scoring sleep staging and detecting sleep disorder events, even with standard methods. Despite these challenges, improvements in accuracy and reliability of the new systems introduced here will follow suit the advancements in further understanding in neurological and physiological studies of sleep and more objective clarification of sleep evaluation methods. To ensure fair comparison among different methods, choosing the right statistical metrics for evaluation is crucial. Several evaluation metrics are being used, including agreement rate, sensitivity, specificity.

Smart technologies toward sleep monitoring at home: In the past, sleep monitoring was only possible in specialized clinics using PSG, which required patients to spend a night hooked up to a variety of sensors and electrodes. Fortunately, advancements in technology have made it possible for us to monitor our sleep patterns in the comfort of our own homes through simplified and innovative methods. These methods offer a non-intrusive way of monitoring our sleep without disturbing our natural sleep cycle. By monitoring our sleep each day, we can analyze our sleep quality, identify any sleep-related disorders, and detect any comorbid chronic or mental illnesses in early stages. This enables us to take preventative action and seek treatment before any symptoms become more severe. Quantitative analysis of sleep is the first step towards environmental conditioning and sleep modulation, which can help us improve our sleep quality and alleviate any related symptoms and illnesses. With smarter technologies for sleep monitoring, we can move from passive sleep monitoring to active participation. This means that we can take control of our sleep and work towards improving our overall quality of life. By introducing smarter technologies, we can achieve a more personalized form of sleep monitoring that takes into account our unique sleep patterns and needs. Ultimately, this will help us achieve a better night's sleep and enjoy a healthier and happier life.

IoT-Based Wireless Polysomnography Intelligent System for Sleep Monitoring: Polysomnography (PSG) is the gold-standard diagnostic tool used to identify obstructive sleep apnea (OSA) in patients. However, due to the limited number of sleep labs and beds available, patients often have to wait an extended period before being diagnosed and treated. Furthermore, the unfamiliar environment, as well as physical restrictions during a PSG test, may interfere with the patient's sleep, leading to incomplete or inaccurate results. To overcome these limitations, it is suggested that PSG tests be conducted in the patient's own home. In the development of an IoT-based wireless polysomnography system for sleep monitoring, a miniature, wireless, portable, and multipurpose recorder has been developed, which is battery-powered. The system uses a Java-based PSG recording program that collects various bio-signals and converts them into the European data format. PSG records obtained from the system can be used to identify the patient's sleep stages and diagnose OSA. This system is lightweight, portable, and consumes low power, making it ideal for use in the home environment. To evaluate the feasibility of the proposed PSG system, a comparison was made between the standard PSG-Alice 5 Diagnostic Sleep System and the proposed system. The experiment involved several healthy volunteers who were simultaneously monitored by both systems under the supervision of specialists at the Sleep Laboratory in Taipei Veteran General Hospital. A comparison of the results of the time-domain waveform and sleep stage of the two systems shows that the proposed system is reliable and can be applied in practice. The proposed system offers a reliable, convenient, and non-invasive method of diagnosing OSA in patients, particularly those who have difficulty accessing sleep laboratories. Moreover, it enables long-term monitoring and research of personal sleep patterns in the comfort of the patient's home. With the IoT-based wireless polysomnography system, PSG tests can be conducted with ease, accuracy, and convenience, leading to more efficient and effective diagnosis and treatment of OSA.

A New Era in Sleep Monitoring: The Application of Mobile Technologies in Insomnia Diagnosis: Sleep disorders, such as insomnia, can severely affect a patient's quality of life. Studies have shown that insomniacs have a risk of hypertension that is 350% higher than normal sleepers. Insomnia can also increase the risk of diabetes, anxiety, and depression. The current methods for evaluating insomnia include sleep measurements based on polysomnographic (PSG) signals and questionnaires. However, PSG systems are uncomfortable and inconvenient since they require patients to stay overnight at sleep centers. There is a growing interest in portable devices that enable the assessment of insomnia in a natural environment, such as the patient's home. Recent technological advancements have made it possible to monitor a patient's sleep continuously at home and send the data to a remote clinical back-end system for analysis and reporting. This chapter provides a comprehensive analysis of the sleep monitoring technologies that can be used for insomnia assessment and treatment. It highlights the technical challenges of sleep monitoring, describes various types of technologies, and discusses their applications in insomnia assessment. Additionally, it provides an overview of some model-based signal processing techniques for sleep staging and insomnia detection. Finally, the chapter concludes with a discussion on future directions for the deployment of effective in-home patient monitoring systems for insomnia diagnosis.

3.1.3 Formulation of Problem

Our project aims to monitor the environmental and physical parameters in a given area. For this purpose, we'll be using an array of sensors that includes a humidity sensor for measuring temperature and humidity, a gas sensor for detecting smoke, and an audio sensor for measuring sound levels. To collect this data, we'll be using an ESP32 microcontroller that is capable of transmitting this data wirelessly to an IoT server, allowing us to monitor this data remotely. In addition to these sensors, we'll also be using a Max 30102 Finger Oximeter Heart Rate Module SpO2 sensor for measuring heart rate and oxygen saturation level. This sensor will be connected to an Arduino Uno microcontroller, which will also transmit the data to the same IoT server as the other sensors. To make the process more feasible for users, we'll be using two separate microcontrollers. This way, users won't have to wear multiple sensors while sleeping, which could be uncomfortable. Furthermore, the pulse oximeter can be used as a wearable band to make the process more comfortable for users. Once all the data is uploaded to the IoT server, we'll be using a machine learning model to predict sleep quality. The SVM (Support Vector Machine) algorithm will be used in the machine learning model, which is capable of analyzing the data to determine the quality of sleep. With this information, we can make data-driven decisions to improve the sleep quality of individuals. We will also use a 5V buzzer for gas detection. If the MQ2 smoke sensor detects any gas then it will work as alarm to alert people.

3.1.4 Analysis

Support Vector Machines (SVM) is a machine learning algorithm used for classification tasks. It finds an optimal hyperplane to separate different classes by maximizing the margin.

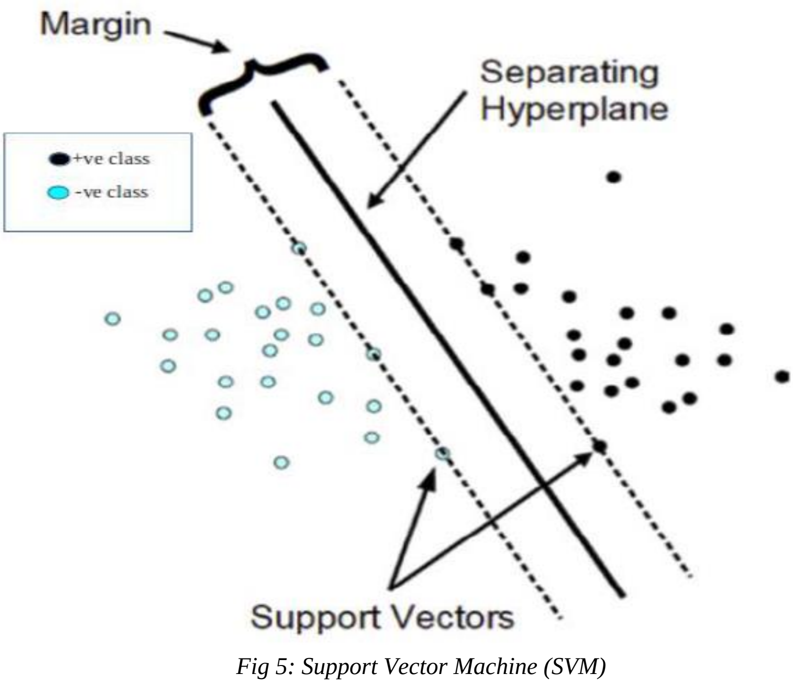


Fig 5: Support Vector Machine (SVM)

Important Terminology

Hyperplane: A hyperplane aka decision boundary/surface is an n-dimensional Euclidean space that distinctly separates the data points. The data points on either side of the hyperplane belong to different classes. If there is a p-dimensional feature set, the dimension of the hyperplane will be p-1.
Support Vectors: The individual data points that are closest to the hyperplane are called the support vectors. These points are the only contributing samples in estimating the maximal margin hyperplane. They support the appearance of the hyperplane.
Margin: The width that the boundary could be increased before hitting a data point. In simple terms, the distance between the hyperplane and the support vectors is referred to as the Margin.
Linear separability: A dataset is linearly separable if there is at least one line that clearly distinguishes

the classes.
Non-linear separability: A dataset is said to be non-linearly separable if there isn't a single line that clearly distinguishes the classes.

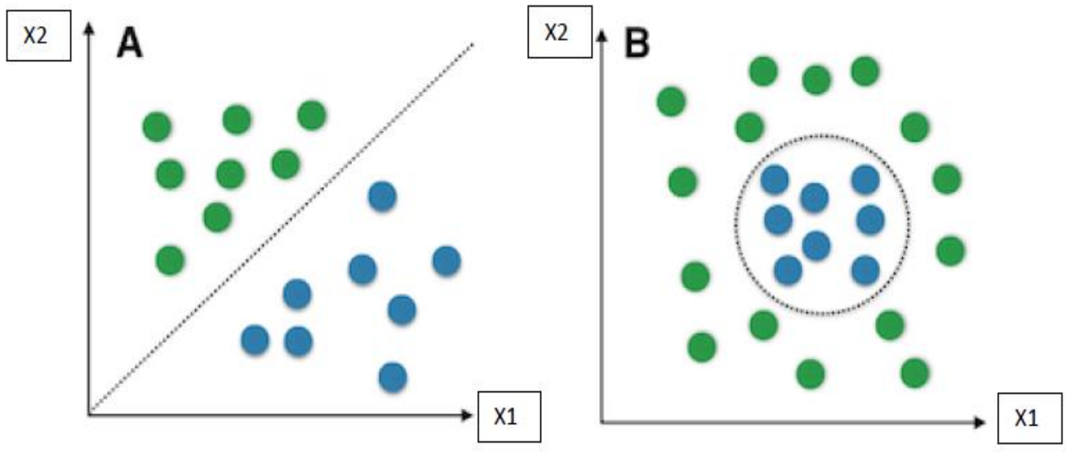


Fig 6: Linearly separable and linearly non-separable

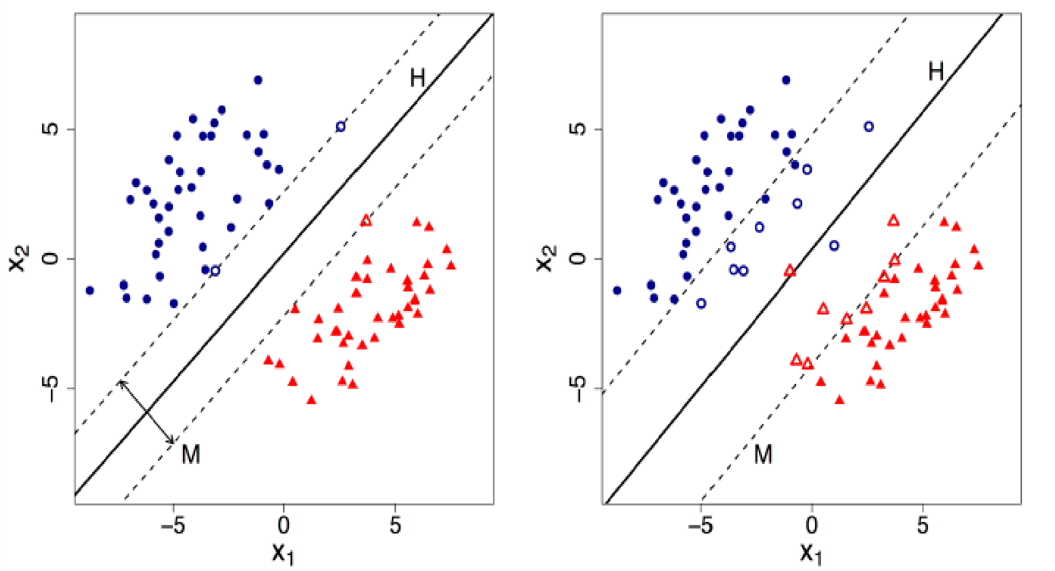
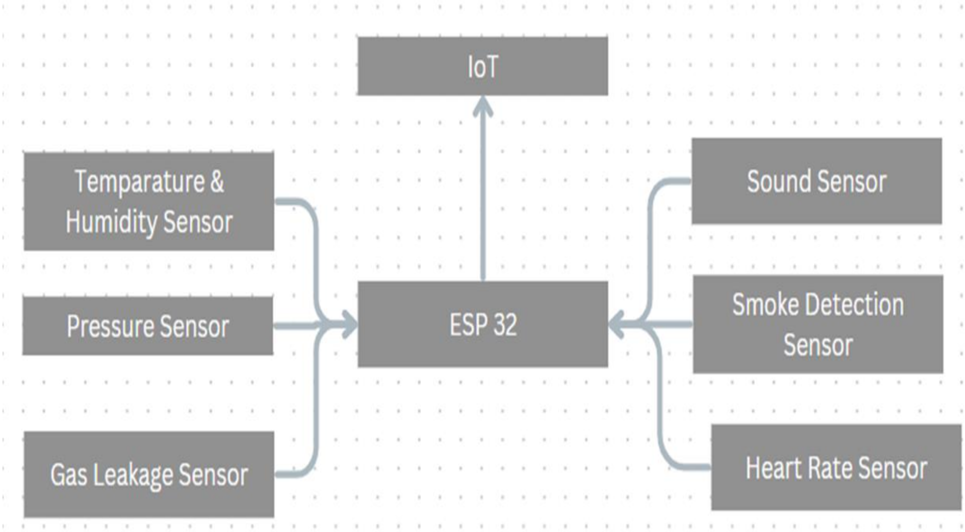


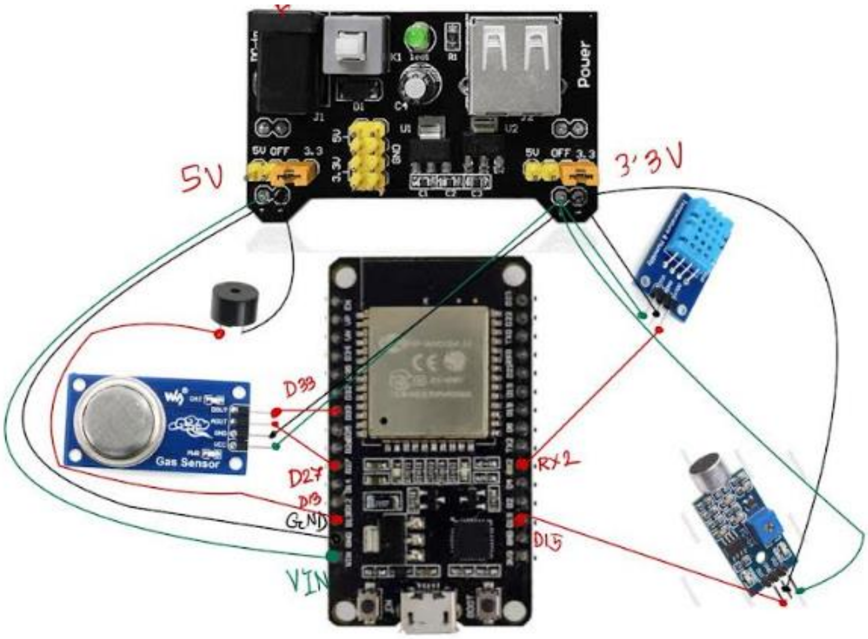
Fig 7: Hard margin and soft margin

Hard Margin: The maximal margin classifier or Hard margin aims to find the hyperplane that maximizes the margin, which is the distance between the hyperplane and the nearest data points (support vectors) from each class. This classifier is typically used in the context of linearly separable data, where classes can be perfectly separated by a hyperplane. It does not allow for any misclassification errors and aims to create the widest possible margin between classes.
Soft Margin: The support vector classifier or soft margin is an extension of the maximal margin classifier that allows for some misclassification errors. In real-world datasets, perfect linear separation may not be possible due to noise or overlapping classes. The SVC introduces a penalty parameter (C) that controls the trade-off between maximizing the margin and minimizing the misclassification errors. This allows the SVC to handle non-linearly separable data and achieve better generalization to unseen data.

3.2 Design Method



3.3 Circuit Diagram



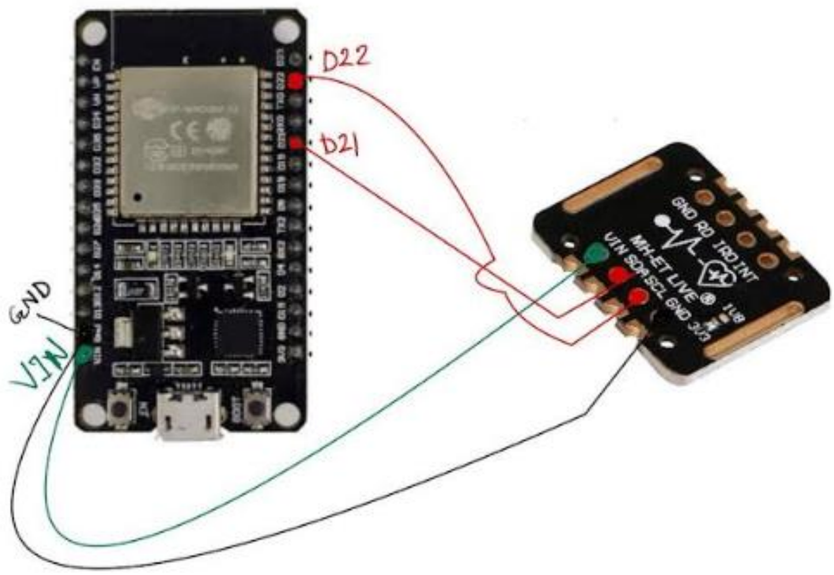


Figure : Circuit Diagram of our project

3.4 Full Source Code of Firmware

We implemented the sensor data by microcontrollers and used these data in machine learning model.

3.4.1 Machine Learning Code:

```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
```

+ Code + Markdown

```
df = pd.read_csv('/kaggle/input/sleep-quality-dataset/micro_project_dataset.csv')
df.head()
```

	Humidity	Temp.	dB	BPM	SpO2	Gas Conc.	Predict
0	50.0	25.0	50	60	9900%	0.0	high
1	55.0	27.0	50	70	100	0.0	high
2	57.0	26.0	55	65	99	0.0	high
3	56.0	24.0	52	66	98	0.0	high
4	54.0	27.0	54	64	98	0.0	high

Here we read data from dataset. We see here are 6 sensors data and prediction. We import necessary library from header file.

[6]:

```
index_to_delete = 1
df.drop(index_to_delete, inplace=True)
df.head()
```

[6]:

	Humidity	Temp.	dB	BPM	SpO2	Gas Conc.	Predict
2	57.0	26.0	55	65	99	0.0	high
3	56.0	24.0	52	66	98	0.0	high
4	54.0	27.0	54	64	98	0.0	high
5	51.0	23.0	51	59	97	0.0	high
6	49.0	28.0	49	61	95	0.0	high

We deleted first row for our convenience.

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 375 entries, 2 to 376
Data columns (total 7 columns):
 #   Column     Non-Null Count  Dtype
---  ------     --------------  -----
 0   Humidity   375 non-null    float64
 1   Temp.      375 non-null    float64
 2   dB         375 non-null    int64
 3   BPM        375 non-null    int64
 4   SpO2       375 non-null    object
 5   Gas Conc.  374 non-null    float64
 6   Predict    375 non-null    object
dtypes: float64(3), int64(2), object(2)
memory usage: 20.6+ KB
```

Total number of dataset and data type are described here.

```
df.shape
```

```
(375, 7)
```

```
df.isnull().sum()
```

```
Humidity      0
Temp.         0
dB            0
BPM           0
SpO2          0
Gas Conc.     1
Predict       0
dtype: int64
```

We checked if there are any null column or not.

```
df=df.dropna()
```

+ Code + Markdown

```
# Split the data into features and target variable
X = df.drop(columns=['Predict'])  # Features
y = df['Predict']  # Target variable
```

```
y = y.map({'low': 0, 'medium': 1,'high':2})
```

Here the data is split into features and target variables. We classified our prediction low as 0, medium as 1 and high as 2.

```
features=['Humidity','Temp.','dB','BPM','SpO2','Gas Conc.','Predict']
```

```
# Plot the frequency distribution of each feature
for feature in features:
    plt.figure(figsize=(10,8))
    sns.countplot(x=feature, data=df, palette='Set2')
    plt.title('Frequency Distribution of ' + feature)
    plt.xlabel(feature)
    plt.ylabel('Frequency')
    plt.show()
```

A frequency distribution graph is plotted here.

```
# Plot scatter plots for each feature
for feature in features[:-1]:
    plt.figure(figsize=(8, 6))
    sns.scatterplot(x=df.index, y=df[feature], alpha=0.5)
    plt.title('Scatter plot of ' + feature)
    plt.xlabel('Index')
    plt.ylabel(feature)
    plt.tight_layout()
    plt.show()
```

In this part we plotted scatter plots for each of the features.

```
# Create a single scatter plot for all features
plt.figure(figsize=(8, 6))
for feature in features[:-1]:
    sns.scatterplot(x=df.index, y=df[feature], hue=df['Predict'], label=feature, alpha=0.5)
plt.title('Scatter plot of Features with Correct Prediction Label')
plt.xlabel('Index')
plt.ylabel('Value')
plt.legend()
plt.tight_layout()
plt.show()
```

We create a single scatter plot of all features in a single frame.

```python
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.svm import SVC
from sklearn.metrics import accuracy_score
```

```python
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
```

```python
# Initialize the SVM classifier
svm_model = SVC(kernel='rbf',degree=3,gamma='scale')

# Train the SVM classifier
svm_model.fit(X_train, y_train)
```

In this part we used SVM algorithms to create boundaries between the class of datatset and predict the sleep quality.

```python
# Predict the target variable for the test set
y_pred = svm_model.predict(X_test)
```

```python
# Evaluate the accuracy of the model
accuracy = accuracy_score(y_test, y_pred)
print("Accuracy:", accuracy)
```

```
Accuracy: 0.96
```

```python
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix

# Calculate the confusion matrix
cm = confusion_matrix(y_test, y_pred)

# Create a heatmap
plt.figure(figsize=(8, 6))
sns.heatmap(cm, annot=True, cmap='Blues', fmt='g', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.title('Confusion Matrix')
plt.show()
```

We see that our ML model can predict data with 96% accuracy. We also created a confusion matrix for better overview.

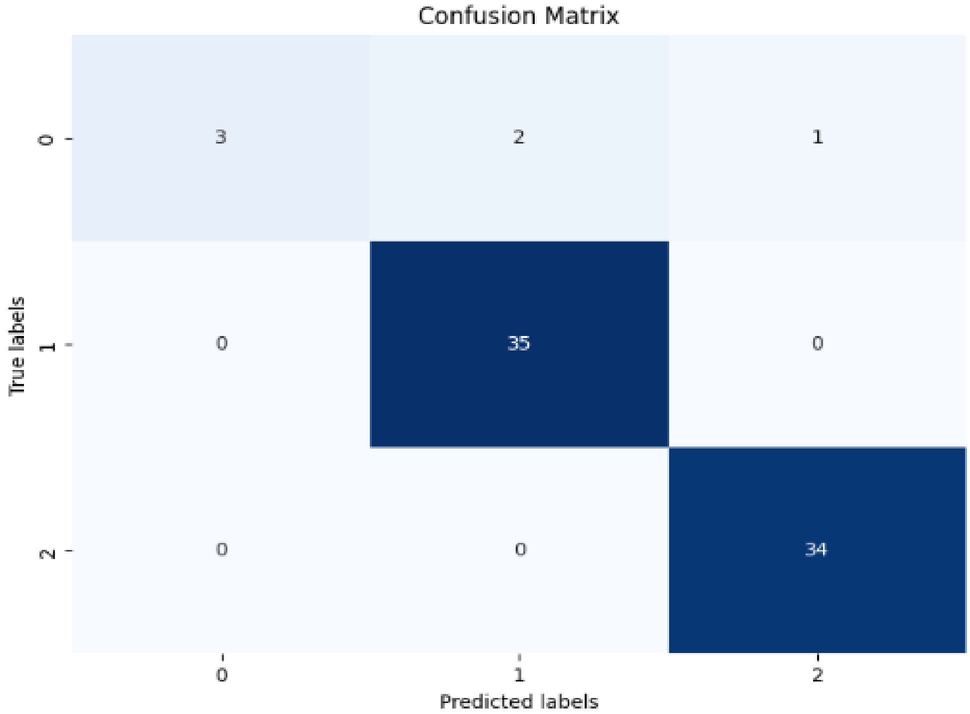


Fig 8: Confusion Matrix

From confusion matrix it is evident that the model can predict low sleep quality three times out of three times whereas it can predict medium sleep quality 35 times out of 37 times and high sleep quality can be accurately predicted 34 times out of 35 times.

3.4.2 Arduino Code for Environment and Health Monitoring:

```
    #include<WiFi.h>
#include "ThingSpeak.h"
#include "DHT.h"
#define DHT11PIN 16
#define AO_PIN 14
#define sound_SENSOR_PIN 15
//#include <Wire.h>
//#include "MAX30105.h"

//#include "heartRate.h"

const char* ssid = "Asif"; // your network SSID (name)
const char* password = "12345678"; // your network password
WiFiClient client;

unsigned long myChannelNumber = 1;
const char * myWriteAPIKey = "HHLI2RON1K7OOI77";
unsigned long lastTime = 0;
unsigned long timerDelay = 3000;

DHT dht(DHT11PIN, DHT11);


void setup()
{
```

```
  Serial.begin(115200);
/*            Start            the            DHT11            Sensor            */
  dht.begin();

  WiFi.mode(WIFI_STA);

  ThingSpeak.begin(client);                // Initialize ThingSpeak
}

void loop()
{
  if ((millis() - lastTime) > timerDelay)
    { // Connect or reconnect to WiFi
    if(WiFi.status() != WL_CONNECTED){
      Serial.print("Attempting to connect");
      while(WiFi.status() != WL_CONNECTED){
        WiFi.begin(ssid, password);
        delay(5000);
      }
      Serial.println("\nConnected.");
      }
    }
  float humi = dht.readHumidity();
  float temp = dht.readTemperature();
  Serial.print("Temperature: ");
  Serial.print(temp);
  ThingSpeak.writeField(myChannelNumber, 2,temp, myWriteAPIKey);

  Serial.print("°C ");
  Serial.print("Humidity: ");
  Serial.println(humi);
  ThingSpeak.writeField(myChannelNumber, 1,humi, myWriteAPIKey);

  int gasValue = analogRead(AO_PIN);
  if(gasValue>1800)
  {
       Serial.println("High Gas Concentration");
       ThingSpeak.writeField(myChannelNumber, 4,1, myWriteAPIKey);
  }
  else{
      Serial.println("Gas Concentration is in Control");
      ThingSpeak.writeField(myChannelNumber, 4,0, myWriteAPIKey);
  }

  int sensorValue = analogRead(sound_SENSOR_PIN);
  float voltage = sensorValue * (3.3 / 4095.0); // Convert analog value to voltage
  float dB = 20 * log10(voltage / 0.0063);// Conversion to dB (calibration factor
0.0063)
  Serial.print("Sound level (dB): ");
  Serial.println(dB);
  ThingSpeak.writeField(myChannelNumber, 3,dB, myWriteAPIKey);
  delay(10);
}
```

```
#include <Wire.h>
#include "MAX30105.h" //sparkfun MAX3010X library
#include<WiFi.h>
#include "ThingSpeak.h"
MAX30105 particleSensor;

const char* ssid="Asif";
const char* password="12345678";

WiFiClient client;

unsigned long myChannelNumber=1;
const char* myWriteAPIKey="HHLI2RON1K700I77";
unsigned long lastTime=0;
unsigned long timerDelay=3000;

double avered = 0;
double aveir = 0;
double sumirrms = 0;
double sumredrms = 0;
int i = 0;
int Num = 100; // calculate SpO2 by this sampling interval
int Temperature;
int temp;
float ESpO2; // initial value of estimated SpO2
double FSpO2 = 0.7; // filter factor for estimated SpO2
double frate = 0.95; // low pass filter for IR/red LED value to eliminate AC component
#define TIMETOBOOT 3000 // wait for this time(msec) to output SpO2
#define SCALE 88.0 // adjust to display heart beat and SpO2 in the same scale
#define SAMPLING 100 //25 //5 // if you want to see heart beat more precisely, set SAMPLING to 1
#define FINGER_ON 30000 // if red signal is lower than this, it indicates your finger is not on the sensor
#define USEFIFO
const byte RATE_SIZE = 4; //Increase this for more averaging. 4 is good.
byte rates[RATE_SIZE]; //Array of heart rates
byte rateSpot = 0;
long lastBeat = 0; //Time at which the last beat occurred

float beatsPerMinute;
int beatAvg
void setup()
{
Serial.begin(9600);
Serial.setDebugOutput(true);
Serial.println();

Serial.println("Running...");
delay(3000);

// Initialize sensor
while (!particleSensor.begin(Wire, I2C_SPEED_FAST)) //Use default I2C port, 400kHz speed
{
Serial.println("MAX30102 was not found. Please check wiring/power/solder jumper at MH-ET LIVE MAX30102 board. ");
//while (1);
}

//Setup to sense a nice looking saw tooth on the plotter
byte ledBrightness = 0x7F; //Options: 0=Off to 255=50mA
byte sampleAverage = 4; //Options: 1, 2, 4, 8, 16, 32
byte ledMode = 2; //Options: 1 = Red only, 2 = Red + IR, 3 = Red + IR + Green
//Options: 1 = IR only, 2 = Red + IR on MH-ET LIVE MAX30102 board
int sampleRate = 200; //Options: 50, 100, 200, 400, 800, 1000, 1600, 3200
int pulseWidth = 411; //Options: 69, 118, 215, 411
int adcRange = 16384; //Options: 2048, 4096, 8192, 16384

// Set up the wanted parameters
particleSensor.setup(ledBrightness, sampleAverage, ledMode, sampleRate, pulseWidth, adcRange); //Configure sensor with these settings

particleSensor.enableDIETEMPRDY();
WiFi.mode(WIFI_STA);
ThingSpeak.begin(client);
}

void loop()
{
if ((millis() - lastTime) > timerDelay)
{ // Connect or reconnect to WiFi
if(WiFi.status() != WL_CONNECTED){
Serial.print("Attempting to connect");
while(WiFi.status() != WL_CONNECTED){
WiFi.begin(ssid, password);
delay(5000);
}
Serial.println("\nConnected.");
}
}

uint32_t ir, red, green;
double fred, fir;
double SpO2 = 0; //raw SpO2 before low pass filtered

#ifdef USEFIFO
particleSensor.check(); //Check the sensor, read up to 3 samples
```

4. Implementation

4.1 Description

In this project we used some sensors like MAX30102 for measuring BPM and oxygen saturation level, MQ2 sensor for gas detection, sound sensor to measure sound level in dB and a DHT11 sensor for temperature and humidity measurement.

MAX30102: This sensor is a high sensitivity pulse oximeter and heart rate sensor for wearable health monitoring device.

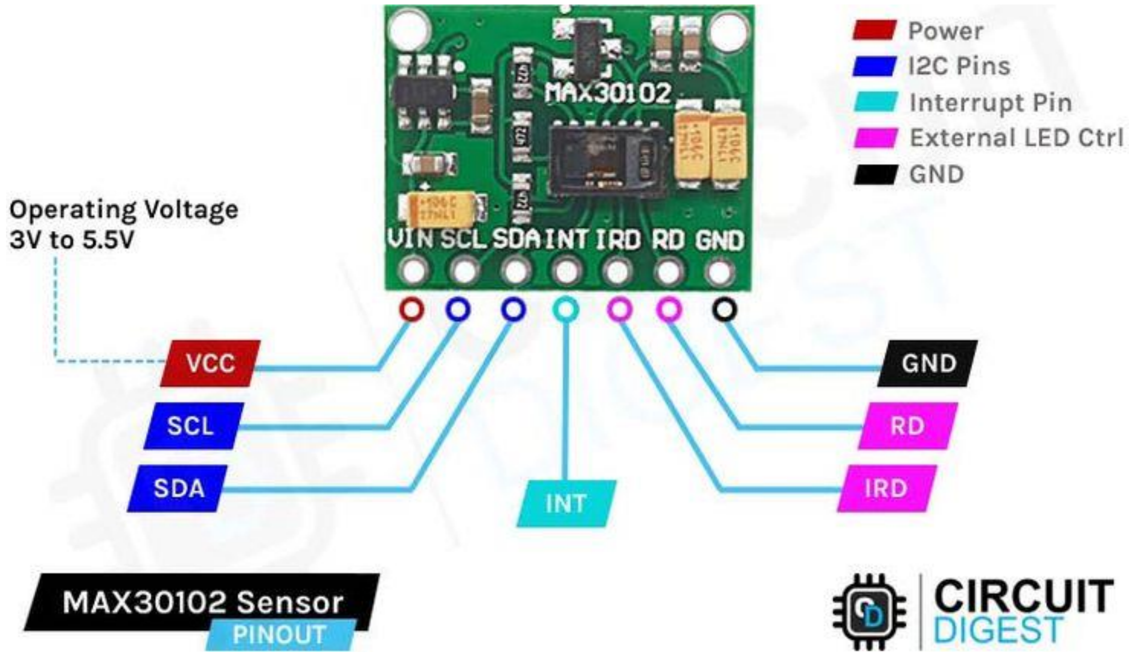


Fig 9: MAX30102 sensor

The MAX30102 sensor is a highly advanced mechanism that employs two LEDs (one Infrared and one Red), a photodetector, and sophisticated signal processing algorithms to derive vital physiological data. By emitting light through the skin and measuring the reflected light, the sensor can determine a range of crucial physiological measurements, including heart rate and blood oxygen levels. This process, known as Photoplethysmogram, is based on the principle that blood absorbs light, which varies depending on the levels of oxygen in the blood. The sensor uses specific wavelengths of light to measure the absorption rate, which helps to determine the oxygen levels in the blood. Similarly, by detecting the changes in blood volume in the capillaries under the skin, the sensor can determine the heart rate. The MAX30102 sensor is an incredibly valuable tool in various applications, including fitness tracking, medical diagnostics, and research. Its operation is both straightforward and effective, making it easy to use for both professionals and consumers. The sensor's ability to provide accurate and real-time data on heart rate and blood oxygen levels has revolutionized the way we monitor and manage our health.

MQ2 Gas Sensor: Winsen manufactures the MQ-2 smoke and combustible gas sensor. It has a 300–10,000 ppm detection range for combustible gases. Alarms for gas leaks in homes and smoke and propane detectors with a high sensitivity are its most popular uses.

Fig 10: MQ2 Gas Sensor

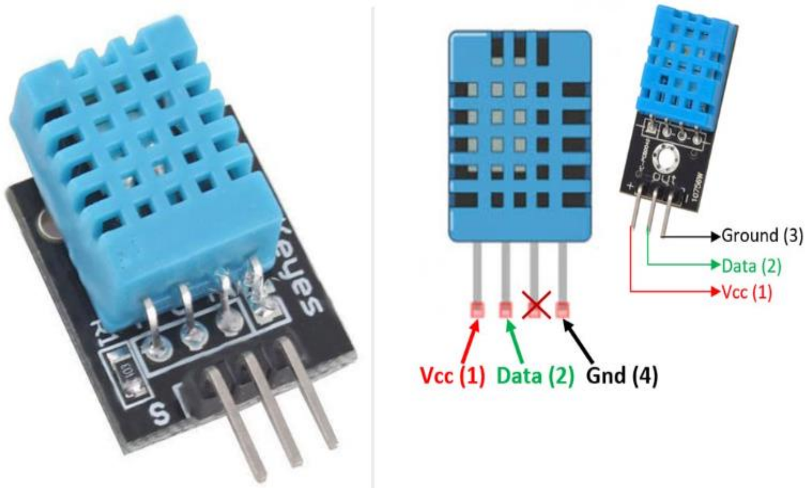
The MQ-2 type smoke sensor is a device that is widely used to detect smoke in various settings. It uses a semiconductor gas sensing material called tin dioxide as its primary component. Tin dioxide is a unique material that is highly sensitive to changes in the ambient environment. When the MQ-2 type smoke sensor operates at temperatures between 200 and 300°C, tin dioxide absorbs oxygen from the air. This process reduces the electron density on the semiconductor and increases resistance. This is because oxygen molecules attach to the tin dioxide surface and capture electrons, which reduces the number of free electrons available for conduction. When smoke comes into contact with the tin dioxide surface, it modifies the barriers at grain boundaries, and this changes the conductivity on the surface. As a result, the conductivity of the tin dioxide surface changes proportionally to the degree of smoke density. The higher the smoke density, the higher the conductivity and the lower the output resistance. The MQ-2 type smoke sensor is a highly reliable device that can detect smoke in a wide range of environments. It is commonly used in residential and commercial buildings to detect smoke from fires, and it is also used in industrial settings to detect smoke from manufacturing processes.

Sound Sensor: When we speak or hear sounds, they are converted into electrical signals by a device called a sound sensor. This device consists of a small board that contains a microphone and processing circuitry. The sound sensor also has a level comparator chip, which helps to measure the intensity of the sound and convert it into a digital signal. This digital signal can then be used by other devices to perform various tasks.

Fig 11: Sound Sensor

The sound sensor is an electronic device that detects sound waves and converts them into an electrical signal. The working principle of a sound sensor is based on the conversion of sound waves into an electrical signal. When sound waves strike the sensor, it causes the diaphragm to vibrate. This vibration generates an electrical signal that is proportional to the amplitude of the sound waves. The diaphragm of the sound sensor is usually a thin, flexible membrane that is placed in the path of the sound waves. When sound waves hit the diaphragm, it moves back and forth, producing a varying voltage that corresponds to the changes in air pressure caused by the sound waves. This voltage is then amplified and processed to produce an output signal that can be used for various applications. Sound sensors are commonly used in a variety of devices, including microphones, speakers, and acoustic instruments. They are also used in industrial applications, such as noise monitoring and control, and in the automotive industry to detect engine and exhaust noise. In addition, sound sensors are used in medical equipment to monitor heart sounds, lung sounds, and other bodily functions. The sensor is factory calibrated and can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%.

DHT11 Sensor



:

Fig 12: DHT11 temperature and humidity sensor

The DHT11 sensor is a device that consists of two critical components: a capacitive humidity sensing element and a Negative Temperature Coefficient (NTC) thermistor for temperature sensing. The humidity sensing capacitor is designed with two electrodes and a moisture-holding substrate as a dielectric between them. Any change in the humidity levels directly affects the capacitance value of the capacitor. The IC measures this capacitance value and then processes the changed resistance value by converting it into digital form. For temperature measurement, the DHT11 sensor uses an NTC thermistor. This thermistor is designed to decrease its resistance value as the temperature increases. To ensure that even the slightest temperature change results in a larger resistance value, the sensor is usually made up of semiconductor ceramics or polymers. The DHT11 sensor comes with an impressive temperature range of 0 to 50 degrees Celsius, with an accuracy of 2 degrees. Its humidity range is from 20 to 80%, with an accuracy of 5%. The sensor has a sampling rate of 1Hz, which means that it generates one reading per second. The DHT11 sensor is designed to be small in size and operate within a voltage range of 3 to 5 volts. It consumes a maximum current of 2.5mA while measuring. The sensor is commonly used in a variety of applications, such as environmental sensing, HVAC systems, and weather stations, among others.

4.2 Data Analysis

From our machine learning model we analyzed data through various alorithms. At first we generated some plots of frequency distribution for each features.

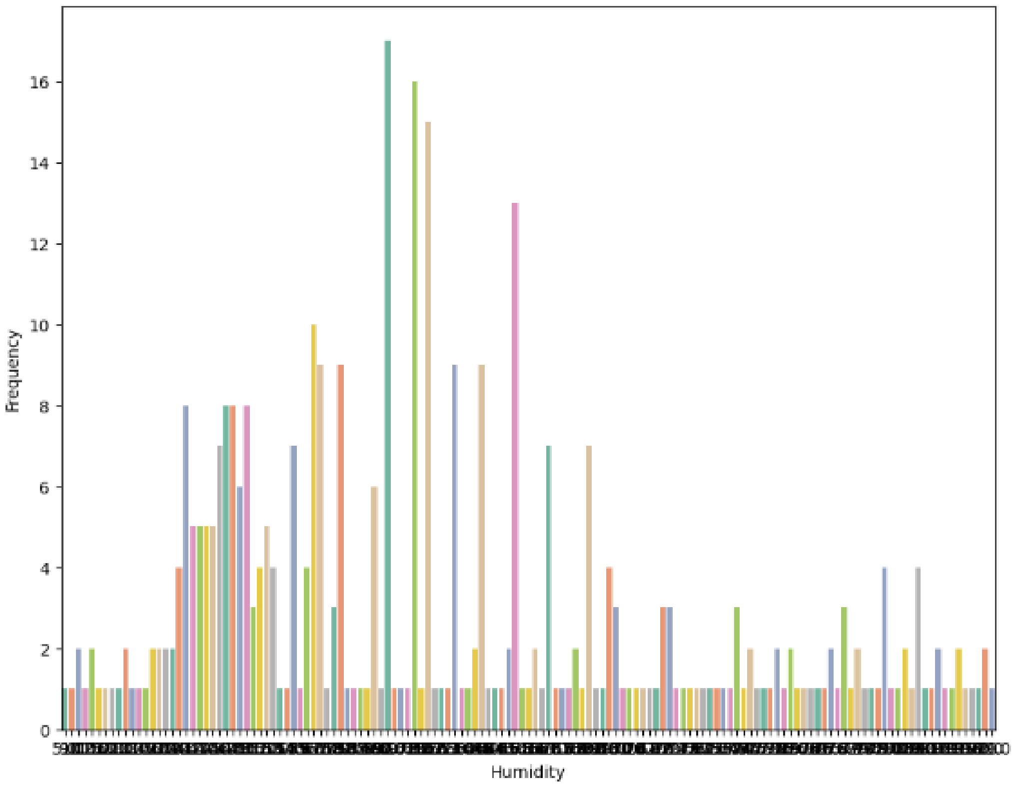


Fig 13: Frequency distribution of Humidity

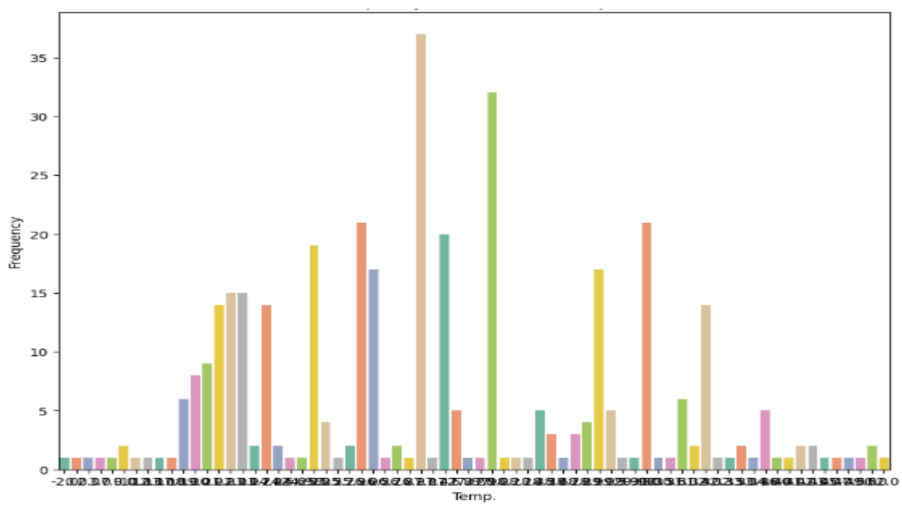


Fig 14: Frequency distribution of Temperature

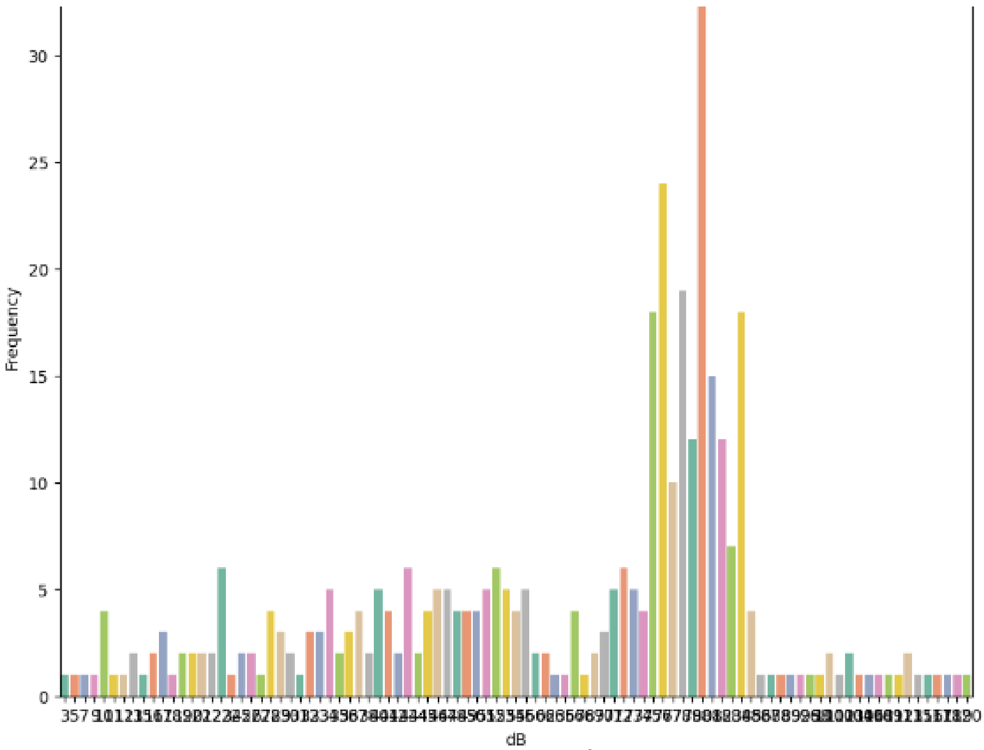


Fig 15: Frequency distribution of Sound level (dB)

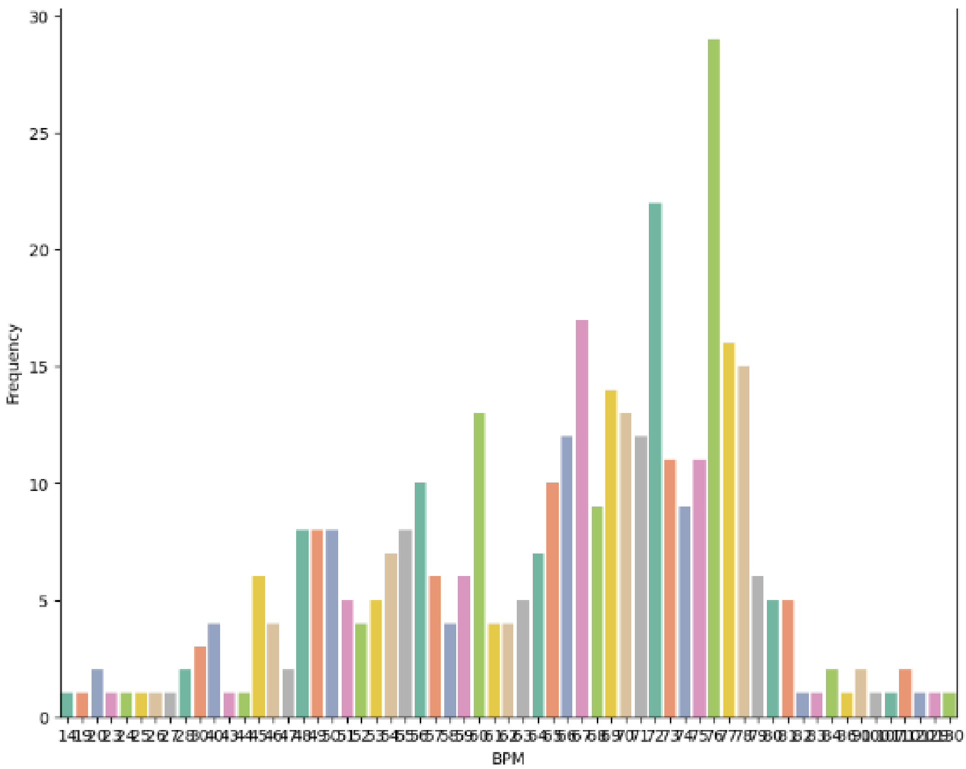


Fig 16: Frequency distribution of heart rate (BPM)

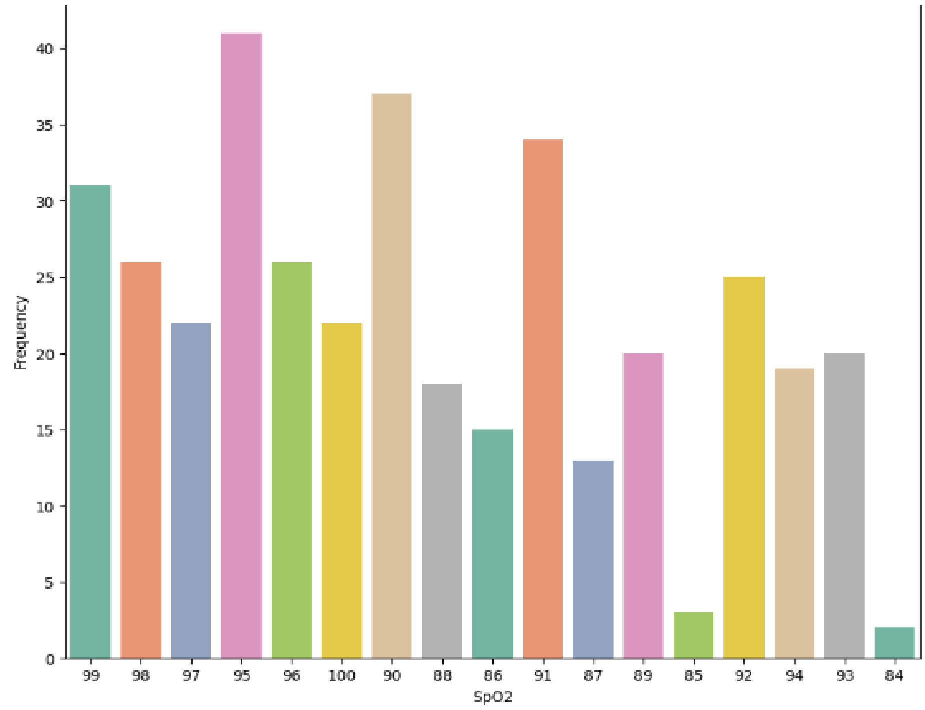


Fig 17: Frequency distribution of SpO2

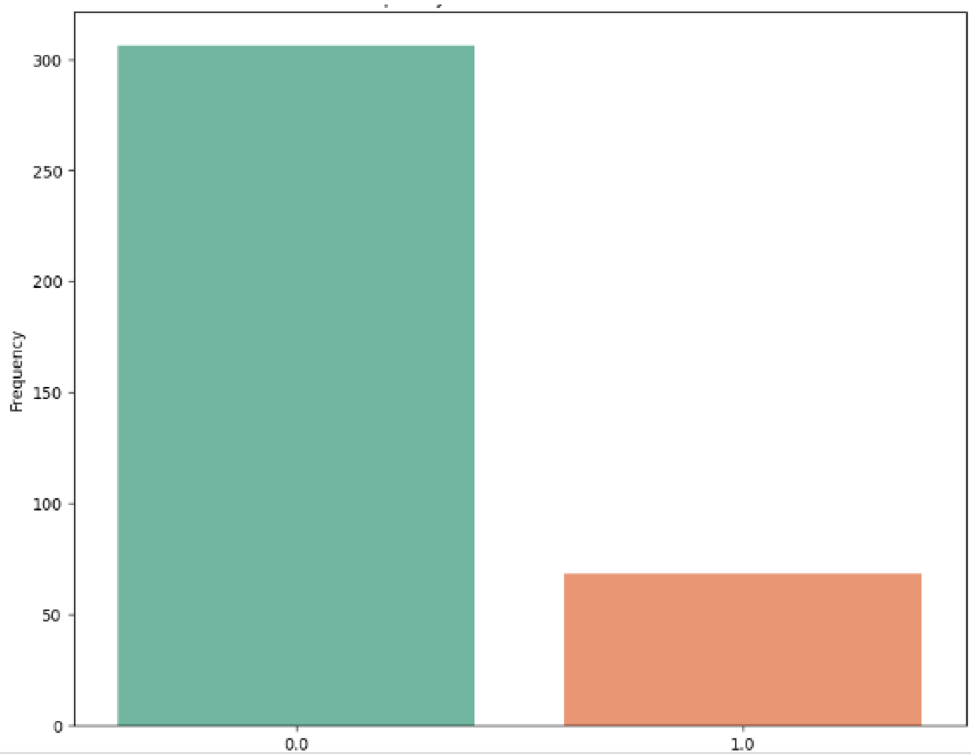


Fig 18: Frequency distribution of Gas Concentration

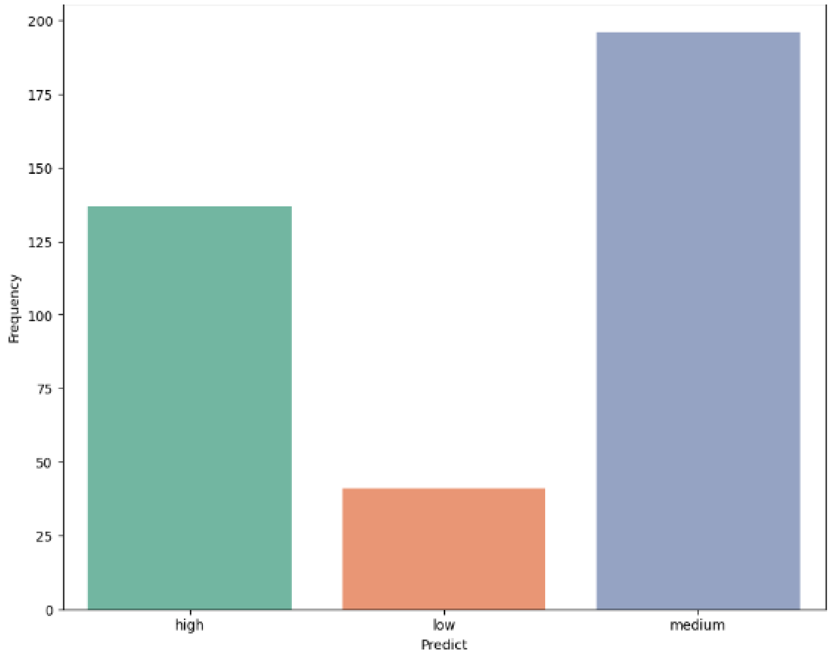
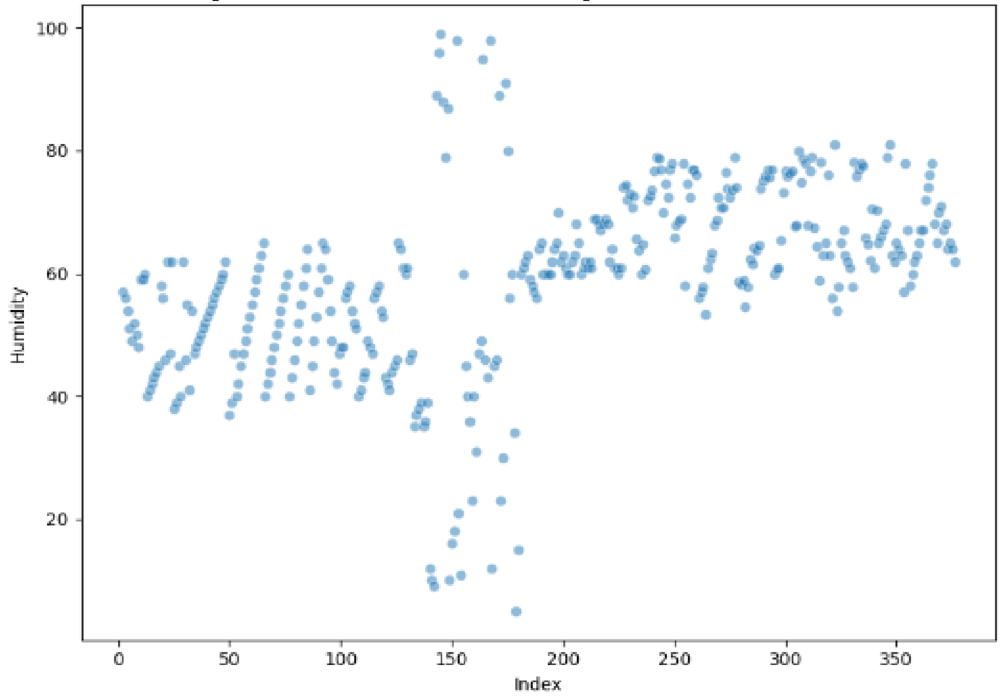


Fig 19: Frequency distribution of sleep quality prediction

We also generated scattered plots of our collected data with prediction.



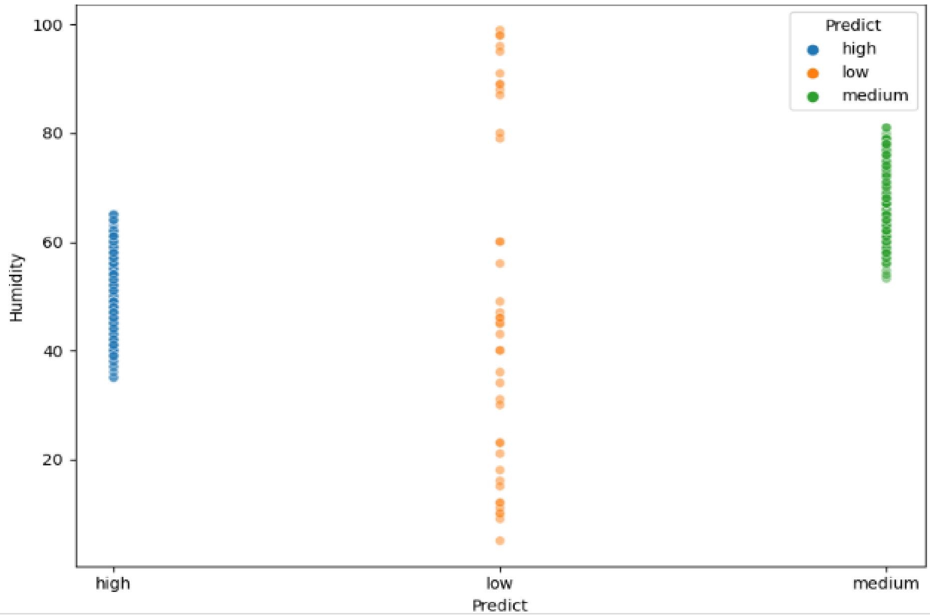
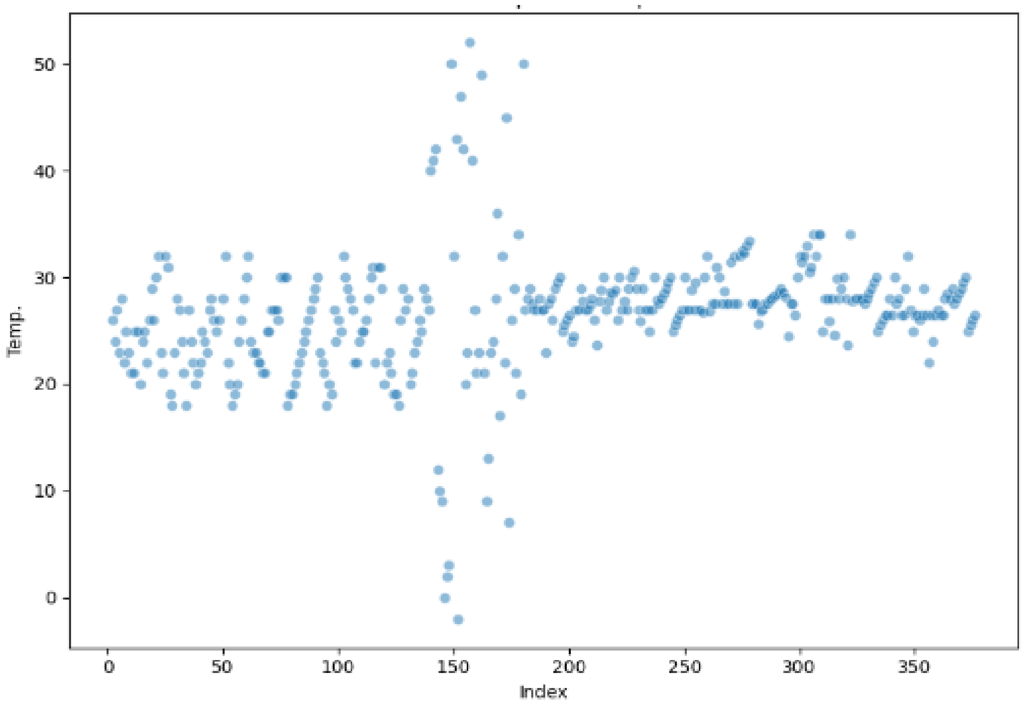


Fig 120: Scatter plot of humidity with prediction



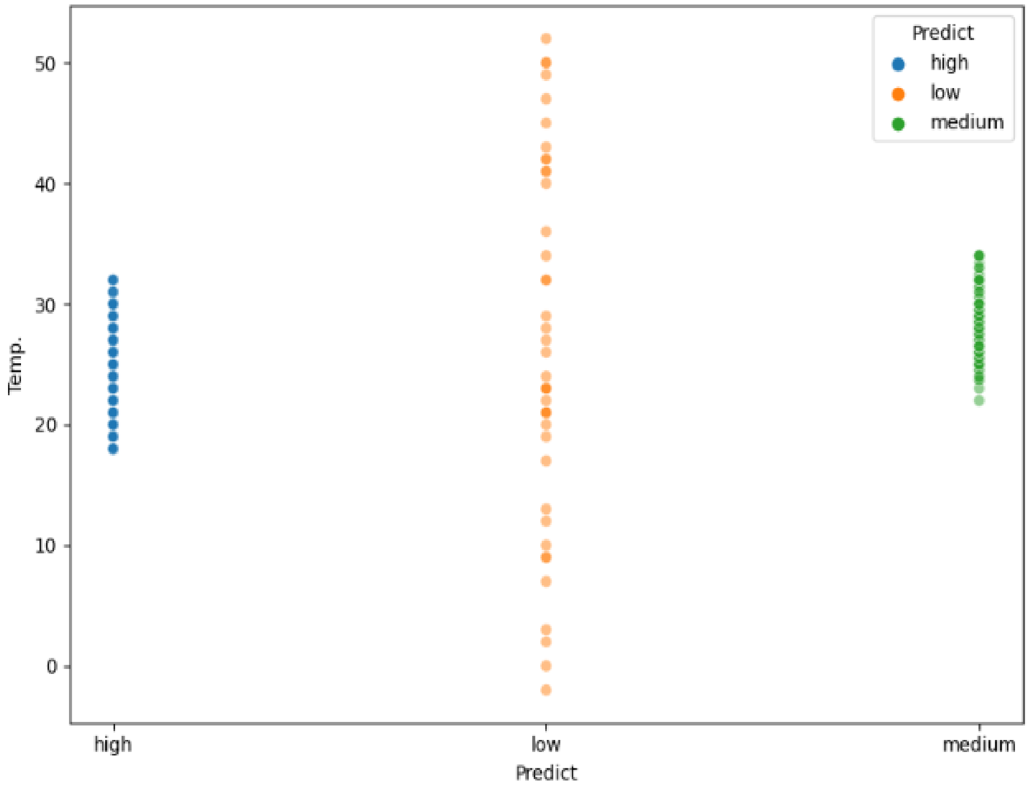
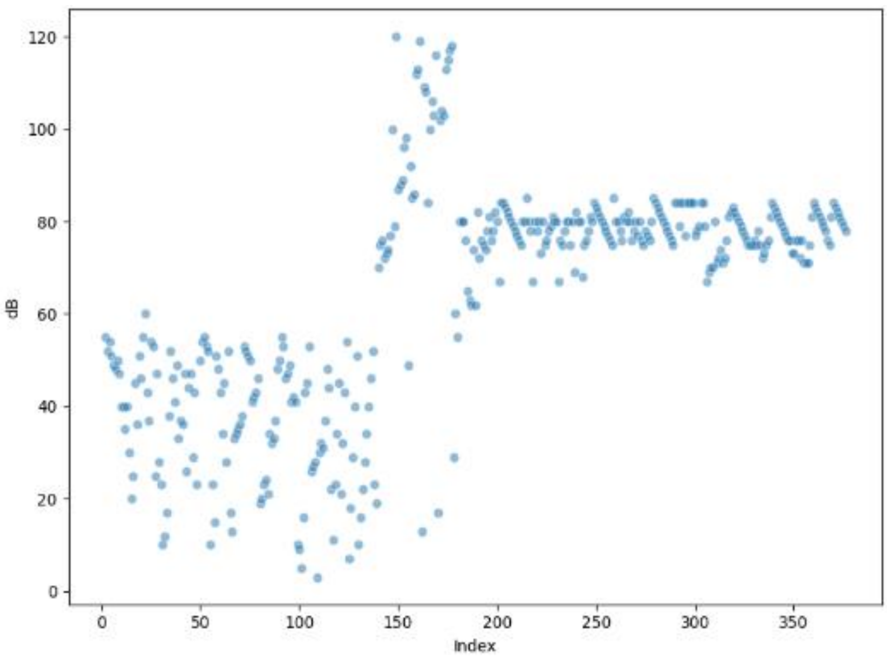


Fig 21: Scatter plot of temperature with prediction



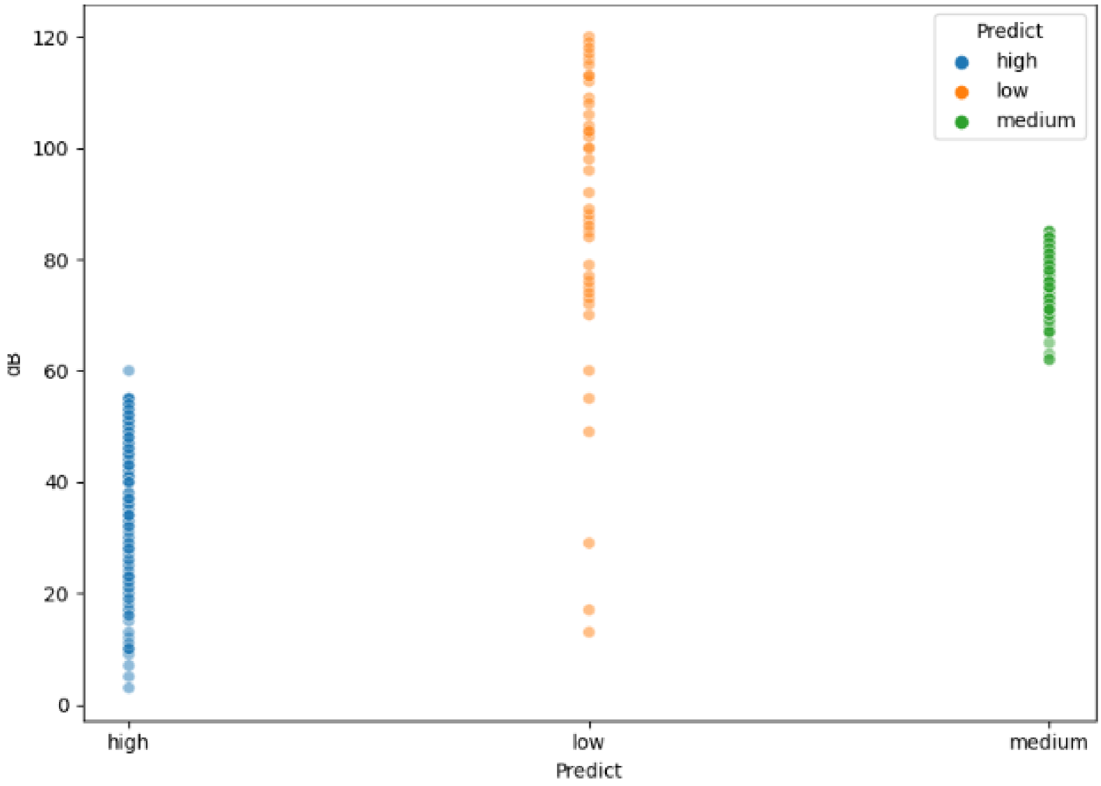
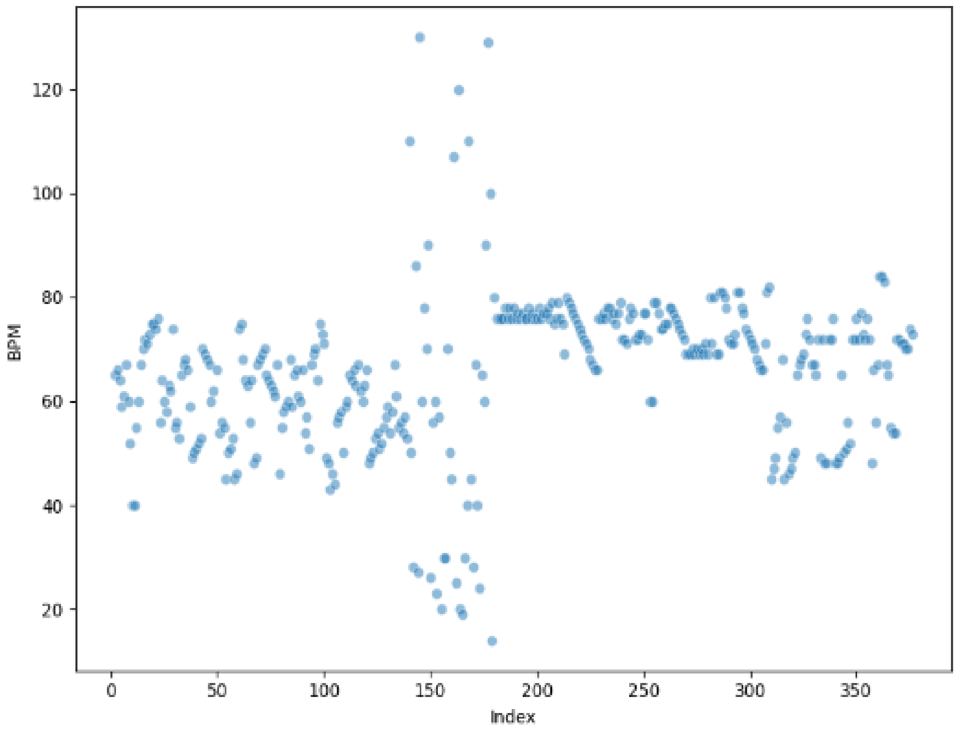


Fig 22: Scatter plot of sound level (dB) with prediction



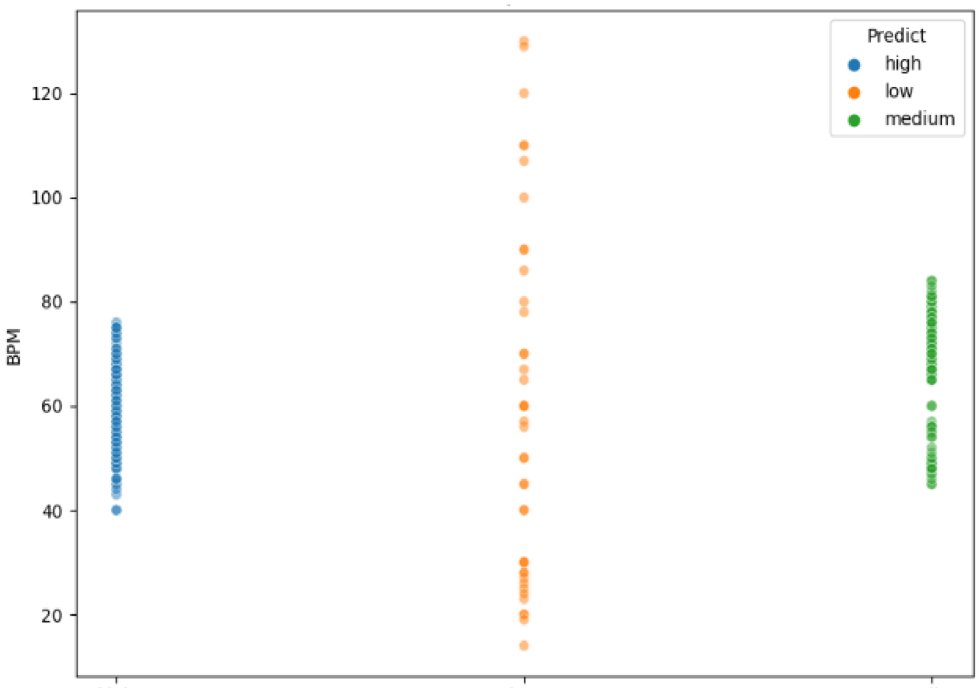
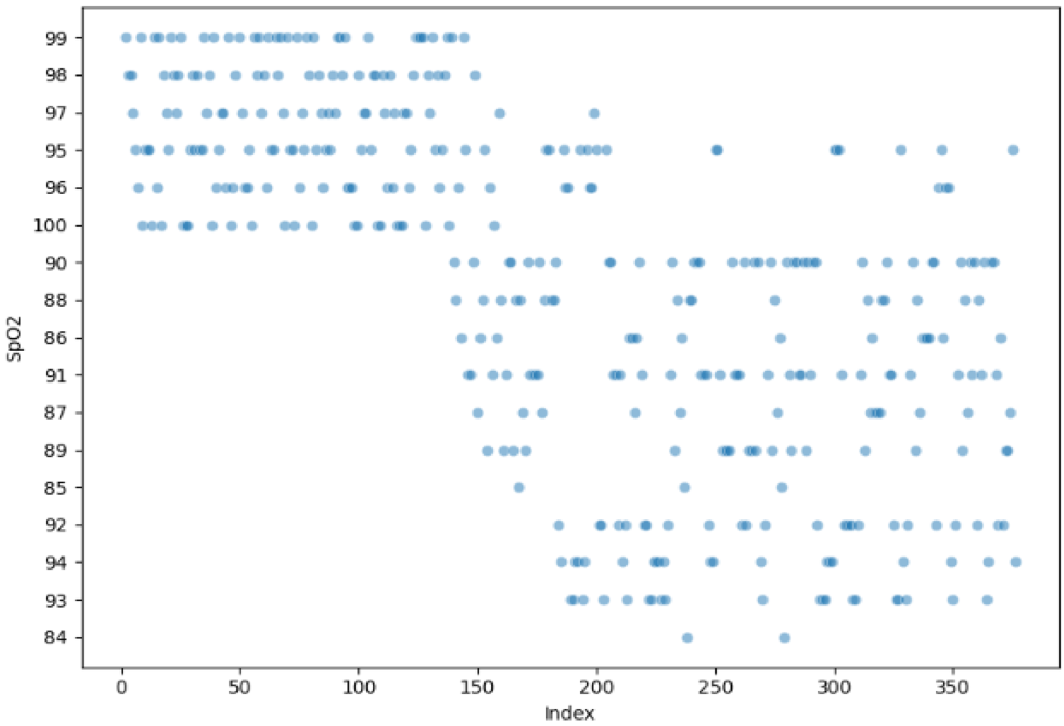


Fig 23: Scatter plot of heart rate (BPM) with prediction



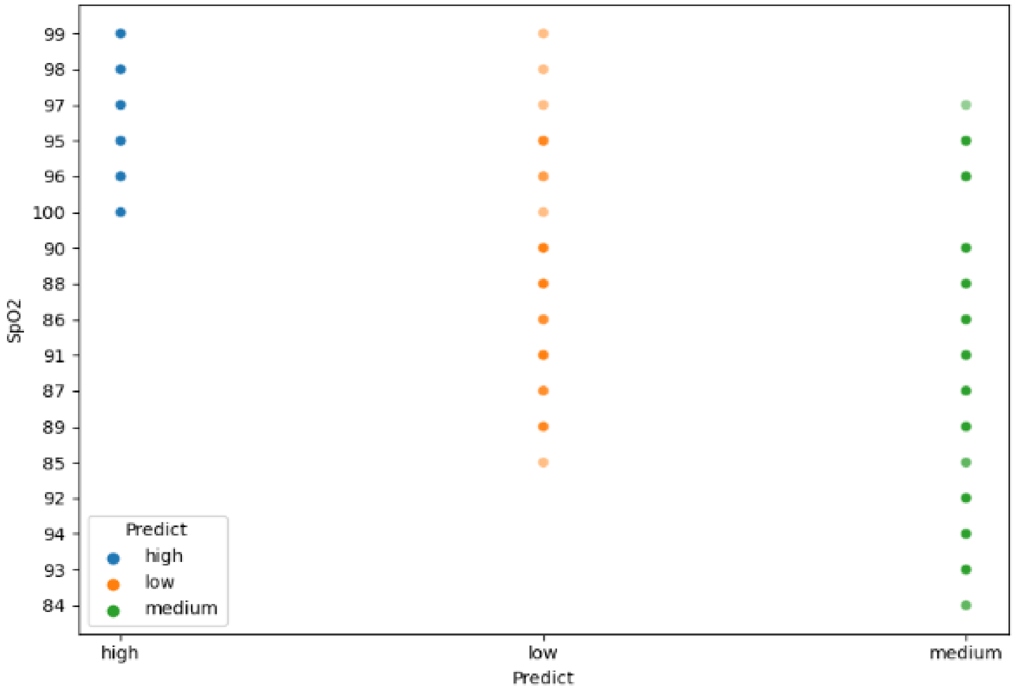
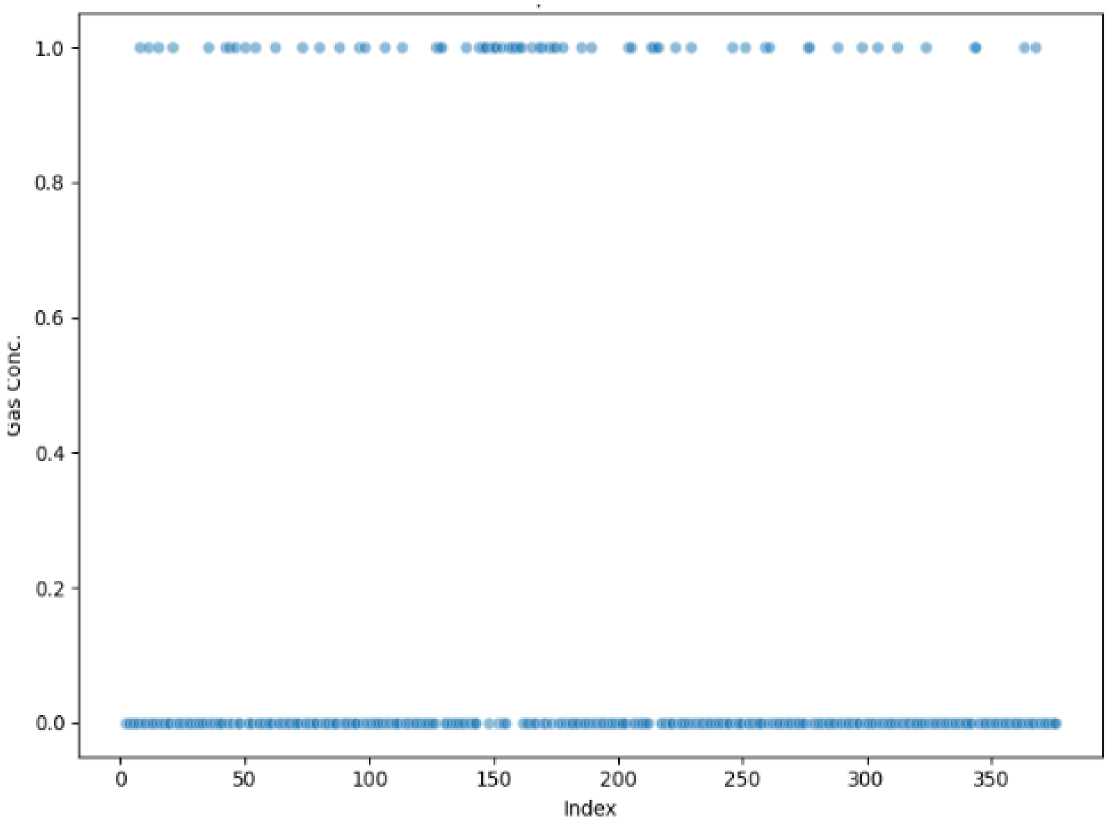


Fig 24: Scatter plot of SpO2 with prediction



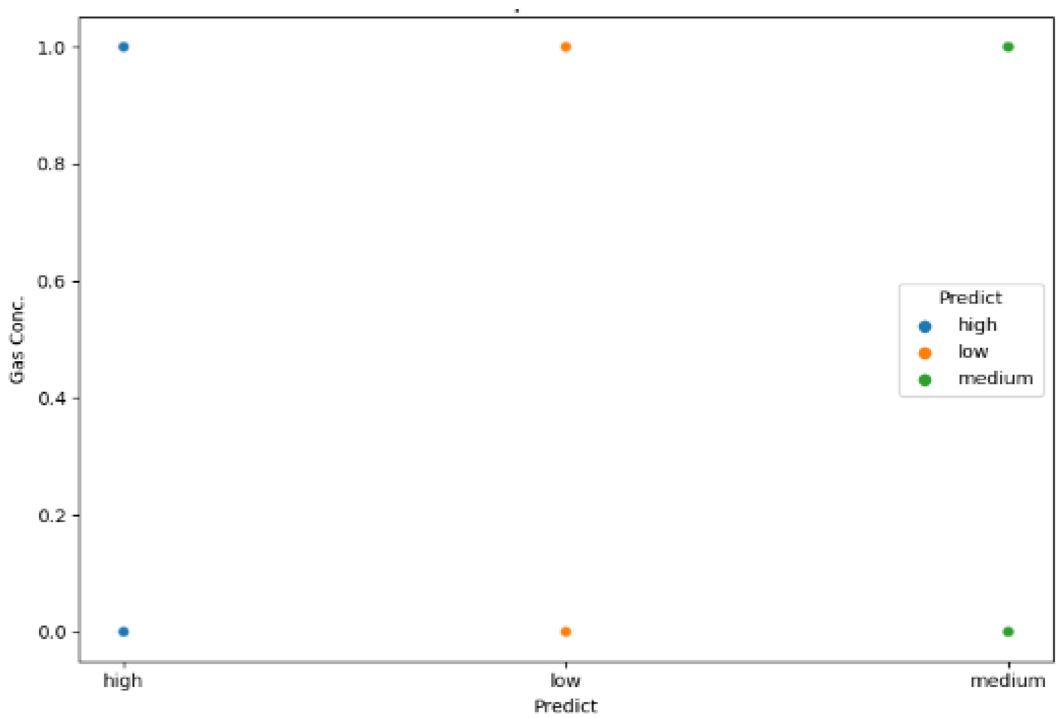


Fig 25: Scatter plot of Gas concentration with prediction

4.3 Results

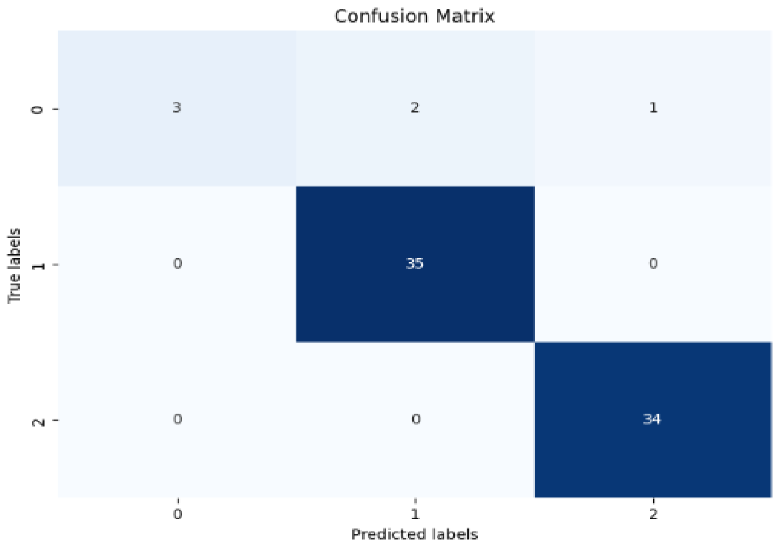
4.3.1 Machine Learning Outputs

We obtained 96% accuracy with our model.

```
# Evaluate the accuracy of the model
accuracy = accuracy_score(y_test, y_pred)
print("Accuracy:", accuracy)
```

```
Accuracy: 0.96
```

Upon examining the confusion matrix, we can conclude that our machine learning model is performing exceptionally well. The error rate is significantly low, indicating that the model is making very few mistakes. This level of accuracy and precision in our model's performance ensures that it meets the requirements for the task at hand. We can confidently say that our machine learning model is not only efficient but also reliable.



Here is a plot of features with correct prediction Label

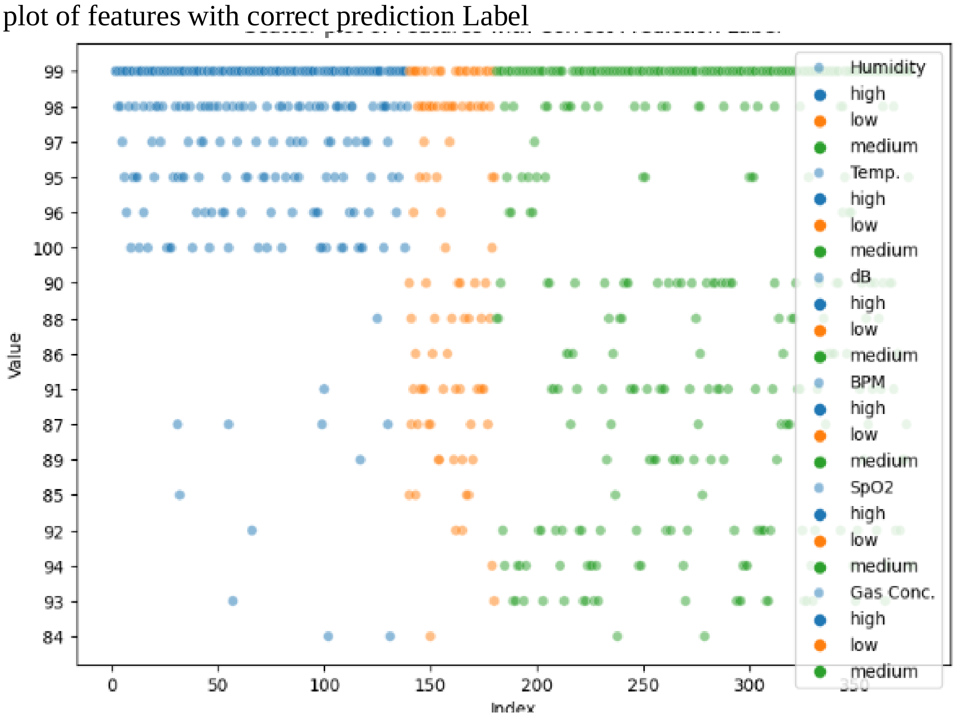


Fig 25: Scatter plot of features with correct prediction

4.3.2 IoT Results

Fig 26: IoT Result

5 Design Analysis and Evaluation

5.1 Novelty

The IoT Sleep Monitoring and Safety System distinguishes itself among sleep monitoring solutions by ingeniously combining various sensors and cutting-edge technologies, offering a comprehensive method to tackle issues related to sleep health and safety. Numerous essential characteristics enhance the uniqueness of this endeavor:

1. **Integration of Multiple Sensors:** By combining a variety of sensors such as heart rate and oximeter sensors, humidity and temperature sensors, gas leakage detection sensors, and sound sensors, this project sets itself apart from traditional sleep monitoring systems. By combining these sensors, a thorough evaluation of several aspects affecting both sleep quality and safety may be achieved.
2. **Efficient Data Integration:** The system demonstrates exceptional performance in real-time data fusion, combining data from many sensors to offer a detailed comprehension of the sleep setting. This instantaneous evaluation enables prompt and precise reactions to changes in essential indicators, surroundings, or possible risks to safety.
3. **Internet of Things (IoT) Connectivity:** Leveraging the power of IoT, the system provides smooth communication between sensors and the IoT platform. This connectivity enables users to remotely monitor and regulate, granting access to live data and notifications through an intuitive interface, encouraging proactive management of sleep-related factors.
4. **Highlighting Safety with Gas Leak Detection:** The use of gas leak detection sensors sets this system apart, taking it a step above conventional sleep monitoring. This safety-oriented feature deals with possible dangers in sleeping areas, making sure that individuals are quickly notified of gas leaks, thereby improving overall safety while resting.
5. **Incorporation of Machine Learning:** The powerful machine learning algorithm implementation as a quality tracker is a very unique concept. The dataset was collected and trained by efficient modelling technique to minimize errors.
6. **Encouraging Well-Informed Decision-Making:** Through the integration of many data sources into a unified interface, the system enables users to make knowledgeable choices regarding their sleep patterns. This supports a proactive approach to sleep health, enabling users to discover trends, enhance their sleep environment, and address possible difficulties swiftly.

In summary, the IoT Sleep Monitoring and Safety System innovatively integrates sensor technologies, connectivity, and a user-centric approach to create a comprehensive solution that transcends standard sleep monitoring, addressing both health and safety concerns. This full integration presents the initiative as a pioneering endeavor in the domain of tailored well-being solutions.

5.2 Design Considerations

5.2.1 Considerations to public health and safety

The development and deployment of the IoT Sleep Monitoring and Safety System are anchored by a firm commitment to public health and safety. As we usher in a new era of technological solutions geared at boosting individual well-being, it becomes necessary to examine the broader ramifications of these breakthroughs on the larger community. This section describes essential concerns integrated in the design and implementation of our project, ensuring that public health and safety remain paramount throughout its existence.

1. Privacy Protection: Given the sensitive nature of health data, strong procedures have been adopted to ensure user privacy. The system adheres to established data protection standards, guaranteeing that all personal and health-related information is encrypted and available only to authorized personnel. As “Thingspeak” is a secure IoT platform, it can be said that the privacy and security is quite strong. Anonymity and confidentiality are key components of our design, establishing a sense of trust among users.

2. Security Protocols: Robust security protocols are included into the IoT Sleep Monitoring and

Safety System to thwart any cyber attacks and illegal access. As the system relies on interconnected devices and cloud-based services, guaranteeing the integrity and security of data is vital.

3. Ethical Data Usage: The ethical collecting and exploitation of data are important ideas guiding our research. User consent is sought transparently, outlining the precise information gathered and its intended purpose. Furthermore, the system leverages anonymized and aggregated data for research purposes, keeping ethical norms in contributing to scientific knowledge without violating individual privacy.

4. Community Awareness and Education: Recognizing the importance of community awareness, the project includes measures to educate users and the wider public about the benefits and responsible use of the IoT Sleep Monitoring and Safety System. This not only allows individuals to make informed decisions about their well-being but also creates a larger knowledge of how technology may positively impact public health and safety.

By addressing these concerns, our research aims to contribute not just to individual health and safety but also to the greater society environment. Through a balanced and ethical approach, the IoT Sleep Monitoring and Safety System stands as a beacon for responsible innovation in the area of health technology.

5.2.2 Considerations to environment

The IoT Sleep Monitoring and Safety System is built with a deep understanding of its environmental impact, indicating a dedication to sustainability. The selection of materials and components for the hardware is governed by eco-friendly concepts, stressing recyclability and decreased environmental footprint. Moreover, energy efficiency is a primary issue, with the system tailored to minimize power usage without affecting functionality. The manufacturing methods correspond to ecologically friendly standards, and attempts are made to eliminate electronic waste through modular and upgradable components. Additionally, the project advocates a paperless approach, with documentation and user guides made available digitally to further reduce resource usage. By embracing these ecologically sensitive practices, the IoT Sleep Monitoring and Safety System strives to contribute to a healthy planet while addressing the vital issues of individual well-being and safety.

5.2.3 Considerations to cultural and societal needs

The IoT Sleep Monitoring and Safety System recognizes the varied cultural and social settings in which it operates, using a user-centric approach that respects individual choices and beliefs. Customization capabilities inside the system provide for cultural variances in sleep behaviors, allowing users to adjust their sleep environment to correspond with their specific cultural and social needs. Language options and culturally sensitive user interfaces contribute to inclusion, ensuring accessible for a wide range of users. Moreover, the initiative is committed to increasing community engagement by implementing feedback systems and culturally relevant instructional tools. Recognizing the importance of social connections in general well-being, the system invites users to share their sleep data selectively with trustworthy persons, establishing a supporting network around health and safety. By addressing cultural and social needs, the IoT Sleep Monitoring and Safety System strives to expand its relevance and influence among varied groups, encouraging inclusiveness and cultural sensitivity.

5.3 Limitations of Tools

While the IoT Sleep Monitoring and Safety System represents a huge advance towards comprehensive sleep health and safety solutions, it is crucial to realize its inherent defects and limits. One noteworthy constraint resides in the accuracy of sensors, notably the heart rate and oximeter sensors, which may be altered by factors such as skin tone, ambient lighting, and sensor calibration. Users are cautioned to interpret the data with caution and consider potential differences. Additionally, the system's performance is dependent on a reliable internet connection for real-time data transfer, rendering it vulnerable to connectivity failures in particular circumstances. The dependency on electrical power sources for sensors and the central unit may offer issues during power outages, underlining the need for contingency measures. The gas leakage detection sensors, while proficient, have limitations in detecting specific gases, and users should be aware to other potential threats. Furthermore, the system's assessment of environmental conditions may not account for individual preferences, as what is regarded optimal can change dependent on cultural and personal characteristics. Acknowledging these faults and limitations is vital for users and stakeholders to deploy the IoT Sleep Monitoring and Safety System cautiously, understanding its capabilities and potential constraints in varied settings. Continuous refining and updates will be pursued to overcome these difficulties and enhance the system's overall reliability.

5.4 Impact Assessment

5.4.1 Assessment on Social and Cultural Issues

The IoT Sleep Monitoring and Safety System undergoes a rigorous study considering its impact on social and cultural dynamics, acknowledging the complicated interplay between technology and human behavior. Socially, the project is positioned to build interpersonal ties through its sharing features, enabling users to engage their trusted network in debates surrounding sleep health. Emphasis is put on user liberty and control over data sharing, respecting varied cultural values about privacy. The system's user interface and customization choices accommodate to varied cultural expectations and preferences, enabling inclusion. However, cultural nuances and various sleep routines provide ongoing issues, needing a continual discussion with users to refine the system's adaptability. While the project navigates these complexities, its commitment to understanding and addressing social and cultural considerations is paramount, ensuring that the IoT Sleep Monitoring and Safety System not only integrates seamlessly into diverse lifestyles but also contributes positively to the collective discourse on well-being.

5.4.2 Assessment of Health and Safety Issues

A complete study of the IoT Sleep Monitoring and Safety System emphasizes its vital role in resolving health and safety concerns. The integration of heart rate and oximeter sensors provides vital information into physiological well-being during sleep, enabling users to monitor their health proactively. The system's real-time alarms for potential threats such as gas leaks assist greatly to creating a safe sleep environment. Emergency response integration gives an additional layer of security, permitting fast involvement in urgent situations. However, it is vital to acknowledge the inherent limitations in sensor accuracy and the potential for false alarms, needing user education to interpret data prudently. Ongoing upgrades and user feedback channels are vital to refining the system's responsiveness and reliability. Overall, the IoT Sleep Monitoring and Safety System appears as a viable option in improving both health and safety during sleep, with a dedication to ongoing improvement and user empowerment.

5.5 Sustainability and Environmental Impact Evaluation

The IoT Sleep Monitoring and Safety System exhibits a commitment to sustainability through thoughtful design decisions and operating practices. The concept promotes eco-friendly materials and energy-efficient components in its hardware, intending to reduce environmental impact. The emphasis on recyclability and modular design contributes to a reduction in electronic waste, matching with principles of responsible manufacturing. Energy efficiency methods not only address environmental concerns but also enhance long-term cost-effectiveness for users. By adopting a paperless approach and making paperwork available digitally, the project significantly decreases its carbon footprint. As the system evolves, a devotion to continual research and development ensures that sustainability remains at the forefront, integrating technological innovation with environmental responsibility. Through these endeavors, the IoT Sleep Monitoring and Safety System intends to set a standard for sustainable behaviors within the area of health technology.

5.6 Ethical Issues

The IoT Sleep Monitoring and Safety System highlights various ethical problems that deserve serious study. Firstly, the gathering and handling of sensitive health data, including heart rate and physiological information, necessitate comprehensive privacy controls to ensure user confidentially. Transparent consent mechanisms and secure data storage are crucial to protect individual privacy rights. Additionally, ensuring that the system runs in a manner consistent with cultural norms and respects varied values is vital. Striking a balance between offering important insights and avoiding undue intrusiveness into users' personal life is a complex ethical dilemma. Regular user education on data interpretation and the system's capabilities is crucial to empower individuals in making educated decisions about their health. Overall, the ethical implications of the IoT Sleep Monitoring and Safety System underline the significance of constant examination, openness, and user-centric design to ensure that technology innovation corresponds with ethical principles and social values.

6 Reflection on Individual and Team work

6.1 Individual Contribution of Each Member

ID	Name	Contribution
1906075	Md. Mehedi Hasan	Building Machine Learning Training Model, developing heart sensor circuitry
1906078	Asif Aftab Ronggon	Implementing machine learning code and ESP32 code
1906079	Md. Faiyaz Abid	Hardware implementation of safety circuit, testing and debugging
1906088	Md. Shahin Ferdous	Building Machine Learning Training Model, Hardware implementation and debugging

6.2 Mode of Team Work

The project idea was given by Asif Aftab Ronggon. The software part of this project was mostly done by him. Faiyaz Abid and Shahin Ferdous did the hardware connection and debugging part together. The machine learning training model was developed by Mehedi Hasan, accompanied by Shahin Ferdous. Finally, Asif trained the model and developed the machine learning algorithm to show the result.

7 Communication

7.1 Executive Summary

The IoT Sleep Monitoring and Safety System represents a pioneering endeavor in the realm of health technology, aiming to revolutionize sleep monitoring and safety. This comprehensive project integrates advanced sensors, including heart rate and oximeter sensors, humidity and temperature sensors, gas leakage detection sensors, and sound sensors, within an Internet of Things (IoT) framework. The system provides real-time insights into physiological well-being, environmental conditions, and potential safety hazards during sleep. The report details the conceptualization, design, and implementation of the project, emphasizing its potential impact on individual health and safety. Noteworthy considerations include privacy protection, security protocols, and ethical data usage, ensuring responsible innovation. The assessment of social, cultural, health, and safety issues underscores the project's commitment to user-centric design and continuous improvement. Additionally, the report highlights the system's sustainability initiatives, emphasizing eco-friendly practices. Despite acknowledged limitations, the IoT Sleep Monitoring and Safety System stands as a promising solution with ongoing potential for refinement. As technology intersects with well-being, this project sets a standard for ethically driven innovation, contributing to a healthier and safer future for individuals and communities alike.

8 Project Management and Cost Analysis

8.1 Bill of Materials

Product name	**Price (Tk)**
BMP280 Pressure Sensor	290
DHT11 Temperature and Humidity Sensor	170
ESP32 Devkit V1 NodeMCU	575
MAX30102 Heart Rate and Pulse Oximeter Sensor	390
MQ2 Smoke Sensor	125
MQ9 Gas Leakage dectection sensor	194
Sound Sensor	69
Breadboard	130
Jumper Wire (1 Set)	80
Total	**2023**

9 Future Work

The future of sleep monitoring systems is looking bright with numerous advancements and innovations aimed at providing more accurate, comprehensive, and user-friendly solutions for tracking and improving sleep quality. Future systems may incorporate sensors beyond just accelerometers, such as heart rate monitors, temperature sensors, and even EEG (electroencephalogram) sensors. The integration of data from multiple sensors can provide a more holistic view of sleep patterns and overall health. There will likely be significant advancements in wearable sleep monitoring devices to make them more comfortable, unobtrusive, and convenient for users to wear throughout the night. This could involve miniaturization of sensors, flexible materials, and seamless integration into clothing or bedding. Sleep monitoring systems can track long-term trends in sleep patterns and offer insights into how lifestyle factors, such as diet, exercise, and stress, impact sleep quality over time. This data can empower individuals to make informed decisions to optimize their sleep health and improve their overall well-being. Sleep monitoring systems will continue to be valuable tools for sleep research and clinical applications. Researchers can use data collected from these systems to study sleep disorders, circadian rhythms, and the effects of sleep on overall health and well-being. With the increasing amount of personal health data collected by sleep monitoring systems, there will be a growing emphasis on ensuring user privacy and data security. Future systems will need robust encryption and privacy controls to protect sensitive health information, such as sleep patterns, heart rate, and other vital signs. In conclusion, the future of sleep monitoring systems looks promising with a wide range of advancements and innovations aimed at providing more accurate, comprehensive, and user-friendly solutions for tracking and improving sleep quality. With the continuous advancements in wearable technologies and data analytics, we can expect a future where people have more control over their sleep health, and researchers have a better understanding of the factors that impact sleep quality.

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