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Pillow Based Sleep Tracking Device Using Raspberry Pi

Venkatachalam Seviappan

PILLOW-BASED SLEEP TRACKING DEVICE USING RASPBERRY PI

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Computer Science

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Dr. Jennifer Jin, Advisor,Computer Science and Engineering

Dr. Fadi Muheidat, Committee Member

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ABSTRACT

Almost half of all people have sleep interruptions at some point in their lives, making sleep disorders a common issue that affects a sizeable section of the population. Both their physical and emotional well-being may suffer as a result of this.Insomnia, which is a prevalent sleep disorder, is identified by symptoms including insufficient sleep duration and quality, trouble initiating sleep, multiple nighttime awakenings, early morning awakenings, and non-restorative sleep. It is essential to employ sleep monitoring systems to detect sleeping disorders as soon as possible for prompt diagnosis and treatment. To avoid sleep related health issues, there are plenty of Wearables based tracking devices in the market today. Yet, the need to set it up, wear it every day and night to be able to track required data, is a cumbersome process that requires human intervention.So, I have come up with the idea of developing a pillow-based sleep tracking device to suggest an alternate to Wearables, given that pillows are stationary devices that would involuntarily be used by everyone during their nap times. The process includes steps of measuring the sensory data obtained by a pressure sensor which is connected to a pressure amplifier bag placed under the pillow, targets detecting sleep duration and REM cycles. Sound levels of snoring detection is achieved through sound sensor (sleep-disordered respiration), temperature and humidity levels throughout the sleep time is measured by sensory reaction of a DHT-11 temperature and humidity sensor, set up with pillows and positional sleep area.

ACKNOWLEDGEMENTS

My project, “Pillow based Sleep tracking device using Raspberry Pi” has been the result of motivation and encouragement from many, whom I would like to thank.I take this opportunity to express my sincere thanks to **Dr.Sastry Pantula**, Dean for College of Natural Sciences, California State University San Bernardino for providing us the necessary facilities and support for successful completion of this academic year and project. I would like to sincerely thank our Director of the Department, **Dr.Khalil Dajani,** Department of Computer Science**,**California State University San Bernardino for his guidance and encouragement throughout .

I express my sincere thanks and gratitude to my Project advisor **Dr.Jennifer Jin**, for her sustained support and guidance in this experimental field of IOT, which helped me in the timely completion of the project.

I sincerely thank **Dr. Fadi Muheidat**, Associate Professor,Department of Computer Science,California State University San Bernardino and **Dr. Yan Zhang**, Assistant Professor,Department of Computer Science,California State University San Bernardino for being my committee members. I present my gratefulness to their advice and support in various dimensions of the project work.

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CHAPTER ONE

INTRODUCTION

Objective

Rapid advancements in Wireless Sensor networks and Internet of things (IOT), seemingly has become the X-factor in creating convenience around day to day activities in human life. Internet of Things is defined as a network of devices and sensors interlinked to sense, measure and calculate all data and activities recorded through the system in an efficient manner. As we know, IOT has several domain applications based on the field's requirement. Health and Wellness being a field gaining increasing prominence as of today, it has created an impeccable demand for E-health systems, Wearables, and non-Wearables in the consumer market. The importance of wellness driven Internet of Things (IoT) is witnessed when medical services need to be rendered to remote areas. It is an intelligent technology that utilizes the Internet in integration with existing medical equipment, being able to monitor patients at home remotely and in real time for chronic diseases [1]. Sleep monitoring is an important factor in human health .The problem of sleep disorders is significant in terms of health. About half of the population may experience sleep problems at some point in their life, and they have the potential to have a negative impact on both physical and mental health. Insomnia is a sleep disorder marked by grievances regarding the length and caliber of sleep, trouble in initiating sleep, early or nocturnal awakenings, and non-restorative sleep. To facilitate early identification, diagnosis, and prompt treatment of sleep disorders, the use of sleep monitoring systems is crucial. These systems furnish healthcare providers with precise quantitative data on abnormalities in sleep duration and patterns [2] [3].

To avoid sleep related health issues, there are plenty of Wearables based tracking devices in the market today. Yet, the need to set it up, wear it everyday and every night in order to be able to track required data, is a cumbersome process that requires human intervention. So I have come up with the idea of developing a pillow based sleep tracking device to suggest alternative to Wearables, given that pillows are stationary devices that would involuntarily be used by everyone during their nap times.

Challenges

In this embedded development process using IOT, there are several challenges that need to be considered when developing this pillow-based sleep tracking device using Raspberry Pi , pressure sensor, sound sensor,and temperature & humidity sensor. Power management is a significant challenge when developing any IoT device, including sleep trackers. To ensure that the device has enough power to last through the night, the device must be designed to consume as little power as possible. This requires careful selection of components and optimization of software. Sensor Integration is critical to the success of a sleep tracking device. The pressure sensors must be accurately calibrated and integrated with the Raspberry Pi. Additionally, the data received from the sensors must be processed in real-time, requiring the use of appropriate algorithms.The device must be able to communicate with other devices, such as smartphones, laptops, or other IoT devices, to enable data transfer and analysis. This requires integrating the appropriate communication protocols into the device and ensuring that they are reliable in providing connectivity. Collecting and analyzing sleep data requires advanced algorithms and software.

This involves filtering out noise from sensor data, identifying sleep stages, and providing relevant sleep metrics to users. Finally,designing a user-friendly interface and incorporating features such as alarms, reminders, and personalized recommendations can enhance the overall user experience of the sleep tracker.

Scope of the Project

The scope of this module is quite broad, as it has potential applications in various fields such as healthcare, sports, and wellness.This can help individuals monitor their sleep patterns, identify any disruptions, and make necessary lifestyle changes to improve the quality of their sleep. This can have a significant impact on their overall health and well-being.

It can provide users with personalized recommendations, such as sleep hygiene practices, relaxation techniques, and sleep aids, based on their sleep patterns and preferences.

Athletes and sports enthusiasts can use the device to monitor their sleep quality and adjust their training and recovery schedules accordingly. This can also help prevent injuries and improve performance.

Project Analysis

An analysis over the project and its domain was done with the help of Google trends analysis to understand the scope of the project and ongoing interests and researches in this domain.

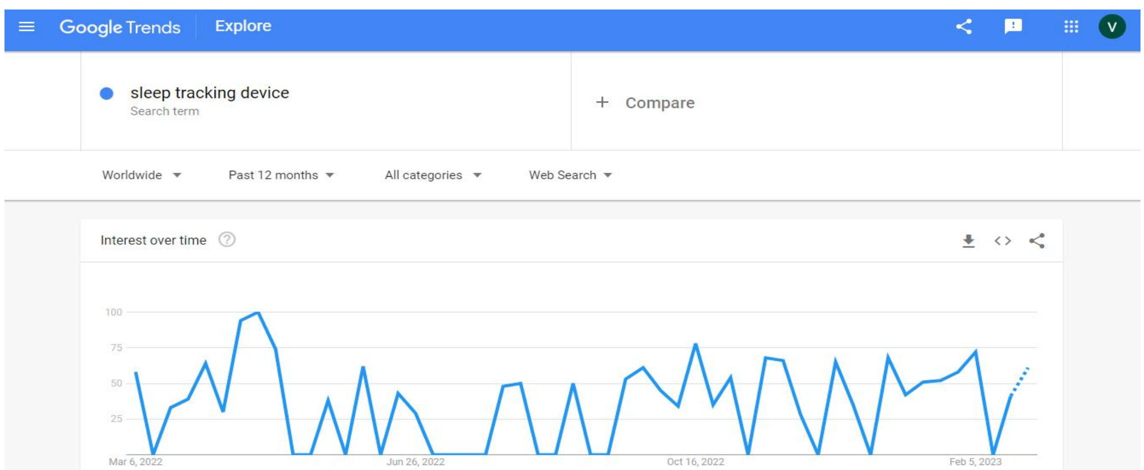

Figure 1: Interest Over Time Worldwide Since 2022

The figure 1 represents the interest over sleep tracking devices among consumers worldwide over the last one year which has rating google trends rating score of 70 on a scale of 100.

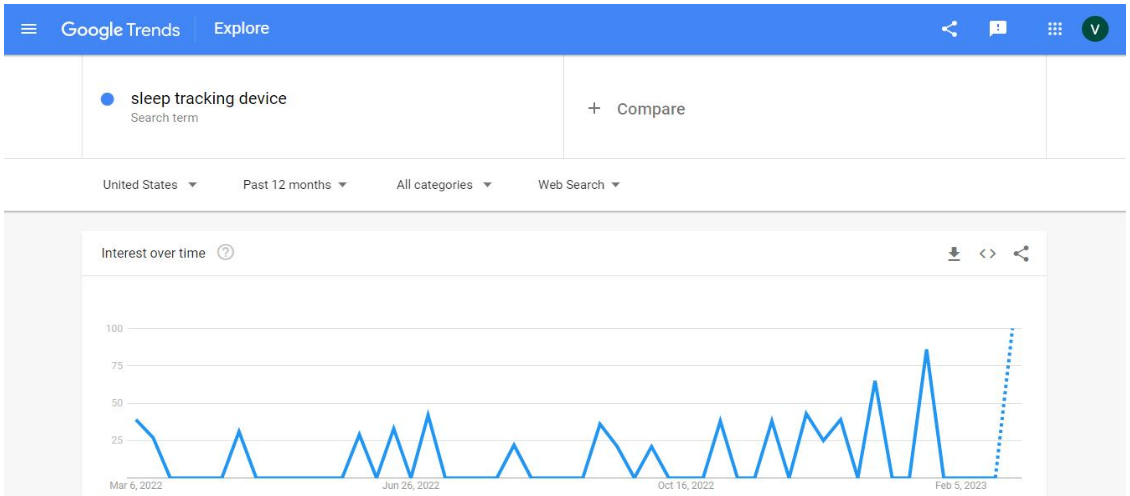

Figure 2: Interest Over Time In United States For Past 12 Months

The figure 2 deciphers the interest over sleep tracking devices among consumers within the United States of America over the last year, which has rating google trends rating score of 100 on a scale of 100.

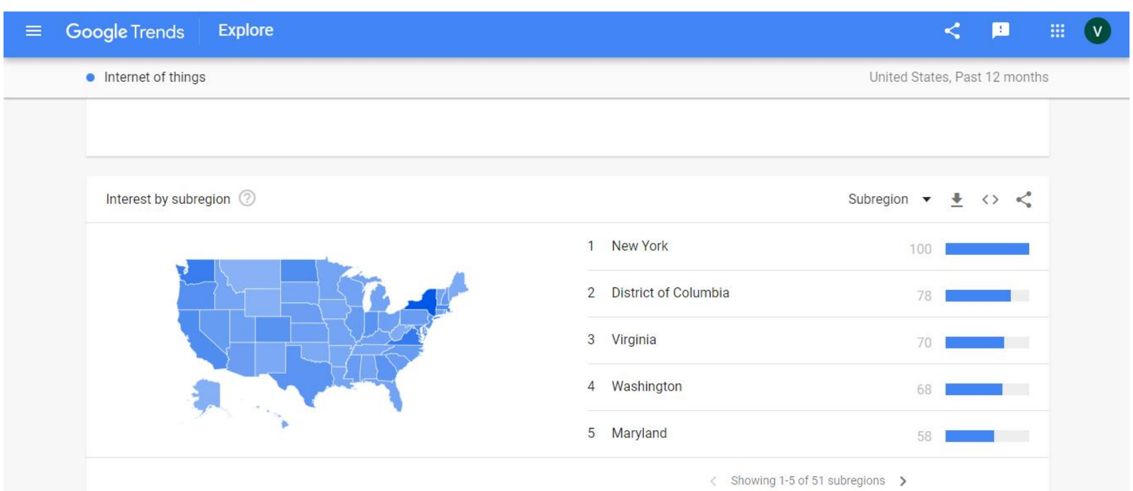

Figure 3: Region Based Interests Across the United States

The figure 3 represents the regional interests in sleep tracking devices based on IOT across different states in the United States of America.Amongst east coast cities, New York city tops the list with an interest score of 100, followed by Washington DC,Virginia,and Maryland with a score of 78,70,and 68 respectively.

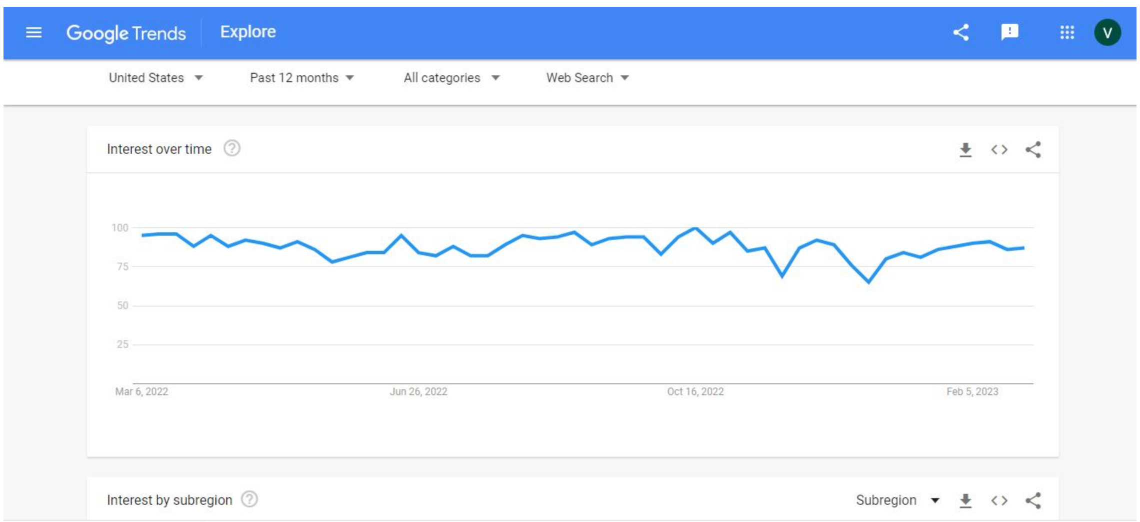

Figure 4: Interest Over Time in Sub Regions Within the United States.

From the above figure 4, one can decipher the level of interest in this research domain. India and the USA show higher interest and inclination to learn more about this field. When interest is calculated over a fixated time period, one can decipher that interest in sleep tracking seems to be high in the United States. Upon analyzing interests across the major cities in the East Coast New York seems to be a hub for IOT driven startups.

Survey Report and Summary

Overall, a pillow-based sleep tracking IoT device can be a useful tool for monitoring sleep patterns. Yet it is important to consider its limitations, potential inaccuracies, and privacy concerns before using it. User engagement, Comfort, Accuracy and Limited information are key factors to be aware and careful of. Users should also consider other factors, apart from sleep, that can affect their overall health.In conclusion, this task requires careful consideration of various challenges. The device must be designed to consume minimal power, integrate accurately calibrated sensors, enable reliable communication, analyze data efficiently, provide a user-friendly interface, handle large data volumes, ensure data security and privacy, and be compatible with various platforms.

CHAPTER TWO

LITERATURE REVIEW

Introduction

Having read and analyzed a range of sources in order to gain a comprehensive understanding of the topic by referring to other journals, I was able to build upon the work of others and create a more robust understanding and detailed analysis.The paper written by Sangeetha et al.[7],revolves around proposing a cost-effective, and reliable method for detecting sleep apnea.The smart mattress is equipped with pressure sensors that detect the pressure changes caused by the patient's breathing patterns. The pressure signals in this system are collected and processed using IoT technology to identify the presence of sleep apnea.Additionally, the device they developed includes a mobile app that enables users to monitor their sleeping patterns and receive alerts in the event of any instances of aberrant breathing.

Their paper presents the results of a pilot study conducted on a small sample size of 10 subjects with suspected sleep apnea. The results show that the smart mattress was able to accurately detect sleep apnea in all 10 subjects, with a sensitivity of 100% and a specificity of 97.5%. The study also explains the feasibility and usability of the system, with all subjects reporting ease of use and comfort while sleeping on the smart mattress.

This next paper written by Oliveira, V et al.[5] proposes the design and development of a smart pillow that can monitor sleep quality remotely. Their goal of this study is to provide an unobtrusive and comfortable way to monitor sleep, without the need for any external sensors or devices.The smart pillow they had intended to develop by their method, has a number of sensors including an accelerometer, a temperature sensor, and a humidity sensor, to monitor the user's sleeping habits.The data collected by these sensors are transmitted wirelessly to a smartphone or a computer, analyzed to provide insights into the user's sleep quality. The authors discuss the selection of the sensors, the choice of the micro controller, and the software used to collect the data along with the challenges they faced during the development process, such as the need to balance accuracy and comfort, and the need to minimize power consumption to extend the battery life of the pillow.

In addition to the above two papers being referred for my comprehensive understanding pertaining to the field of healthcare monitoring systems, I had reviewed an other paper published by Hoque, E., et al. [4] proposes a system for monitoring body positions and movements during sleep using wireless sensor platforms (WISPs). This focuses on different sleep positions and movements .Their system uses a network of WISPs that are placed under the mattress to capture data related to sleep positions and movements. Each WISP is equipped with an accelerometer that measures acceleration in three dimensions and a temperature sensor that measures the temperature of the mattress. The WISPs communicate wirelessly with a base station, which collects the data and sends it to a computer for processing.The data collected by the system includes the acceleration in three dimensions and the temperature of the mattress at different time intervals. The system uses this data to detect changes in sleep positions and movements, such as rolling over, shifting position, or getting out of bed. The system can also detect changes in the temperature of the mattress, which can be used to determine the timing and duration of sleep. [4]

Theory Guided Conceptual Advantages

Having read the above explained conceptual journals pertaining to the topic I chose to work, understanding each of their individual advantages was the crucial part of this writing.The paper published by Sangeetha et al.[7], provides an advantage that the smart mattress approach is non-invasive and does not require any sensors to be attached to the body of the person.This is advantageous over other traditional sleep apnea detection methods that involve invasive procedures.Their mattress developed in this research can provide real-time monitoring of sleep apnea, allowing for timely interventions and treatment. This is particularly useful for people with severe sleep apnea who require continuous monitoring.The approach is comparatively cost-effective to traditional sleep apnea detection methods, which can be expensive and require specialized medical equipment.

Following this, the next paper written by Oliveira, V et al.[5] shows to be advantageous, where the authors conducted a series of experiments with human subjects. They compared the results obtained from the smart pillow to those obtained from a commercial sleep monitoring device. The results showed that the smart pillow was able to provide reliable data on the user's sleep quality, and was more comfortable and less obtrusive than the commercial device being an important advantage for the proposed system.Along with this,The next paper published by Hoque, E., et al. [4] proves to be advantageous where their evaluation experiments involve comparing the data collected by the WISPs to the data collected by video cameras, which are considered the gold standard for sleep monitoring.The results show a high correlation between the two sets of data, indicating the system's effectiveness in detecting sleep positions and movements.One strength of the paper is its innovative use of WISPs to monitor sleep positions and movements by including a comprehensive evaluation of the system, providing evidence to support its effectiveness in detecting sleep positions and movements.

Limitations and Summary

Though the above papers discussed has numerous advantages, there are few points to considered as limitation after a detailed understanding of their respective work.The paper published by Sangeetha et al.[7] ,The smart mattress approach has not been extensively validated in large-scale clinical studies, making it difficult to determine its accuracy and effectiveness in detecting sleep apnea.Ideas on evading technical limitations, such as connectivity issues or sensor malfunction in this smart mattress which can occur at times and can affect the accuracy of sleep apnea detection is not discussed here..The next paper written by Oliveira, V et al.[5] where the smart pillow relies on battery power to function, which means that it needs to be charged periodically. The battery life of the pillow may also be limited, depending on how frequently it is used and how many sensors are active. This may limit the convenience of using the pillow and require frequent charging, which could be inconvenient for some users. The experiments conducted by the authors to validate the accuracy and reliability of the smart pillow were conducted on a limited sample size. This means that the results may not be generalized to a larger population.The final discussed paper written by Hoque, E., et al. [4] have limited their working area to twin mattresses. Being able to generally implement on other types of mattresses will increase its standard and efficiency. and reliability. Though with such body movement data, sleep cycle is yet to be inferred in these systems.

CHAPTER THREE

SYSTEM REQUIREMENTS

Hardware Requirements

Single Board Computer	:	Raspberry Pi 4B
Hardware modules	:	Arduino Pro Mini, USB to TTL Module, Pressure Amplifier Bag
Sensors	:	Barometric Pressure sensor, DHT-11 Temperature and Humidity Sensor, Sound sensor.
Applications	:	VNC Viewer,Android App
Memory (RAM)	:	8 GB
Storage	:	64 GB
Key Board	:	Standard Windows Keyboard
Monitor	:	SVGA

Software Requirements

Operating System	:	Windows XP, Windows 7, Windows 8.1 and more
Programming Language	:	Python
Tools	:	HTML, CSS, Numpy, Pandas
Software	:	ANDROID VERSION 10.0 or more (For Android App)

CHAPTER FOUR

SYSTEM DESIGN

System Diagram

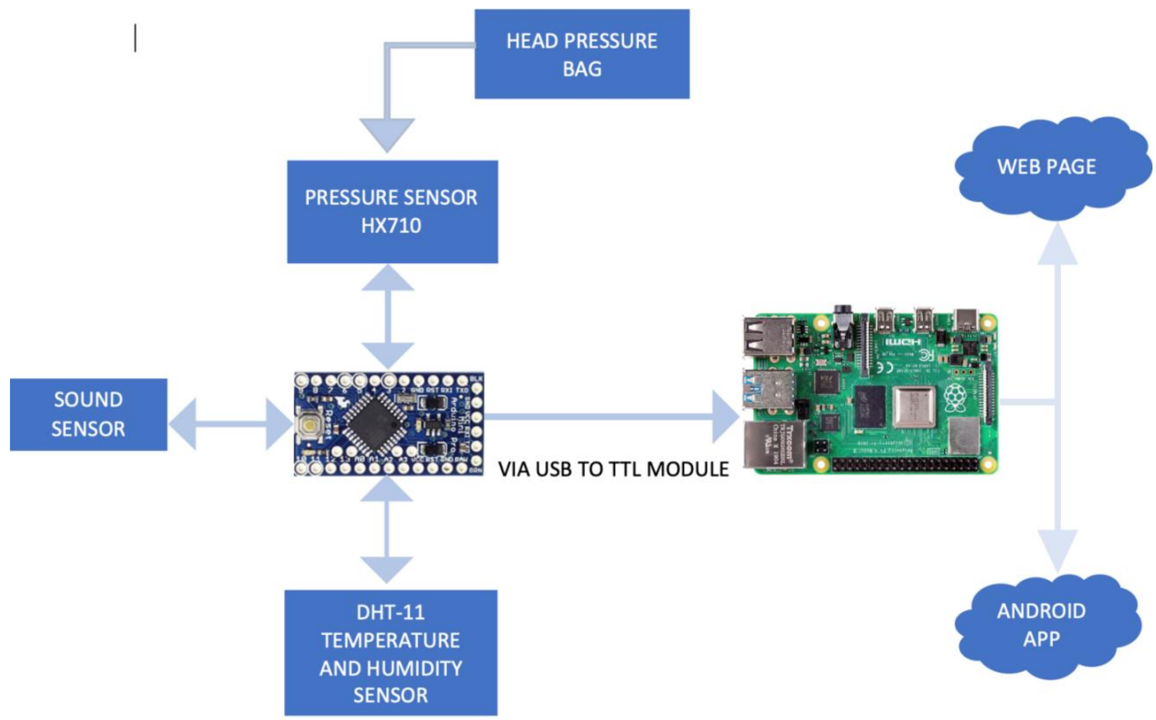

Figure 5: System Diagram

The structural views of a functional system are described in this figure 5 system architecture, which is the conceptual model. We can make inferences about the system's architecture and behaviour thanks to this approach.

Flow Diagram

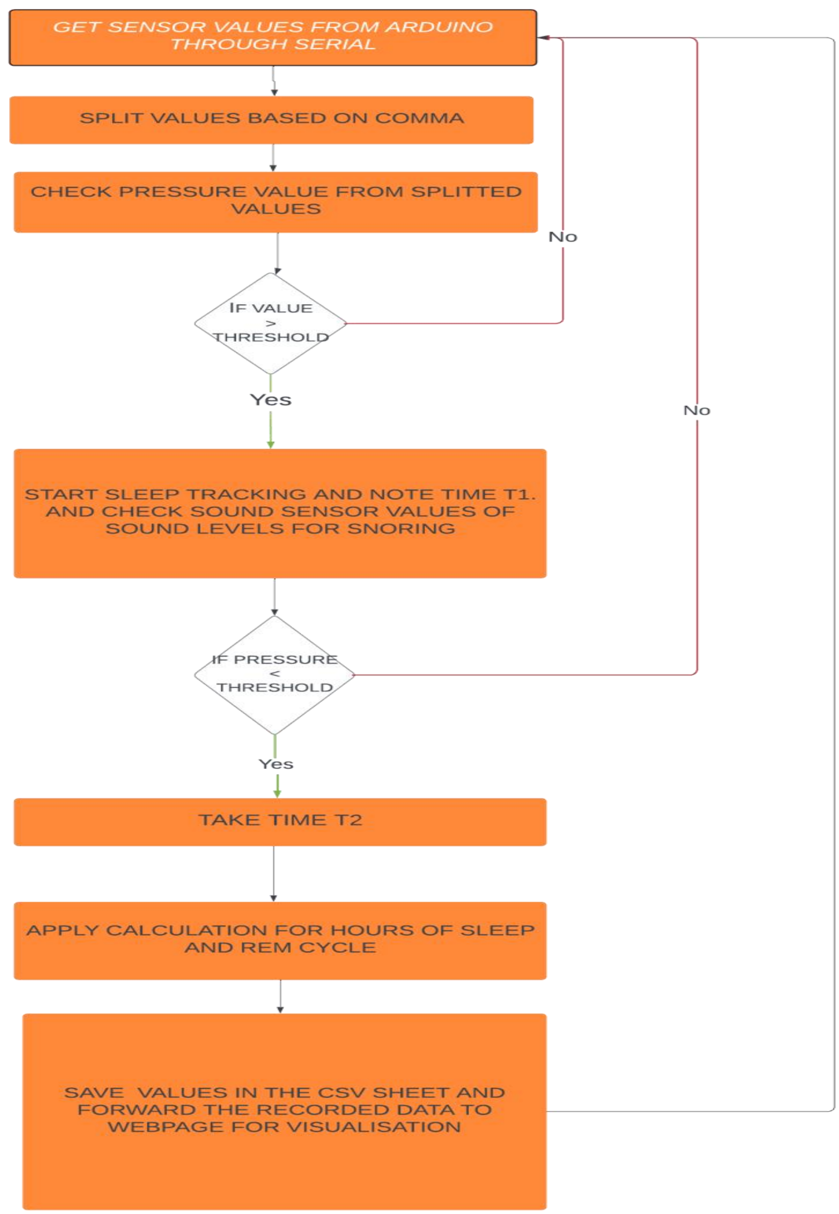

Figure 6: Flow Diagram

Figure 6 represents the functional flow of the hardware and software components integration which showcases a step-by-step operational process of the designated model proposed.

Use-Case Diagram

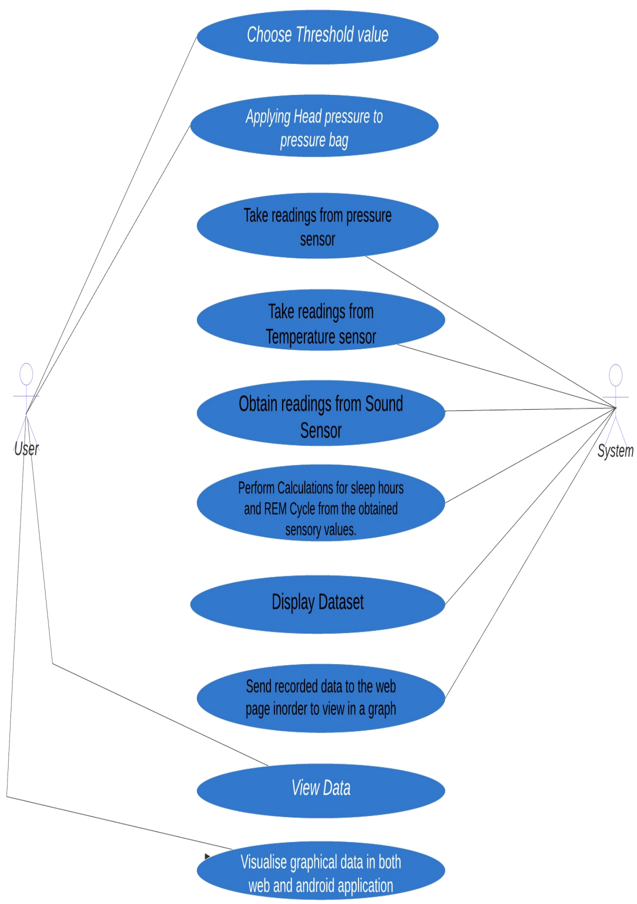

Figure 7: Use-Case Diagram

Figure 7 is a Use-Case diagram that represents the interactions between actors (users or external systems) and a system, as well as the various use cases (functional requirements) of the system.

Sequence Diagram

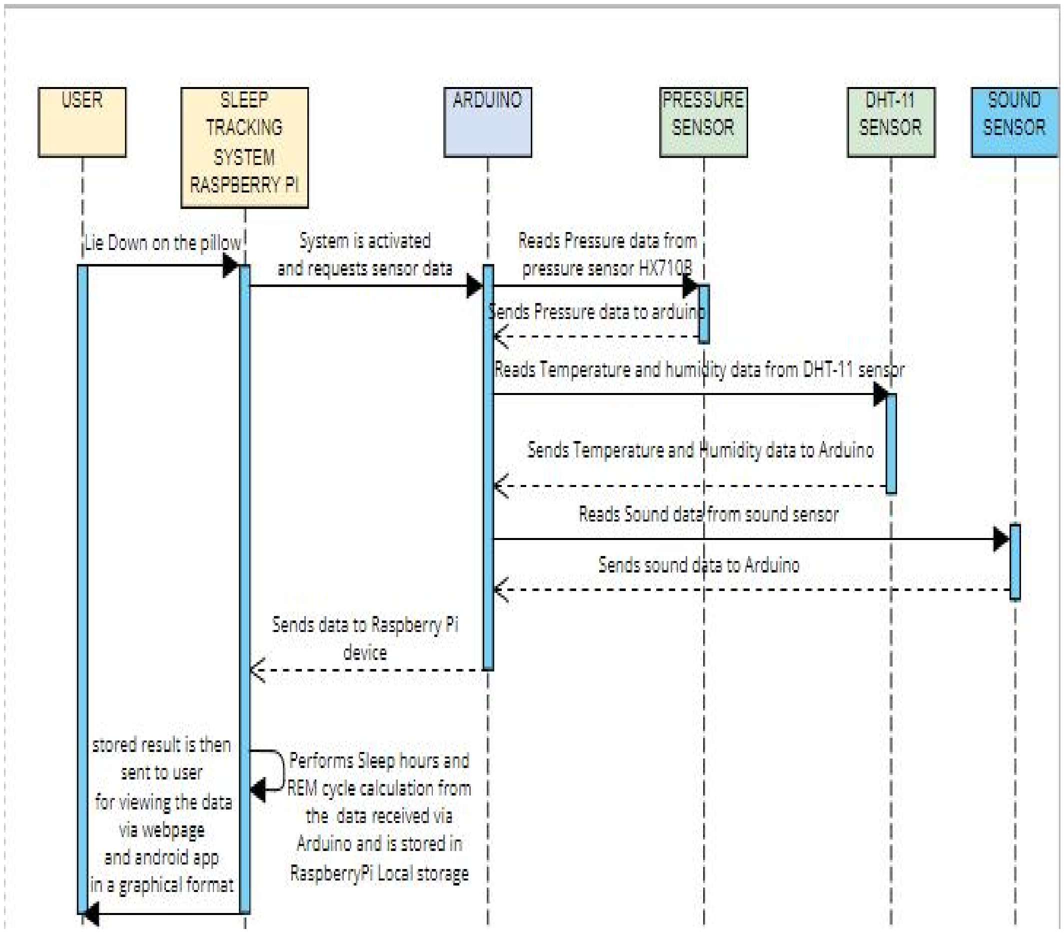

Figure 8: Sequence Diagram

Figure 8 represents a sequence diagram which is a type of Unified Modeling Language diagram that is used to describe the interactions between objects or components in a system in a chronological order. Sequence diagrams show how objects or components interact with each other and in what order during a specific scenario or use case.Sequence diagrams are useful for understanding the flow of a system, identifying potential issues or bottlenecks, and communicating the behavior of a system to stakeholders.

Class Diagram

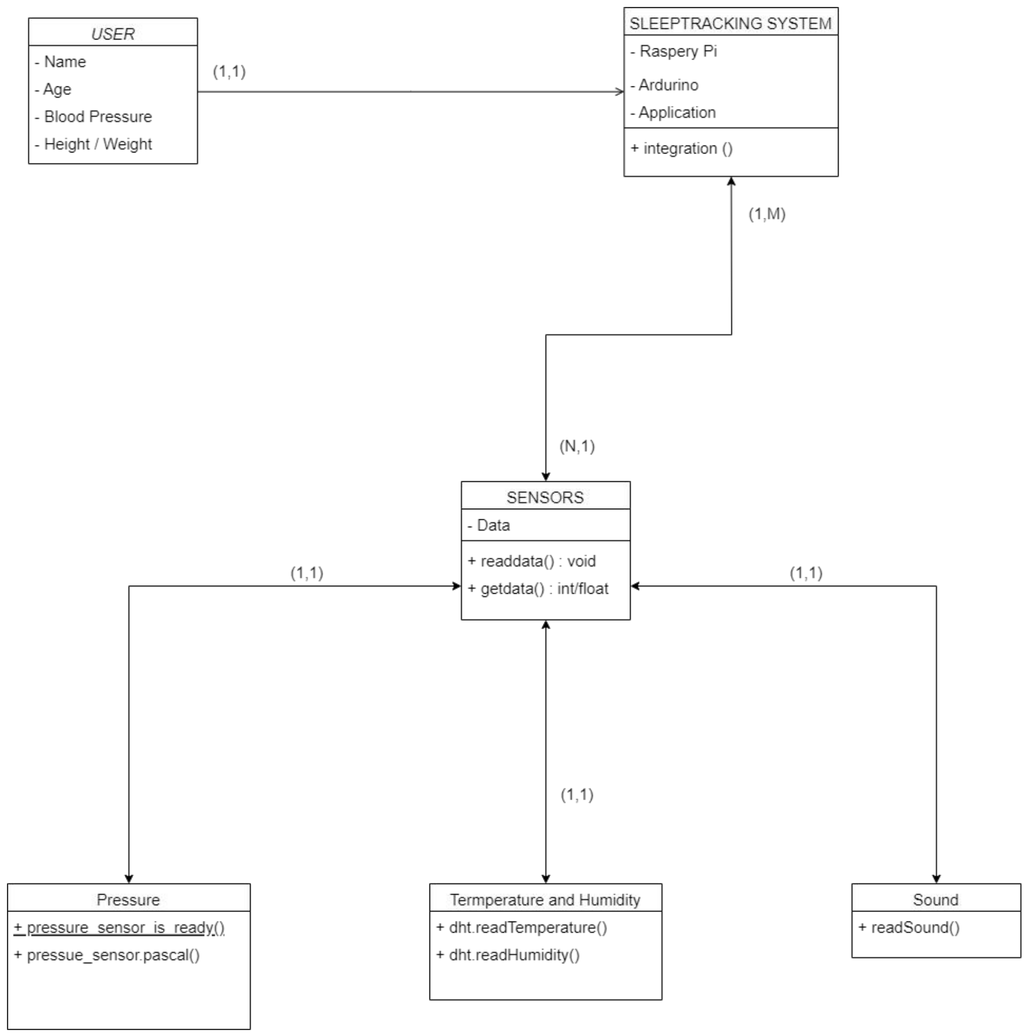

Figure 9: Class Diagram

Figure 9 is a class diagram that represents the structure and relationships of the classes in this system. This class diagram shows the classes, interfaces, attributes, methods, and relationships between sensors,raspberry pi,Arduino and software module. Each class has a set of attributes and methods that define its behavior.

CHAPTER FIVE

SYSTEM ANALYSIS

Proposed System

This project pillow based sleep tracking is proposed to provide personalized sleep information as an alternate suggestion to Wearables. This would involve testing the device to ensure that it is accurate and reliable in measuring pressure during sleep and validating the device's performance by comparing the data it collects to data collected by traditional sleep monitoring devices like smartwatch or fitness tracker to provide a more comprehensive analysis. This would involve designing and developing the physical device, which would include integrating connections with the pressure sensors into a pillow using a pressure amplifier bag and ensuring that the device is comfortable and safe to use during sleep.The main purpose of the project is suggesting an alternate to Wearables with products that work with no human intervention yet enabled with similar sensor technologies. So, the pillow is designed in such a way that it targets detecting sleep duration which consists of total sleeping time, sleep stages, temperature and humidity. Wearables reduce convenience as there is human action involved with the need to set it up, wear it everyday/ every night in order to be able to track required data, which is a cumbersome process. Utilizing of a smart pillow, can help in tracking of different metrics with no human intervention, increasing the convenience element in their everyday lives.

Process in the Internet of Things:

The process includes steps of measuring the sensory data obtained by a barometric pressure sensor which is connected with an pressure amplifier bag placed under the pillow. When head pressure is applied towards this pressure bag, it records the pressure applied on the pillow after the threshold limit and transfers the obtained pressure via a tube present in the bag, which is connected to the barometric pressure sensor. To get the accurate pressure sensors value, I have used the HX710B library to extract the data. Also in addition,I have used the serial and datetime library for time data from the Raspberry Pi. This helps in getting to know the start time of the sleep as the pillow gets activated once a head movement is detected in the bag. From this we will be able to calculate the sleep duration until the device being used. The next part in this project is calculation of REM cycle which is done through the time data that is obtained based on the time received from the pressure sensor as the detection cycle begins.Moving to an additional feature,Continuous average temperature and humidity of the surrounding during the entire sleep, we will be tracked using the respective temperature and humidity sensors (DHT 11) positioned along with the other sensors Snoring detection is planned here which is achieved through sound sensor that is set up with pillows positional sleep area. For the sound sensor, I have directly read the digital output from the sensor and based on the intermittency and threshold, the data is plotted in graph for better visualization.

To ensure a smooth data transferring between sensors and Raspberry pi, I have also incorporated an Arduino pro mini as an intermittent device that is connected to the raspberry pi with the help of a USB to TTL module which act as a data transferring system between Arduino and Raspberry Pi. Collectively all these data recorded will be in Raspberry Pi device's local storage. The plan is to transmit the information obtained from sensors to be displayed in graphical user interface application which will be done using Pandas, and Plotly for an interactive visualization of the obtained data. Having utilized python programming language, helped me extract the obtained sensor values present in the Raspberry Pi,thereby leading the way to calculate sleep Hours, REM cycle and to store the data in a local CSV file.

This IOT product is developed with a notion of being an offline storage device rather than being cloud-based as cloud processing requires active internet flow,and considering this being a sleep related health product, I decided to avoid the use of cloud technology for storage keeping the radiation factor in mind due to the internet during entire sleep.

App Development

I Have created a web view android application for visualizing the data received from the sensing technologies and Raspberry Pi which the users wish to see. They will be able to visualize the Sleep duration, Sleep cycle,Temperature,Humidity,Sound levels in snoring in a graphical format in this app. When the user is able to connect to the same WiFi as of the sleep tracking device, the summary of data over the calendar period that the device was actively used will be available in graph for easy visuals of interpreting and understanding the data.

Significance of the Project

A pillow-based sleep tracking device that tracks sleep duration, sleep stages, snoring detection using pressure sensors, and sound sensors can provide a wealth of information about an individual's sleep patterns and habits. This information can be significant in several ways:

Sleep duration: Knowing how long an individual sleeps can help them understand whether they are getting enough sleep to meet their needs. It can also help them identify any patterns or trends in their sleep duration, such as whether they sleep longer on certain days or at certain times of the year.

Sleep stages: Knowing the different stages of sleep that an individual goes through during the night can provide insight into the quality of their sleep. For example, if an individual is spending more time in deep sleep, it may indicate that they are getting more restful sleep.

Snoring detection: A pillow-based sleep tracking device with snoring detection capabilities can help identify whether an individual is snoring, and if so, how frequently and loudly. This information can be valuable for those who are concerned about the impact of snoring on their sleep quality or the sleep of their partners.

Sound sensors: A pillow-based sleep tracking device with sound sensors can detect and record any sounds that the individual makes during sleep, such as talking or snoring. This can help us understand their sleeping habits and routines better.

From an embedded engineer's perspective, a pillow-based sleep tracking device that tracks sleep duration, sleep stages, snoring detection using pressure sensors, and sound sensors can be a significant development for several reasons.

Sensors: The use of pressure sensors and sound sensors can provide a wealth of data about an individual's sleep patterns and habits. These sensors can be designed to be accurate and reliable, and can be integrated into the device in a way that is minimally intrusive to the user.

Data processing: The data collected by the pressure sensors and sound sensors can be processed and analyzed to extract meaningful insights about the individual's sleep. This may involve the use of algorithms techniques to classify different sleep stages, detect snoring, and identify other patterns and trends in the data.

User experience: A pillow-based sleep tracking device can provide a more convenient and comfortable experience for the user, as it does not require them to wear a device on their wrist or ankle. This can be especially appealing to those who are sensitive to such issues or who prefer a more natural sleep experience.

Customization: The use of pressure sensors and sound sensors can also allow for customization options, such as the ability to adjust the firmness of the pillow or the material it is made of. This will enable the device to be more precisely adapted to the unique needs and preferences of the user.Overall, a pillow-based sleep tracking device that utilizes pressure sensors and sound sensors can provide a comprehensive view of data about an individual's sleep patterns.

CHAPTER SIX

IMPLEMENTATION

Primary Implementation

Implementing a pillow-based sleep tracker using Raspberry Pi requires integrating the device with various sensors. This mini computer can be programmed to interact with sensors, collect data, and store it. To begin with, I had decided to go with Raspberry Pi and Arduino mini. The Raspberry Pi is the primary device that will process the data collected by the sensors. Arduino mini is used to acquire the sensor data. Here the sensors are interconnected via Arduino which supplies the recorded data to the Raspberry Pi. This connection between Raspberry Pi and the Arduino is established using USB 2.0 to TTL Serial Converter Adapter Module.

In Arduino,The attached pressure sensor will detect the weight applied to the pillow. The pressure sensor will detect when someone is sleeping and measure based on the intensity of pressure in the bag in compliance to the threshold which finally helped me in calculating sleep related data.The DHT-11 temperature and humidity sensor connected to the Arduino will monitor the ambient temperature and humidity in the room. The temperature sensor will measure changes in temperature throughout the night.

Attaching a sound sensor will detect sound levels based on the digital output received from the sensor detection during the night. This will be used to show variations in sound levels during the sleep.

Having established a proper connectivity between the sensors and Arduino using jumper wires, to obtain accurate sensor values from the hardware module,I have used HX710B and DHT-11 Arduino libraries predominantly for those respective values.I have written multiple codes - to collect and calculate data from the sensors in order to store it on the Raspberry Pi and the other to display the data calculated and obtained from sensors in a web page.The code has analyzed the data and visualizes it in a web page dashboard, allowing the user to see trends in their sleep patterns. The dashboard in the developed web page and android application , which holds a generated set of data based on the physical recording measurement being sent by the code displays the duration of sleep, temperature,humidity,REM cycle, and sound levels of snoring in graph.

CHAPTER SEVEN

RESULTS AND DISCUSSION

Operational Workflow of the Proposed System

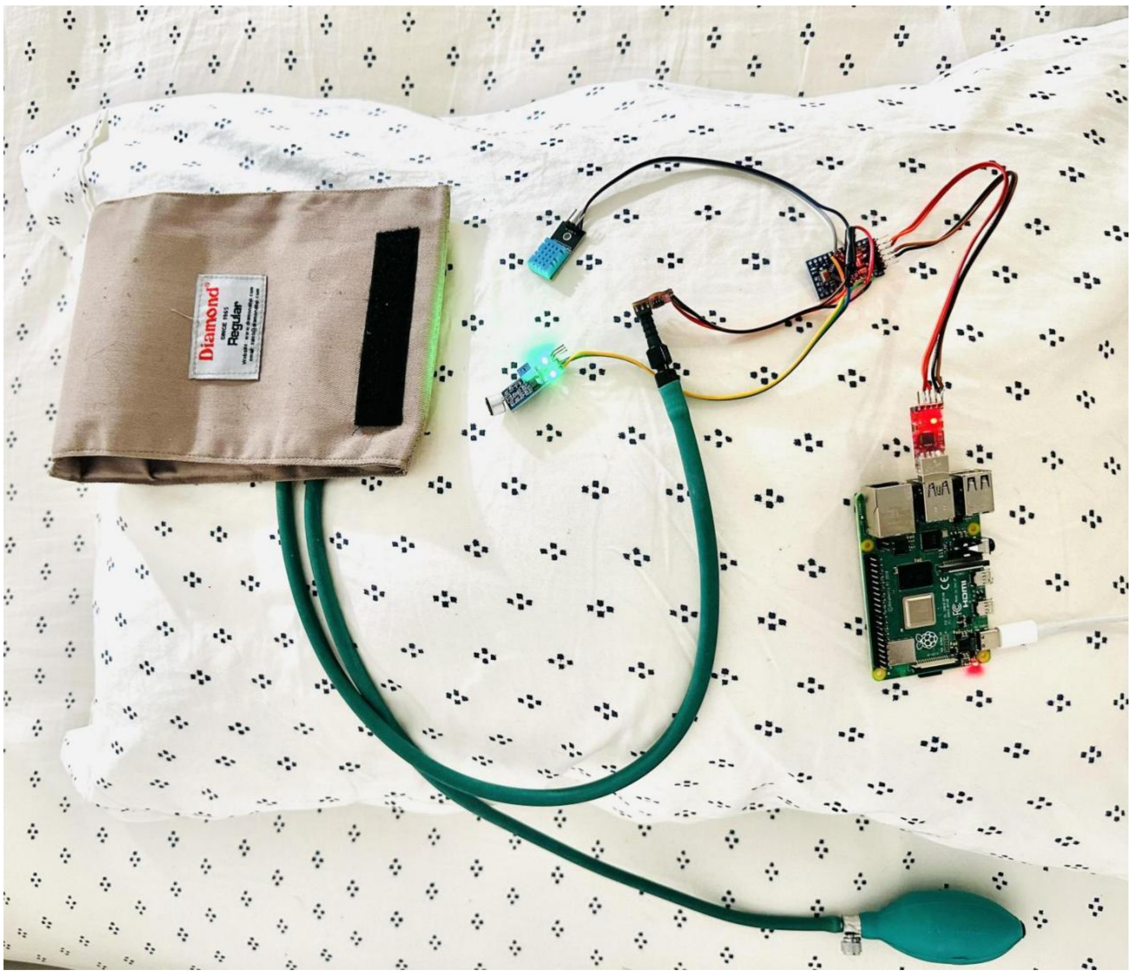

Figure 10: Operational Workflow Of The Proposed System

Video Demonstration URL:

https://drive.google.com/file/d/1HTEV4B55kxsDosjEc0aAM6ls1axuJLg/view?usp=sharing

Total Sleep Hours Graph

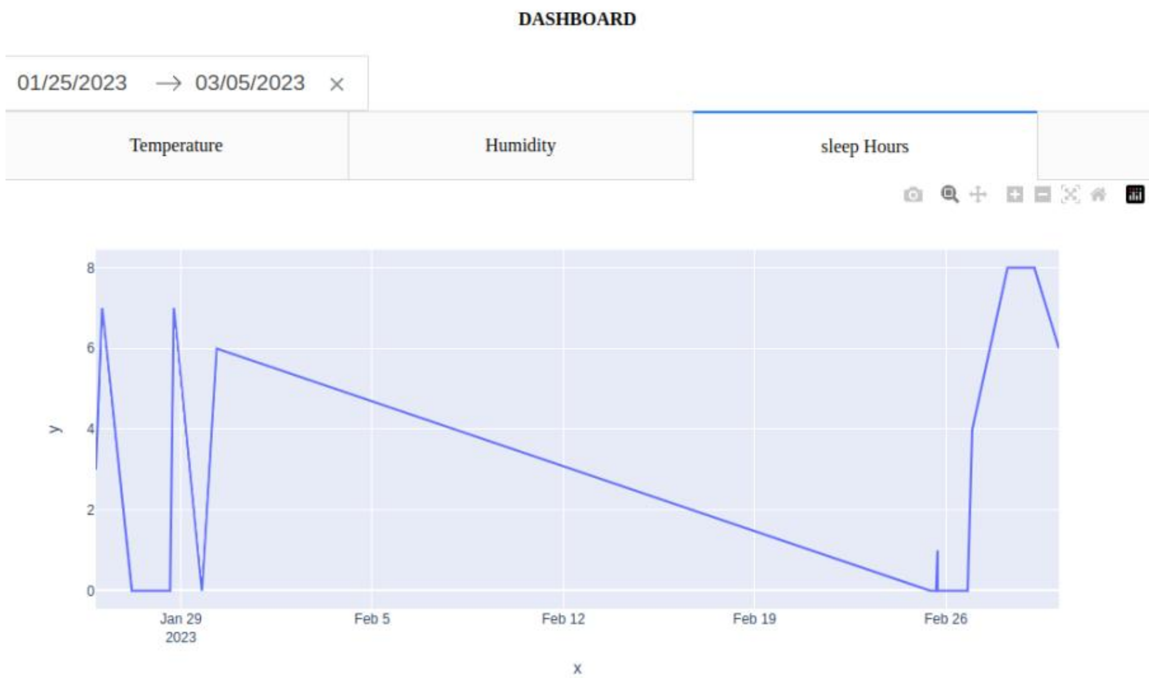

Figure 11: Total Sleep Hours Graph (Jan- Mar 2023)

Figure 11 represents average sleep duration over a calendar period of two months in 2023 with dates represented on the x-axis and no of hours represented on the y-axis.

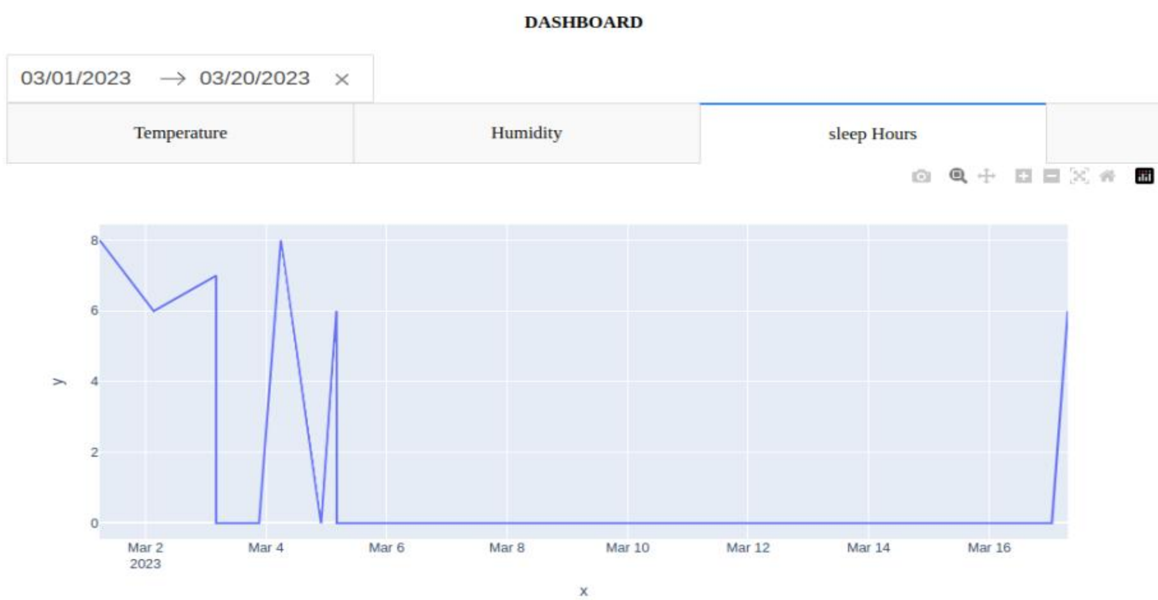

Figure 12: Total Sleep Hours Graph (Mar 2023)

Figure 12 represents the average sleep duration over the month of march 2023 with dates represented on the x-axis and number of hours represented on the y-axis.

REM Cycles Graph

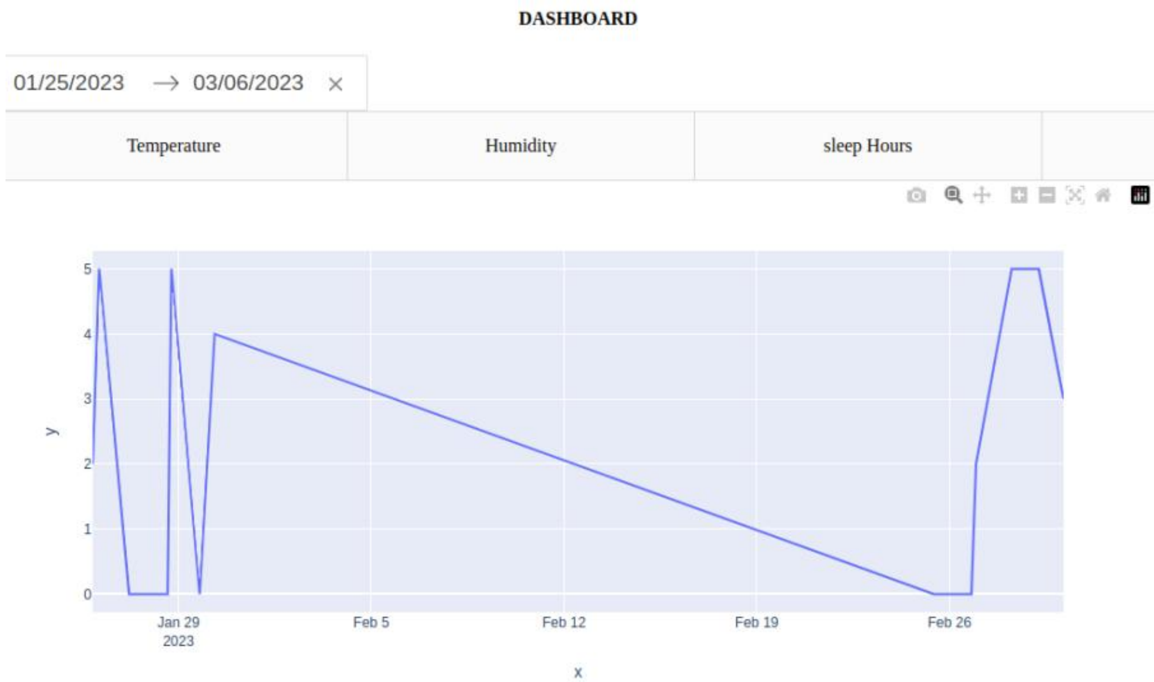

Figure 13: REM Cycles Graph (Jan-Mar 2023)

Figure 13 represents number of REM cycles that an individual will undergo during his entire sleep duration over a period of two months in 2023 with dates represented on the x-axis and number of hours represented on the y-axis.

Figure 14: REM Cycles Graph (Feb- Mar 2023)

The Figure 14 represents number of REM cycles that an individual will undergo during his entire sleep duration during the months of February and March in 2023 with dates represented on the x-axis and number of hours represented on the y-axis.

Temperature Graph

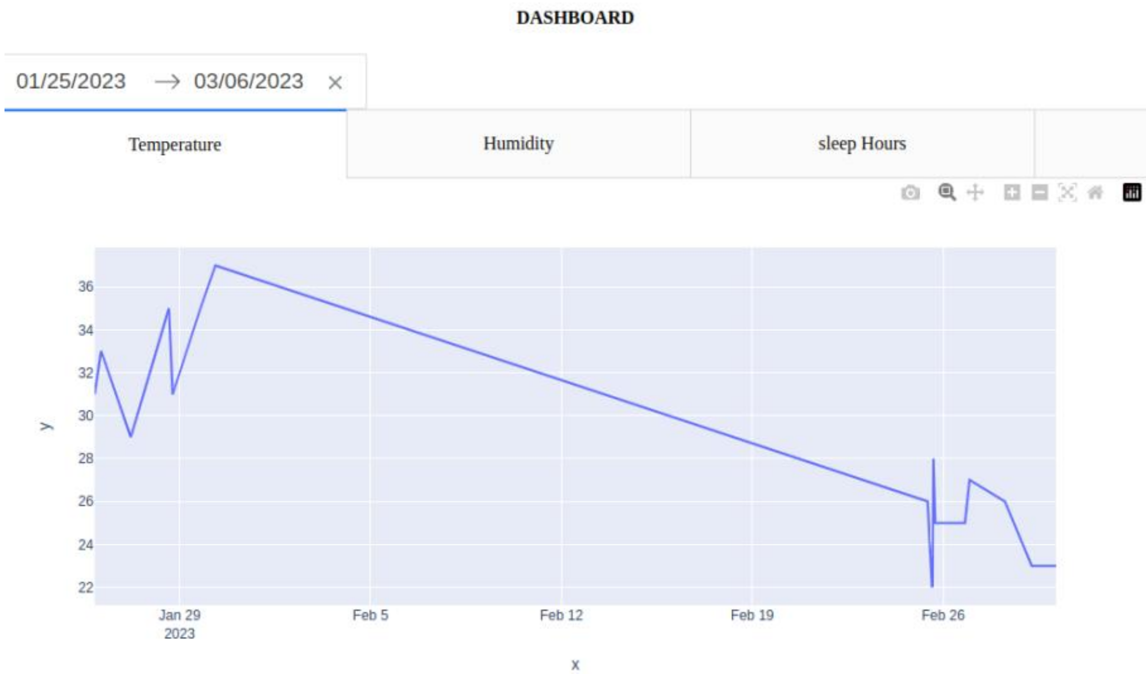

Figure 15: Temperature Graph (Jan-Mar 2023)

The Figure 15 represents the environmental temperature surrounding sleep area for a calendar duration of 2 months in 2023 with dates represented on the x-axis and temperature in Celsius represented on the y-axis.

Figure 16: Temperature Graph (Feb-Mar 2023)

The Figure 16 represents the environmental temperature surrounding sleep area for a calendar between February,and March in 2023 with dates represented on the x-axis and temperature in Celsius represented on the y-axis.

Humidity Graph

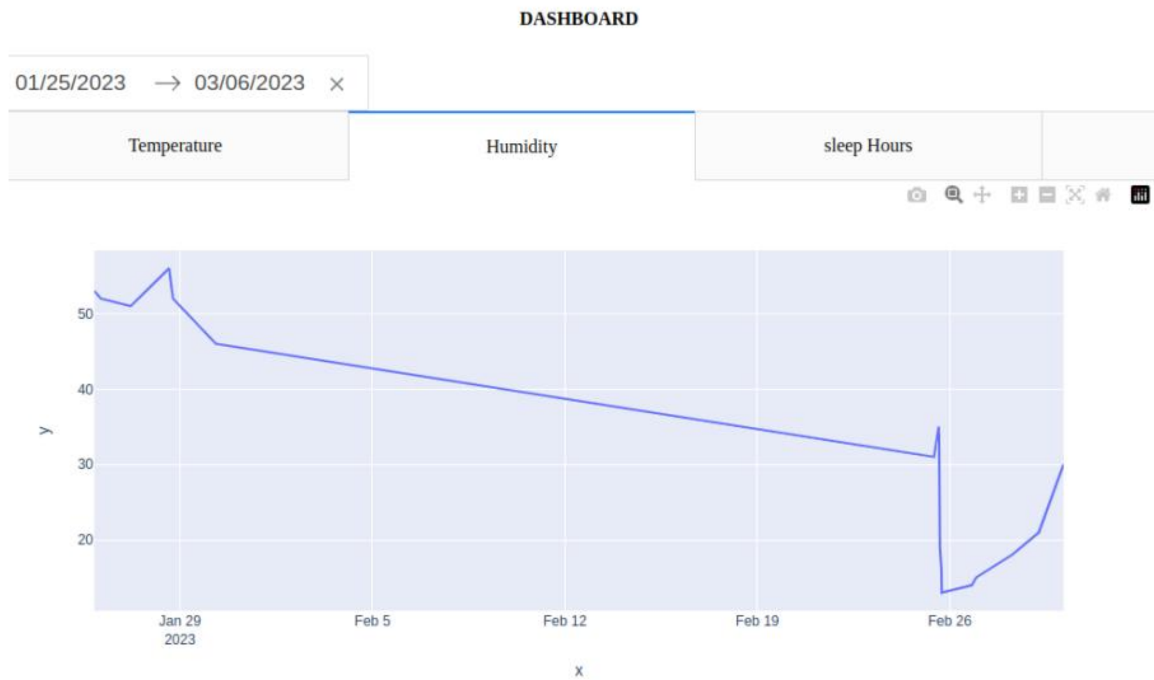

Figure 17: Humidity Graph (Jan-Mar 2023)

Figure 17 represents the environmental humidity surrounding the sleep area for a calendar duration of 2 months in 2023 with dates represented on the x-axis and humidity in percentage represented on the y-axis.

Figure 18: Humidity Graph (Feb- Mar 2023)

Figure 18 represents the environmental humidity surrounding the sleep area for the months of February and March in 2023 with dates represented on the x-axis and humidity in percentage represented on the y-axis.

Sound Levels of Snoring Graph

Figure 19: Sound Levels Of Snoring (Jan 2023)

Figure 19 graph represents the sound levels of snoring during the sleep duration for the month of January in 2023 with dates represented on the x-axis and Sound intensity represented on the y-axis.

Data Validation With Other Commercial Devices

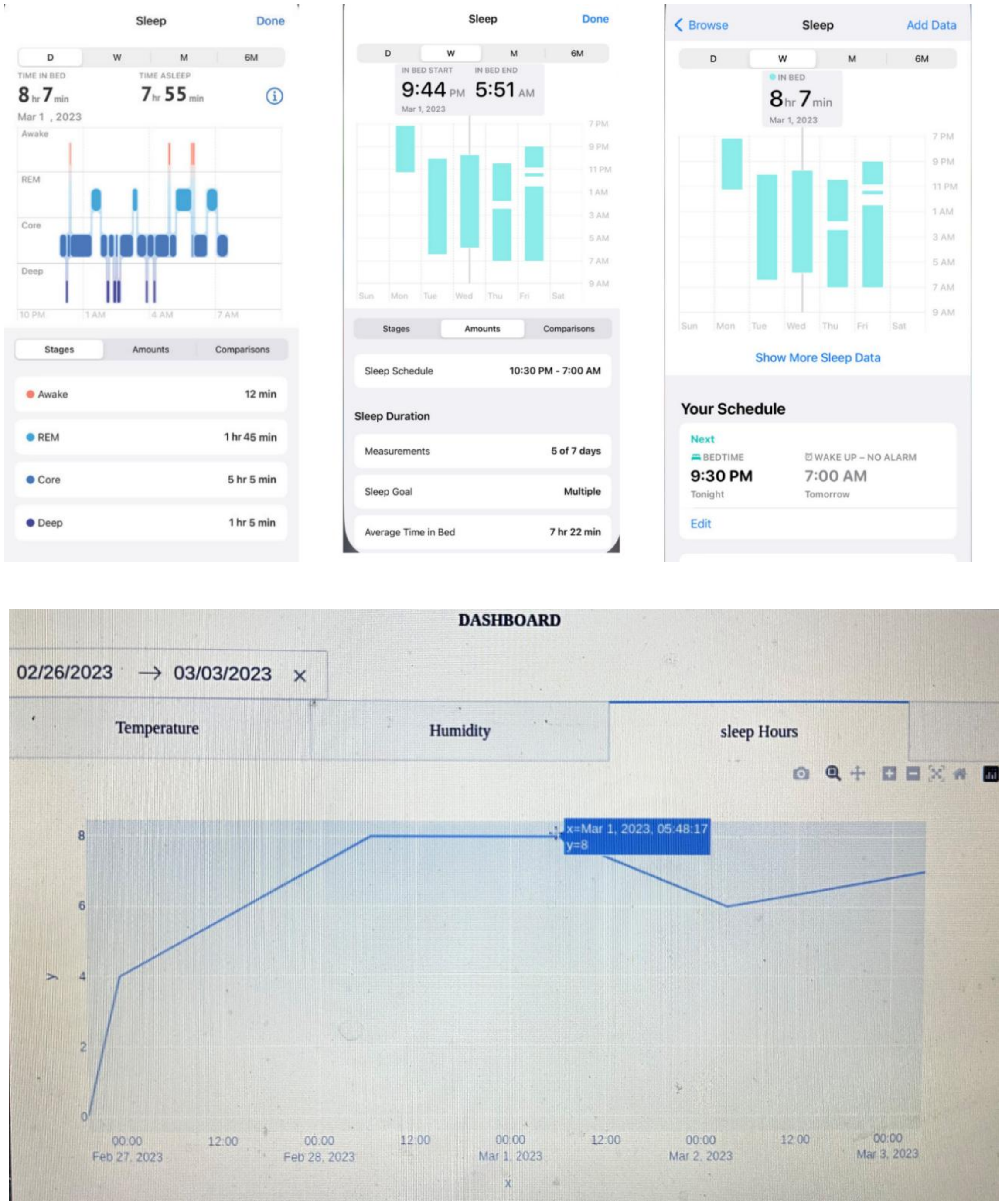

Figure 20: Data Validation with Commercial Device (Mar 1, 2023)

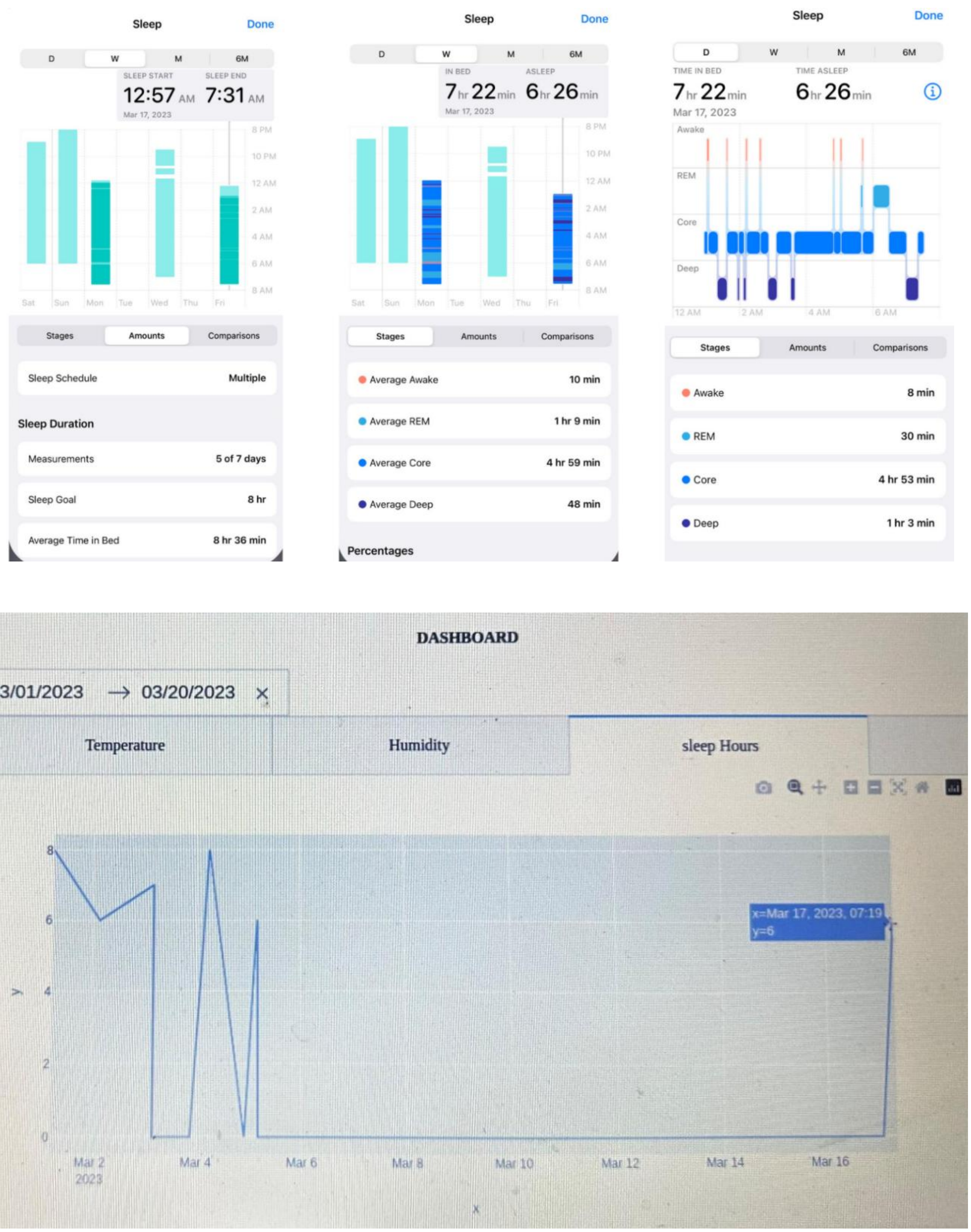

Figure 21: Data Validation With Commercial Device (Mar 11, 2023)

The data captured in figure 20 and figure 21 above represents a sample of sleep tracked through an Apple Series 6 watch for a period of 2 calendar days(March 1, 2023 and Mar 17,2023) simultaneously with the sleep tracking bag. In order to validate the data retrieved from tracking sleep cycles on the pillow, it is compared to the data tracked over the Apple smart watch over the same period.Data shows the amount of time in sleep, start time and end time of sleep, number of REM cycles during the active sleep period,etc. I will also be using a commercial Hygrometer to validate the indoor temperature and humidity.

CONCLUSION

Considering the various aspects of a Pillow based sleep tracking device using Raspberry Pi integrated with multiple sensors through Arduino, it can be concluded that this device will be able to present a number of advantages for monitoring sleep patterns and improving overall sleep quality.By using pressure sensors, the device can detect changes in pressure and movement, which can help determine whether a person is asleep or awake, and how restful their sleep is. In addition, the DHT-11 sensor can measure temperature and humidity, which can also impact sleep quality, while the sound sensor can detect snoring or other disturbances that may disrupt sleep.Another advantage of a Pillow based sleep tracking device is its ease of use. Because it is integrated with Raspberry Pi and Arduino, users can simply place the device under their pillow and allow it to gather data throughout the night.The data can then be easily accessed and analyzed using various software applications or platforms.One limitation is that it may not be able to accurately detect all sleep disturbances or disorders, such as sleep apnea, which may require additional monitoring or medical intervention. In addition, the accuracy of the device may be affected by factors such as the type of pillow used or the user's sleeping position.Some users may find the device uncomfortable or inconvenient to use, or may not want to have electronic devices in close proximity to their head while they sleep.In conclusion, a Pillow based sleep tracking device can be a useful tool for monitoring sleep patterns and improving sleep quality.

APPENDIX A

ARDUINO AND SENSORS INTEGRATION

Code:

```
#include <DHT.h>
#define DHTPIN 4         //The pin that I have digitally connected
#define DHTTYPE DHT11     // DHT 11
DHT dht(DHTPIN, DHTTYPE);
#include "HX710B.h"
const int DOUT = 2;   //sensor data pin
const int SCLK  = 3;   //sensor clock pin

HX710B pressure_sensor;
// constants wont change.They are used here to set the pin numbers:
const int buttonPin = 5;     // the number of the pushbutton pin
const int ledPin =  13;      // the number of the LED pin

// variables will change:
int buttonState = 0;         // variable for reading the pushbutton status
int t,h;
int pres;
void setup()
{
  Serial.begin(9600);
    dht.begin();
```

```
  pinMode(ledPin, OUTPUT);
  pinMode(buttonPin, INPUT);
   pressure_sensor.begin(DOUT, SCLK);

}
void loop()
{
   t = dht.readTemperature();
   h = dht.readHumidity();
   if (pressure_sensor.is_ready())
   {
   pres=pressure_sensor.pascal();
   }
   //Read the state of the pushbutton value:
   buttonState = digitalRead(buttonPin);
     Serial.println(String("%/")+String(pres)+String("/")+String(t)+String("/")+String(
h)+String("/")+String(buttonState)+String("/a"));
  //Serial.println(buttonState);
  delay(100);

}
```

APPENDIX B

DATA READING

```
import serial
from datetime import timedelta
import datetime
import csv
port="/dev/ttyUSB0"
ser=serial.Serial(port, baudrate=9600)
c=1
while(True):
    newdata=ser.readline().decode("utf-8")
    #print(newdata)
    vals=newdata.split('/')
    current_time = datetime.datetime.now().replace(microsecond=0)
    chkpres=int(vals[1])
    if(chkpres>500 and c==1):
        dt1 = datetime.datetime.now().replace(microsecond=0)
        c=2

    print("____________________________________________________")
    print("_____________STARTTIME READING______________________")
    sleep=0
    if(chkpres<600 and c==2):
        dt2 = datetime.datetime.now().replace(microsecond=0)
```

```
        dif=dt2-dt1
        print(dif)
        t=str(dif).split(':')

        total_minutes= int(t[0])*60+int(t[1])*1 +int(t[2])/60
        rem=int((total_minutes-25)/90)
        if(total_minutes>25):
                t2=dif-timedelta(minutes = 0)
                sl=str(dif).split(':')
                sleephr=sl[0]
        else:
                sleephr=0

        c=1
        #print(t)
        print("   ")
print("____________________________________________________________")
        print("Total Minutes: "+str(total_minutes))
        print("Sleep Hour: "+str(sleephr))
        print("REM CYCLE: "+str(rem))
print("________________ENDINGTIMEREAD_________________________")
```

```
print("___________________________________________________")

print("  ")

sleep=1

with open(r'dta.csv','a', newline = '\n') as f:

writer = csv.writer(f)

writer.writerow([current_time,sleep,vals[1],vals[2],vals[3],vals[4],sleephr,rem])

print(current_time,vals)
```

APPENDIX C

WEB PAGE VISUALISATION

```
from dash import Dash, dcc, Input, Output,html,ctx
import plotly.express as px
import dash_bootstrap_components as dbc
import pandas as pd
from datetime import date
import plotly.graph_objs as go
df = pd.read_csv( "dta.csv")
df["Data_Date"] = pd.to_datetime(df["Data_Date"])
app = Dash(__name__, external_stylesheets=[dbc.themes.BOOTSTRAP])
app.layout = dbc.Container(
    [
        dcc.Markdown(
            "#### DASHBOARD",
            style={"textAlign": "center"},
            className="my-4",
        ),
        dbc.Row(
            [
                dbc.Col(
                    [
                        dcc.DatePickerRange(
                            id="datepicker",
```

```
                min_date_allowed=min(df["Data_Date"]),
                max_date_allowed=date(2026, 12, 12),
                end_date=max(df["Data_Date"]),
                start_date=min(df["Data_Date"]),
                clearable=True,
            ),
        ],
        width=5,
    ),
    dbc.Col(
        [
            dcc.Tabs(
                id="tabs",
                value="tab-1",style={
                  'width': '150%',
                  },
                children=[
                    dcc.Tab(
                        label="Temperature",
                        value="tab-1",
                        children=[dcc.Graph(id="pie1")],
                    ),
```

```
dcc.Tab(
    label="Humidity",
    value="tab-2",
    children=[dcc.Graph(id="pie2")],
),
dcc.Tab(
    label="sleep Hours",
    value="tab-3",
    children=[dcc.Graph(id="pie3")],
),
dcc.Tab(
    label="Snore",
    value="tab-4",
    children=[dcc.Graph(id="pie4")],
),
dcc.Tab(
    label="REM Cycle",
    value="tab-5",
    children=[dcc.Graph(id="pie5")],
),
```

```
                    ],
                  ),
                ],
                width=8,
              ),
            ]
        ),
    ]
)
@app.callback(
    Output("pie1", "figure"),
    Output("pie2", "figure"),
    Output("pie3", "figure"),
    Output("pie4", "figure"),
    Output("pie5", "figure"),
    Input("datepicker", "start_date"),
    Input("datepicker", "end_date"),
)
def render_content(start_date, end_date):
    df = pd.read_csv(
    "dta.csv"
    )
```

```
    df["Data_Date"] = pd.to_datetime(df["Data_Date"])
    #end_date=max(df["Data_Date"])
    dff = df.query("Data_Date > @start_date & Data_Date < @end_date")
    pie1_fig = px.line(x=dff["Data_Date"], y=dff["temperature"])
    pie2_fig = px.line(x=dff["Data_Date"], y=dff["humidity"])
    pie3_fig = px.line(x=dff["Data_Date"], y=dff["sleephr"])
    pie4_fig = px.line(x=dff["Data_Date"], y=dff["sound"])
    pie5_fig = px.line(x=dff["Data_Date"], y=dff["rem"])
    return (pie1_fig, pie2_fig, pie3_fig, pie4_fig, pie5_fig)
if __name__ == "__main__":
        app.run(host='0.0.0.0', port=8050,debug=True)
```

REFERENCES

[1] Veiga, A., Garcia, L., Parra, L., Lloret, J., & Augele, V. (2018). An IoT-based smart pillow for sleep quality monitoring in AAL environments. 2018 Third International Conference on Fog and Mobile Edge Computing (FMEC). https://doi.org/10.1109/fmec.2018.8364061

[2] Farrokhi, A., Farahbakhsh, R., Rezazadeh, J., & Minerva, R. (2021). Application of Internet of Things and artificial intelligence for smart fitness: A survey. Computer Networks, 189, 107859. https://doi.org/10.1016/j.comnet.2021.107859

[3] Guillodo, E., Lemey, C., Simmonet, M., Ropars, J., & Berrouiguet, S. (2018). Sleep monitoring and wearables : a systematic review of clinical trials and future applications (Preprint). https://doi.org/10.2196/preprints.13044

[4] Hoque, E., Dickerson, R. F., & Stankovic, J. A. (2010). Monitoring body positions and movements during sleep using WISPs. Wireless Health 2010. https://doi.org/10.1145/1921081.1921088

[5] Oliveira, V., Pereira, F., Carvalho, N., & Lopes, S. (2022). Designing a Smart Pillow for Sleep Quality Remote Monitoring. https://doi.org/10.21203/rs.3.rs-1188952/v1

[6] Karumanchi, M. D., Sheeba, J. I., & Pradeep Devaneyan, S. (2022). Integrated Internet of Things with cloud developed for data integrity problems on supply chain management. Measurement: Sensors, 24, 100445. https://doi.org/10.1016/j.measen.2022.100445

[7] Sangeetha, T., Kumutha, D., Bharathi, M. D., & Surendran, R. (2022). Smart mattress integrated with pressure sensor and IoT functions for sleep apnea detection. Measurement: Sensors, 24, 100450. https://doi.org/10.1016/j.measen.2022.100450

[8] Institute of Medicine (US) Committee on Assuring the Health of the Public in the 21st Century. The Future of the Public's Health in the 21st Century. Washington (DC): National Academies Press (US); 2002. 5, The Health Care Delivery System. Available from: https://www.ncbi.nlm.nih.gov/books/NBK221227/

[9] 22, M. F. | D. (2017, August 7). Mobile Health devices require new strategies for manufacturers. mddionline.com. Retrieved January 23, 2023, from https://www.mddionline.com/digital-health/mobile-health-devices-require-new-strategies-manufacturers

[10] Silver, N. (2020, June 5). How long does it take to fall asleep? average time and tips. Healthline. Retrieved February 12, 2023, from https://www.healthline.com/health/healthy-sleep/how-long-does-it-take-to-fall-asleep