Faculty of Electronics & Computer Technology and Engineering

Development of Sleeping Pattern Monitoring System using Internet of Things

MUHAMMAD NUR IKHWAN BIN MD SHAHRUM

Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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Development of Sleeping Pattern Monitoring System using Internet of Things

MUHAMMAD NUR IKHWAN BIN MD SHAHRUM

A project report submitted
in partial fulfillment of the requirements for the degree of
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APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

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DEDICATION

I would like to dedicate this work to my esteemed parents, Md Shahrum Bin Md Saleh and Morni binti A Majid, whose unwavering support and love have been a constant source of inspiration throughout my life. Your unselfish devotion and tireless encouragement have helped shape my academic and personal endeavors and have been instrumental in my pursuit of higher education and passion for research. I am deeply grateful for the many sacrifices you have made to provide me with every opportunity to succeed, and for the unwavering support you have shown me in every aspect of my life.

This dedication is a small token of my immense appreciation for your guidance, patience, and wisdom, which have helped shape me into the person I am today. Your unwavering love and support have been an invaluable gift, and I can only hope to make you both proud through my academic and personal achievements. Once again, I offer my heartfelt gratitude and deepest appreciation for all that you have done for me, and for the endless support you continue to provide.

ABSTRACT

Lack of adequate sleep can cause various health problems such as heart disease, obesity and diabetes. Therefore, this study aims to develop a system that monitors human sleep patterns using the Internet of Things (IoT) and Raspberry Pi. The system is designed to help individuals improve their sleep quality and overall health by providing insight into their sleep patterns. Therefore, establishing an effective sleep monitoring system is essential to maintaining good health. In this work, the Raspberry Pi microcontroller. motion sensors and a cloud-based database will be used to develop the system. During sleep, the system will record any detected movements and store the information, i.e. data in the cloud, which can be accessed remotely through a mobile application or web interface. the system records motion data and stores it in a cloud-based database, which can be accessed remotely through a mobile application or web interface. In addition, the system will provide valuable insight into a person's sleep patterns, such as sleep duration, time taken to fall asleep, and frequency of waking up. This information is useful for providing personalized feedback and recommendations based on an individual's sleep patterns. The system's user interface is user-friendly, making it easy for individuals to monitor their sleep patterns and make the necessary adjustments to improve their sleep quality. Implementation of the system can help individuals improve their sleep quality and maintain good health. In conclusion, developing a sleep monitoring system using IoT with Raspberry Pi is an effective way to monitor and improve sleep quality. This system provides valuable insight into an individual's sleep patterns, allowing them to make the necessary adjustments to improve their sleep quality and overall health.

ABSTRAK

Kajian ini bertujuan untuk membangunkan sistem pemantauan pola tidur menggunakan Internet of Things (IoT) dan Raspberry Pi. Sistem ini direka untuk membantu individu meningkatkan kualiti tidur dan kesihatan keseluruhan mereka dengan memberikan pandangan tentang corak tidur mereka. Kekurangan tidur yang mencukupi boleh menyebabkan pelbagai masalah kesihatan seperti penyakit jantung, obesiti dan diabetes. Oleh itu, mewujudkan sistem pemantauan tidur yang berkesan adalah penting untuk mengekalkan kesihatan yang baik. Metodologi penyelidikan melibatkan pembangunan sistem yang menggabungkan mikropengawal Raspberry Pi, penderia gerakan dan pangkalan data berasaskan awan. Semasa tidur, sistem merekodkan data gerakan dan menyimpannya dalam pangkalan data berasaskan awan, yang boleh diakses dari jauh melalui aplikasi mudah alih atau antara muka web. Sistem ini memberikan cerapan berharga tentang corak tidur seseorang, seperti tempoh tidur, masa yang diambil untuk tidur dan kekerapan bangun. Penemuan kajian ini menunjukkan bahawa sistem merekodkan data pergerakan dengan tepat semasa tidur dan memberikan maklum balas dan cadangan yang diperibadikan berdasarkan corak tidur individu. Antara muka pengguna sistem adalah mesra pengguna, memudahkan individu memantau corak tidur mereka dan membuat pelarasan yang diperlukan untuk meningkatkan kualiti tidur mereka. Pelaksanaan sistem boleh membantu individu meningkatkan kualiti tidur mereka dan mengekalkan kesihatan yang baik. Kesimpulannya, membangunkan sistem pemantauan tidur menggunakan IoT dengan Raspberry Pi adalah cara yang berkesan untuk memantau dan meningkatkan kualiti tidur. Sistem ini memberikan pandangan berharga tentang corak tidur seseorang individu, membolehkan mereka membuat pelarasan yang diperlukan untuk meningkatkan kualiti tidur dan kesihatan keseluruhan mereka. Penyelidikan masa depan boleh menumpukan pada mengembangkan keupayaan sistem untuk memasukkan metrik kesihatan tambahan dan menilai kesannya terhadap kualiti tidur pada skala yang lebih luas.

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Finally, I would like to thank all, fellow colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

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FACULTY OF ELECTRONIC AND COMPUTER TECHNOLOGY AND ENGINEERING
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LIST OF SYMBOLS

°	-	Angle
uA	-	Microampere
mm	-	Milimeter
m	-	Meter

LIST OF ABBREVIATIONS

V	-	Voltage
P	-	Pixel

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CHAPTER 1

INTRODUCTION

1.1 Background

Sleep, a complex physiological process, occupies approximately one-third of a human's life and is vital to overall health and cognitive function [1]. It is characterized by a temporary suspension of consciousness and significant reduction in motor activity, interlaced with periods of Rapid Eye Movement (REM) sleep and Non-Rapid Eye Movement (NREM) sleep [1]. In terms of cognitive functioning, sleep has been found to play a crucial role in various cognitive processes such as memory consolidation, problem-solving, and emotional regulation. During the REM phase, the brain engages in the consolidation and integration of newly acquired information into the existing neural network, which is pivotal for learning and memory [2]. Sleep deprivation can impair these cognitive functions, leading to deficits in attention, decision-making ability, and memory, thereby undermining cognitive performance and productivity [2].

Sleep also an essential component of human health, and monitoring sleep patterns has become increasingly important in maintaining overall well-being. Recent advancements in technology have enabled the development of sleep monitoring systems using Internet of Things (IoT) devices. One such device that has gained popularity is the Raspberry Pi microcontroller. The Respberry Pi microcontroller is a low-cost, small-sized computer is ideal for developing IoT applications and provides several advantages, including cloud-based data storage, remote data access, and system customization. This study aims to develop a sleep monitoring system using IoT with Raspberry Pi, which will collect motion data during sleep and provide personalized feedback and recommendations based on an individual's sleep patterns. The findings of this study have the potential to contribute to the development of effective sleep monitoring systems that can help individuals maintain good health and well-being by improving their sleep quality.

1.2 Problem Statement

Sleep disorders are becoming increasingly common, and they can have a significant impact on an individual's health and well-being. Traditional methods of monitoring sleep, such as polysomnography, can be expensive and invasive, making them impractical for widespread use. A non-invasive and cost-effective method of monitoring sleep could provide a valuable tool for identifying sleep disorders and improving overall sleep quality.

1.3 Project Objective

The objective of the project is to develop a sleep monitoring system using Internet of Things (IoT) technologies. The system is designed to collect motion data during sleep and provide personalized feedback and recommendations based on an individual's sleep patterns.

a) To design and develop an IoT-based sleep monitoring system using Raspberry Pi microcontroller.
b) To develop an algorithm to analyse the monitored motion data to provides a personalized feedback and recommendation based on an individual's sleep patterns.
c) To evaluate the performance of the developed system in terms of its reliability and accuracy.

1.4 Scope of Project

The scope of this project are as follows:

a) Design and development of a sleep monitoring system using microcontroller Raspberry Pi.

b) The system will collect motion data during sleep and store it in a cloud-based database.

c) The system will be integrated with a tensor flow algorithm to analyzed the monitored motion data for ten data sets from ten users to provide personalized feedback and recommendations.

d) A mobile application or web interface will be provided for users to access their sleep data and customize their settings.

e) The system will be tested considering system 10 users to evaluate the reliability and the accuracy of the developed system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Sleep is a vital physiological process that significantly impacts various aspects of human health and overall well-being. The importance of sleep cannot be understated, as it plays a crucial role in cognitive performance, emotional balance, and physical health. This comprehensive review will examine the key components of sleep, such as adequate sleep duration, deep sleep stages, regular sleep patterns, and heart rate monitoring during sleep.

Sufficient sleep duration is essential for maintaining cognitive abilities, emotional regulation, and overall health. Research by[3] has provided strong evidence supporting the idea that adults require approximately 7-9 hours of sleep per night to ensure optimal health and cognitive performance. A lack of adequate sleep has been associated with various negative consequences, including impaired memory, diminished concentration, mood disturbances, weakened immune system function, and an increased risk of chronic diseases such as obesity, diabetes, and cardiovascular disorders [3]. Furthermore, short sleep duration has been correlated with an increased mortality risk and reduced quality of life [3]. Conversely, obtaining sufficient sleep has been shown to enhance cognitive function, emotional regulation, and immune system function, contributing to overall well-being and longevity [3].

Deep sleep, otherwise known as slow-wave sleep or NREM stage 3 sleep, is a critical sleep stage that facilitates the restorative functions of sleep. During deep sleep, the body undergoes a variety of processes, including tissue repair, growth hormone release, and the removal of metabolic waste products from the brain [4]. Role of deep sleep in consolidating memories, improving learning capabilities, and regulating emotions [4]. Additionally, deep sleep has been suggested to play a vital role in maintaining the structural integrity of the brain's white matter, which is crucial for efficient neural communication [4].

Consistent sleep patterns, characterized by regular sleep-wake schedules, are necessary for maintaining the body's internal biological clock, also known as the circadian rhythm. A stable sleep pattern fosters better sleep quality, daytime alertness, and overall health [4]. Disruptions to sleep patterns can result in sleep disorders, such as insomnia and circadian rhythm sleep-wake disorders, which negatively affect physical and mental health [1]. Recent studies have linked circadian misalignment with a higher risk of developing metabolic and cardiovascular diseases, as well as cognitive decline and mood disorders [1].

Monitoring heart rate during sleep can provide valuable insights into an individual's overall cardiovascular health and sleep quality. Heart rate typically decreases during sleep, reflecting the body's reduced metabolic demands and the influence of the parasympathetic nervous system [1]. Deviations in heart rate during sleep may indicate sleep disorders, such as sleep apnea or periodic limb movement disorder, or underlying cardiovascular conditions [1]. Furthermore, a recent study by Günther et al. [2] highlights the potential of heart rate variability during sleep as a marker of autonomic nervous system function, which can be utilized to assess the restorative quality of sleep. This review underscores the importance of sleep duration, deep sleep, regular sleep patterns, and heart rate monitoring during sleep for optimal physical and mental health. The findings from recent research provide strong evidence supporting the need for individuals to prioritize sleep as a critical component of a healthy lifestyle.

2.2 Sleep and its Significance

Beyond cognitive health, sleep has substantial implications for metabolic and physiological processes. Research indicates that sleep deprivation can lead to metabolic dysregulation, contributing to the development of metabolic disorders such as obesity and type 2 diabetes. This occurs partly due to the dysregulation of appetite-controlling hormones, including leptin and ghrelin, leading to increased feelings of hunger and reduced satiety in sleep-deprived individuals [2]. Moreover, sleep plays a critical role in modulating immune responses. During sleep, the immune system undergoes a series of changes, including the production of certain cytokines and the optimization of T-cell activity. Chronic sleep deprivation can lead to a state of persistent, low-grade inflammation, thereby impairing immune responses and increasing susceptibility to infectious diseases [2].

Sleep also has a direct impact on cardiovascular health. Sleep disorders, such as obstructive sleep apnea, have been linked to an increased risk of cardiovascular diseases, including hypertension, coronary artery disease, and stroke. This is due to the intermittent hypoxia and sleep fragmentation experienced by individuals with sleep apnea, leading to increased sympathetic activity, oxidative stress, and systemic inflammation [2]. Sleep is a vital physiological process that is crucial for maintaining cognitive functioning, metabolic health, immune system functioning, and cardiovascular health.

2.3 Sleep disorders

2.3.1 Definition and importance of sleep disorders

Sleep is a naturally recurring condition of the mind and body distinguished by changes in consciousness, decreased sensory activity, and the suppression of voluntary muscle movements. It is crucial for upholding overall health and wellness. Sleep holds significant importance in numerous physiological functions, including the consolidation of memories, immune system function, metabolism, and regulation of hormones. Throughout the sleep cycle, the body undergoes tissue repair and regeneration, bolstering the immune system, and consolidating memories [5].

Insufficient sleep or inadequate sleep quality can contribute to a range of health issues, including obesity, diabetes, cardiovascular disease, depression, anxiety disorders, and compromised cognitive abilities. The necessary amount of sleep varies depending on an individual's age and specific requirements. Infants typically need around 14-17 hours of sleep daily, while adults generally require 7-9 hours of sleep each day. However, it's important to note that some individuals may necessitate more or fewer hours of sleep than others [5].

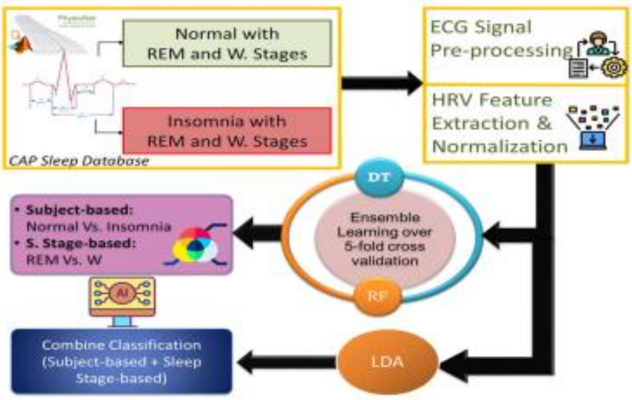
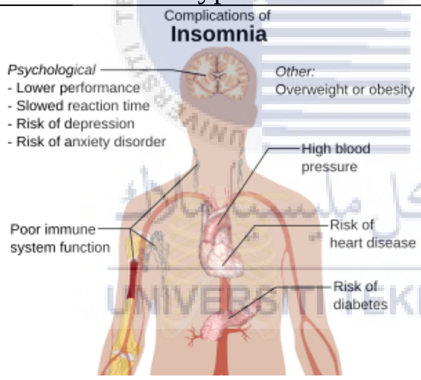
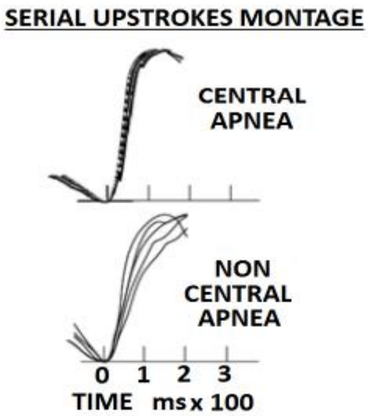


Figure 2.1: Flow of sleep disorder [5]

Sleep exhibits distinct patterns of brain activity, notably encompassing slow-wave sleep and rapid eye movement (REM) sleep [5] Attaining an adequate amount of restful sleep holds paramount importance for sustaining optimal health and well-being. Insufficient or low-quality sleep has been associated with various adverse health consequences, including heightened vulnerability to obesity, diabetes, cardiovascular ailments, depression, anxiety, and cognitive deterioration. Beyond its positive impact on physical health, obtaining sufficient rejuvenating sleep can also enhance mood, cognitive abilities, productivity, and overall life quality [5].

2.3.2 Common types of sleep disorders

Table 2.1:Type of sleep disorders

Type	Explanation
 Figure 2.2: Insomnia [5]	Insomnia refers to a sleep disorder marked by challenges in initiating or maintaining sleep, as well as waking up prematurely and experiencing difficulty returning to sleep. This condition can arise due to various factors, including stress, anxiety, depression, specific medications, and lifestyle elements like the consumption of caffeine or alcohol [5].
 Figure 2.3: Sleep apnea [5]	Sleep apnea is a condition characterized by repeated pauses in breathing during sleep. The cause can be either a blocked airway, known as obstructive sleep apnea, or a failure in the transmission of respiratory signals to the brain muscles, known as central sleep apnea. If left untreated, sleep apnea can result in daytime fatigue, elevated blood pressure, and various other health complications [5].

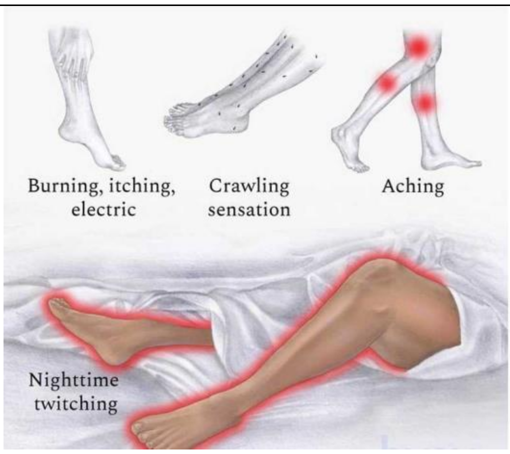
<table>
<tr><th>Type</th><th>Explanation</th></tr>
<tr><td>

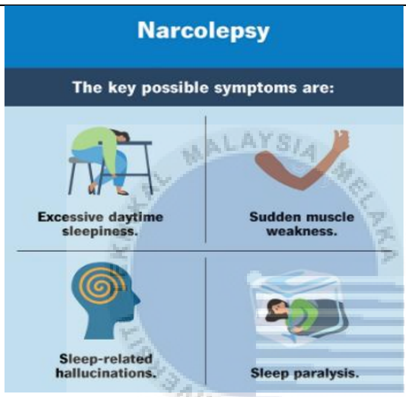
Figure 2.4: Restless leg syndrome [5]</td><td>Restless legs syndrome is a neurological condition characterised by leg pain that causes sleep disruptions. People suffering with restless legs syndrome frequently have an irrepressible impulse to exercise their legs in order to ease discomfort [5], [6].</td></tr>
<tr><td>

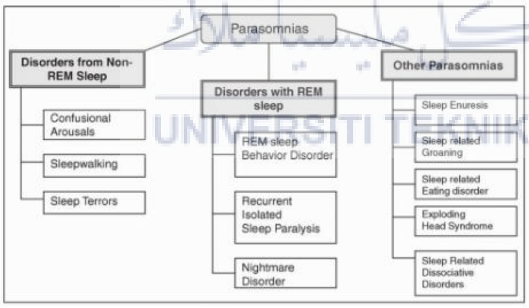
Figure 2.5: Narcolepsy [5]</td><td>Narcolepsy is a neurological disorder that causes excessive daily sleepiness or sudden sleepiness. People with narcolepsy may experience episodes of inappropriate sleep throughout the day, making it difficult to stay awake for long periods of time [5].</td></tr>
<tr><td>

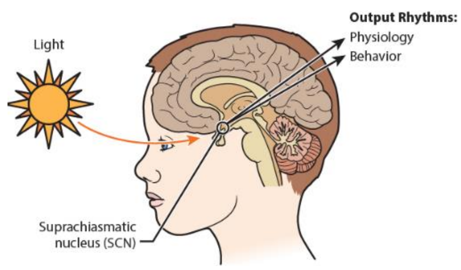
Figure 2.6: Parasomnia [5]</td><td>Parasomnia are abnormal behaviours during sleep that can include things like sleepwalking, night terrors, and REM behaviour disorder (acting out dreams during REM sleep). These behaviours can be disruptive to both the individual experiencing them and their bed partner [5].</td></tr>
<tr><td>

Figure 2.7: Circadian rhythm disorders [7]</td><td>Circadian rhythm disorders are disruptions to the body's natural sleep-wake cycle that can be caused by things like jet lag or shift work schedules and staying awake during the day [7].</td></tr>
</table>

2.3.3 Sleep disorder statistic

This research, titled 'Sleep Disorder During the Third Wave of the COVID-19 Pandemic among Malaysian Adults,'[8] was conducted through an online survey administered via Google Form from January 11th to May 4th, 2021. The primary objective of this study is to comprehensively investigate the correlation between socio-demographic factors and sleep patterns specifically during the third wave of the COVID-19 pandemic in Malaysia. The survey instrument consists of two sections: Section A, focused on gathering socio-demographic details treated as independent variables, and Section B, utilizing the validated Holland Sleep Disorder Questionnaire (HSDQ) to assess sleep-related issues[8].

Stringent ethical considerations were observed, with approval obtained from the ethical review committee of Asia Metropolitan University. Participant identities were strictly maintained in confidence throughout the data collection process. The HSDQ, comprising 32 sleep-related statements and a meticulous scoring system, facilitates the identification of various sleep disorders. Statistical analysis, performed using the Statistical Package for Social Sciences (SPSS version 17.0), aims to elucidate the relationships between socio-demographic variables and sleep disorders[8].

Table 2.2: Prevalence of Key Sleep Disorders Among Malaysian Adults[8]

Sleep Disorders	Prevalence (%)
Restless Legs	34.8
Parasomnia	33.9
Insomnia	29.7

In conclusion, the study conducted between January and May 2021 provides valuable insights into the prevalence and determinants of specific sleep disorders among Malaysian adults during the third wave of the COVID-19 pandemic. Utilizing the Holland Sleep Disorder Questionnaire (HSDQ), the survey indicates significant prevalence rates, with Restless Legs Syndrome (RLS/PLMD) at 34.8%, Parasomnia at 33.9%, and Insomnia at 29.7%. These findings underscore the profound impact of the ongoing pandemic on the sleep health of Malaysian adults. Urgent interventions and tailored strategies are recommended, emphasizing online counseling resources to address the escalating prevalence of these specific sleep disorders among the Malaysian population.[8]

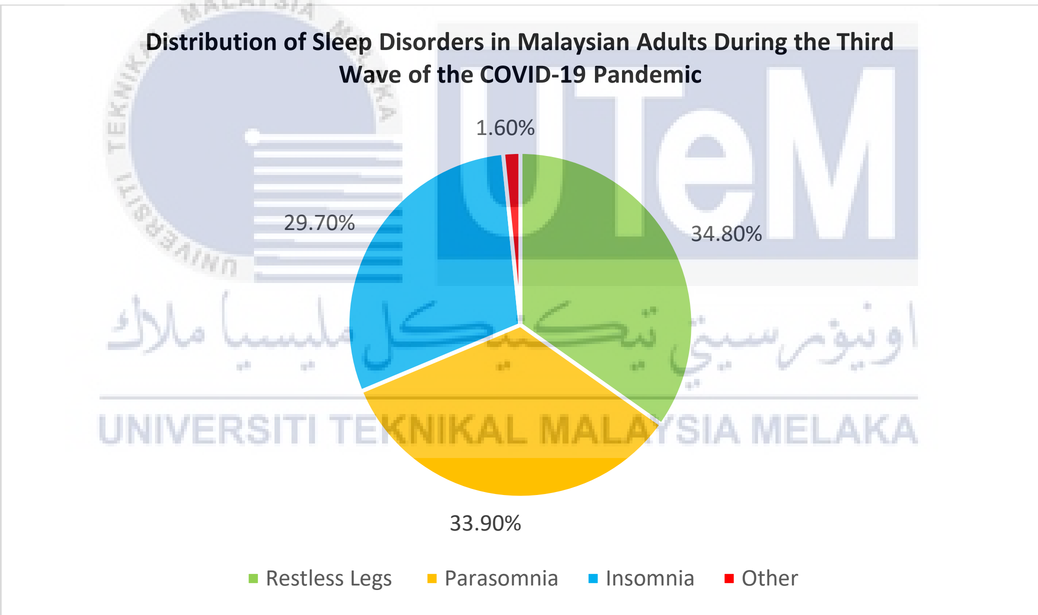
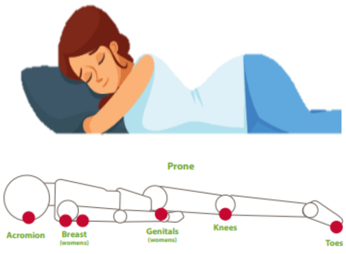
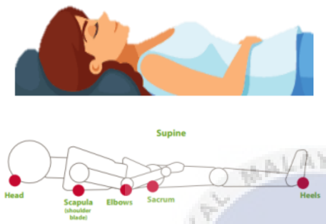
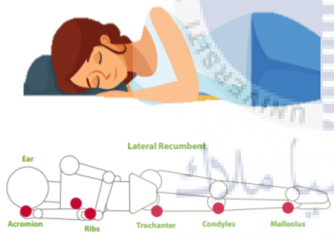


Figure 2.8: Distribution of Sleep Disorders in Malaysian [8]

2.3.4 Type of sleeping position

We spend 40 per cent of our lives in bed; therefore, the correct bed and sleeping position is essential for those with neck, back, shoulder, and hip issues. In addition to preventing the development of problems and halting their recurrence, the correct slumber position can also control their onset [9].

Table 2.3: Type of sleeping position [9]

Sleeping position	Healthy	Unhealthy
 Figure 2.9: Stomach position [9]	• Help to decrease snoring [10].	• Can cause pain and nerve issues [11]. • Puts strain on the spine [11]. • Decrease blood flow [10].
 Figure 2.10: Back position [9]	• Decreases problem with acid flux [11]. • Can help alleviate neck, shoulder and back pain [11].	• Increases snoring [12]. • Makes the symptoms of sleep apnea worse [12].
 Figure 2.11: Side position [9]	• Enables the spine to stay in a neutral position [12]. • Helps alleviate neck, shoulder, and back pain [11]. • Can help decrease snoring and OSA symptom [12].	

2.4 Sleep Monitoring Techniques.

2.4.1 Polysomnography (PSG)

Polysomnography refers to an extensive sleep study that entails the simultaneous monitoring of various physiological indicators during sleep. These measurements include brain activity (electro encephalography, EEG), eye movement (electro oculogram, EOG), muscle activity (electro myography, EMG), heart rate (electro cardiogram, EKG), respiratory rate, blood oxygen level (pulse oximetry) [7]. Polysomnography holds significant value as a diagnostic and therapeutic tool for sleep disorders.

The author explained the recent advancements in portable and wireless PSG systems, as well as the integration of machine learning and AI algorithms, have made PSG more accessible and accurate[13]. Research and technological developments in this field continue as the current sleep monitoring primarily relies on polysomnogram (PSG) tests[14] [15]. These devices enable continuous, long-term monitoring of sleep, thereby providing more comprehensive data. Despite their benefits, privacy and security concerns regarding the sensitive personal data they collect need to be thoroughly addressed [16].

Figure 2.12: Portable PSG Devices [14]

Portable PSG devices enable home sleep investigations [7]. A more natural sleep setting may provide more accurate findings. Portable devices cut sleep lab expenses and wait times. Wireless PSG devices eliminate the necessity for patient-recording equipment hookups, making patients more comfortable [7], [17]. This eliminates cable displacement artifacts and increases mobility. PSG data analysis using machine learning and AI algorithms is promising [7]. These systems automate sleep stage assessment and increase diagnostic accuracy by processing vast amounts of data [16].

The author presents system based on remote PPG features that was evaluated using a small dataset of healthy subjects simulating realistic sleep scenarios. This proof-of-concept study seeks to assess the feasibility of camera-based remote measurement of pulse rate, respiratory rate, and peripheral arterial blood oxygen saturation in obstructive sleep apnea (OSA) patients undergoing nocturnal PSG [13]. However there are disadvantage in some of PSG method. As the author mentions, Traditional Internet of Medical Things (IoMT) systems pose potential security threats as they transmit sensitive, human-centric data over unsecured wireless networks, making them vulnerable to attacks [14].

2.4.2 Actigraphy

Actigraphy is a non-invasive technique for monitoring the rest-activity cycles of humans. It entails measuring movement with a peripheral device endowed with an accelerometer, typically worn on the wrist [18]. By analyzing these movement patterns, sleep and wake states can be inferred [18]. Actigraphy is particularly useful in studying circadian rhythm disorders, insomnia, and evaluating the efficacy of sleep interventions. It can also be beneficial in situations where polysomnography is not practical, such as in home-based or long-term sleep studies [18].

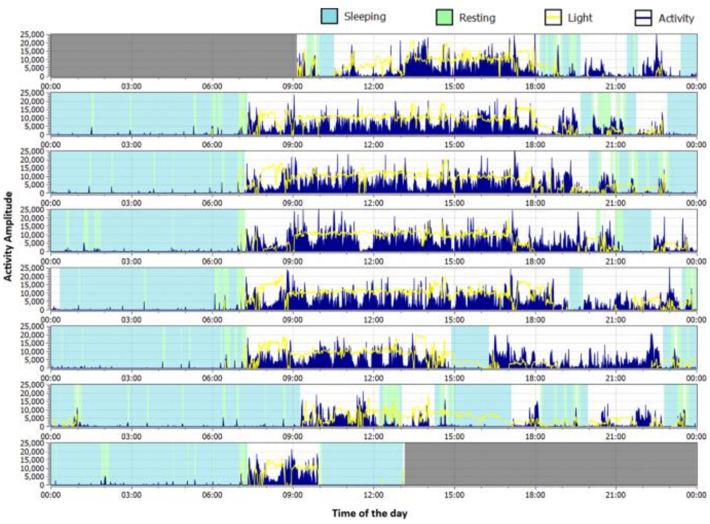


Figure 2.13: How Actigraphy Devices Work [19]

Actigraphy devices measure the frequency and intensity of body movements. These devices consist of an accelerometer, a small piece of technology that detects motion. When the device is worn, it records periods of activity and inactivity[20]. During sleep, the body moves less frequently, so periods of inactivity are often interpreted as sleep. These data are then processed using algorithms to estimate sleep-wake patterns [18].

As author in [19] has proposed A continuous sleep apnea monitoring system that does not require an instrument to measure oxygen saturation (SpO2), pulse rate, and blood pressure in real time. This innovative monitoring device provides a solution to the problems associated with conventional portable sleep apnea monitoring devices. Notably, the acquired observational values from the device bear a strong resemblance to polysomnography results, despite the device's compact design [19].

The primary advantage of actigraphy is its convenience and non-invasive nature. Unlike polysomnography, it does not require a specialized sleep laboratory or trained technicians[19]. The patient can move freely, making it more comfortable and less likely to disrupt sleep [18]. Moreover, actigraphy allows for long-term monitoring, which can provide valuable insights into sleep patterns over time [18]. The results demonstrate promising performance of the algorithm in terms of sensitivity, specificity, positive predictive value, and shows high compactness with polysomnography results[19]. The algorithm shows potential in effectively detecting and distinguishing between central and obstructive sleep apnea events [20][19].

However, actigraphy has limitations. It estimates sleep based on movement, and therefore, it may not accurately differentiate between periods of quiet wakefulness and actual sleep [18]. Also, actigraphy cannot provide the detailed sleep architecture that polysomnography can, such as differentiating between sleep stages or detecting specific sleep disorders like sleep apnea [18]. Finally, the accuracy of actigraphy may be compromised in certain populations, such as those with restless leg syndrome or certain types of movement disorders, where movement may be misinterpreted as wakefulness [18].

2.4.3 Home Sleep Apnea Testing (HSAT)

Sleep apnea, a common sleep disorder, is characterized by interruptions or reduction in airflow during sleep [21]. It involves recurrent instances of upper airway blockage that typically occur while sleeping, often leading to decreased blood oxygen levels [21]. Historically, the diagnosis of sleep apnea relied on polysomnography conducted in sleep laboratories. However, the emergence of Home Sleep Apnea Testing (HSAT) has revolutionized the diagnostic process by enabling patients to undergo evaluation in the comfort of their own homes, offering enhanced convenience and accessibility [20], [21].

Figure 2.14: ApneaTrak HSAT [21].

Sleep apnea, a commonly encountered sleep disorder, entails the interruption or reduction of airflow during sleep [21]. It is characterized by recurrent instances of upper airway obstruction that typically transpire while asleep, often leading to a decline in blood oxygen levels [21]. Conventionally, the diagnosis of sleep apnea involved undergoing polysomnography in sleep laboratories. However, the introduction of Home Sleep Apnea Testing (HSAT) has revolutionized the diagnostic approach, enabling patients to be evaluated in the comfort of their own homes. This advancement brings about improved convenience and accessibility [21].

HSAT is a simplified form of sleep apnea testing performed outside a sleep laboratory, often in the patient's home. The apparatus records essential information such as airflow, respiratory effort, and blood oxygen levels during sleep [21]. It includes devices that record a minimum of channels, namely respiratory effort, airflow, and oxygen saturation. Some advanced HSAT devices also monitor additional parameters such as heart rate, sleep position, and snoring intensity [21]. HSAT has several benefits. First, it offers an increased level of comfort and convenience since patients can be tested in their home environment. This often results in a more natural sleep-wake cycle for the patient, potentially leading to more accurate results [21]. Second, HSAT is generally less expensive than polysomnography, making it a cost-effective solution for diagnosing sleep apnea [21]. It has been suggested that the use of HSAT could help manage the backlog of sleep apnea cases due to the lower cost and increased availability [22].

As mentioned in [23], HSAT procedure is relatively straightforward. Patients are instructed on how to use the device before taking it home, where they will wear it for one or more nights [23]. The device usually includes a nasal cannula or oronasal thermistor to measure airflow, belts to measure chest and abdomen movement, and an oximeter to measure blood oxygen levels [22]. After the completion of the test, the device is returned to the clinic where the data is downloaded and analyzed by a sleep specialist. Data analysis involves assessing the number and duration of apneas and hypopneas, desaturations, heart rate, and sleep position [22]. The results are then discussed with the patient, and a suitable treatment plan is decided upon. This might include lifestyle changes, use of a continuous positive airway pressure (CPAP) device, or surgery in more severe cases [22].

Authors in [23] has conduct a multi center study with 84 patients, where polysomnography and PAT recordings are performed simultaneously. The study utilizes a specific device called WatchPAT, manufactured by Itamar Medical, which records the finger pulse, oximetry, and actigraphy. An algorithm is developed using new parameters derived from the pulse waveform to accurately differentiate between central and obstructive sleep apnea events. The results demonstrate promising performance, the algorithm shows potential in effectively detecting and distinguishing between central and obstructive sleep apnea events [23].

Table 2.4: HSAT severity table [21]

Information	Description
None/normal	AHI is < 5 per hour
Mild	AHI ≥ 5 per hour, but , 15 per hour
Moderate	AHI ≥15 per hour, but <30 per hour
Severe	AHI ≥30

HSAT has demonstrated good sensitivity and specificity for diagnosing sleep apnea, especially moderate to severe cases [22]. However, it may underestimate the apnea-hypopnea index compared to polysomnography, leading to potential misclassification [24]. Furthermore, HSAT's reliability depends heavily on the quality of data collected, which can be influenced by various factors including proper application of the device by the patient, and the patient's sleeping position. It's worth noting that patient instruction and education regarding the use of HSAT devices are crucial to obtaining reliable results [24].

2.4.4 Sleep Diary

A sleep diary serves as a detailed personal record of an individual's sleep behaviors and patterns [25]. The primary purpose of a sleep diary is to gather subjective data on a person's sleep schedule, quality, and duration, contributing significantly to a comprehensive understanding of the individual's overall health and well-being [24]. A well-maintained sleep diary can be an invaluable tool in the identification and management of sleep disorders. It offers a comprehensive picture of a person's sleep habits and is crucial for diagnosing and treating sleep-related health issues. In both clinical practice and research, sleep diaries have been extensively utilized to investigate sleep disorders such as insomnia, sleep apnea, and circadian rhythm disorders [24].

Key elements of a sleep diary typically include bedtime, wake-up time, total sleep duration, perceived sleep quality, number and duration of night-time awakenings, and sleep onset latency. Moreover, a comprehensive sleep diary also records influencing factors like daytime napping, the use of sleep medication or aids, physical activity, diet, caffeine and alcohol intake, and significant daily events or stressors [26].

Fill out before going to bed		
Today's date:	June 13*	
Number of caffeinated drinks (coffee, tea, cola) and time when I had them today:	1 drink, 8 p.m.	
Number of alcoholic drinks (beer, wine, liquor) and time when I had them today:	2 drinks, 9 p.m.	
Naptimes and lengths today:	3:30 p.m., 45 minutes	
Exercise times and lengths today:	None	
How sleepy did I feel during the day today? 1—So sleepy I had to struggle to stay awake during much of the day 2—Somewhat tired 3—Fairly alert 4—Alert	1	

Fill out in the morning		
Today's date:	June 14*	
• Time I went to bed last night: • Time I got out of bed this morning: • Hours spent in bed last night:	11 p.m. 7 a.m. 8	
Number of awakenings and total time awake last night:	5 times, 2 hours	
How long I took to fall asleep last night:	30 minutes	
Medicines taken last night:	None	
How alert did I feel when I got up this morning? 1—Alert 2—Alert but a little tired 3—Sleepy	2	

Figure 2.15: Sleep diary table [25]

As mention in [26] the effective maintenance of a sleep diary requires consistency, honesty, and a commitment to regular recording. Ideally, the diary should be filled out each morning immediately after waking up, ensuring maximum accuracy in recalling the details of the previous night's sleep [26]. To capture a representative picture of an individual's sleep patterns, the diary should be kept for at least two weeks. Daily entries should be made with precise recording of sleep and wake times. Detailed accounts of lifestyle factors and potential sleep disruptors like stress levels, physical activity, and food and beverage consumption should also be meticulously noted [26]. It is critical that individuals record their sleep patterns without trying to alter them. Any necessary changes to sleep patterns should be made only after the collection of baseline data, ensuring an accurate assessment of the impact of any changes [26].

Sleep diaries play a significant role in the assessment of sleep disorders. They provide personalized, detailed insights into an individual's sleep habits over a given time period, supplying information that even sophisticated sleep laboratory studies may not capture [26]. In diagnosing and managing disorders such as insomnia and circadian rhythm disorders, sleep diaries have proven invaluable. Data from the diaries can help identify potential triggers for sleep disturbances, enhance understanding of the correlation between daily activities and sleep patterns, and assist in the development of personalized treatment strategies [26] [25].

2.5 Internet of Things (IoT) and its Application in Healthcare

IoT technology has distinctive characteristics that distinguish it from traditional research fields [27]. Connectivity is a defining characteristic of the Internet of Things, which necessitates establishing connections between various components of IoT hardware and devices, including sensors, interconnected hardware, control mechanisms, and other electronic components. Additionally, connected devices must be able to share data with other IoT ecosystem devices. As the number of connected devices within the IoT environment continues to develop, scalability is a crucial aspect of IoT that bears significant importance. An Internet of Things (IoT) system should be able to accommodate the considerable expansion required to effectively manage the immense quantity of generated data and keep up with the accelerated advancements in this field [27].

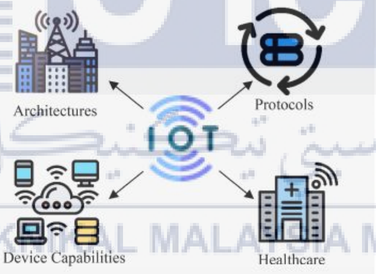


Figure 2.16: IoT device capabilities[27]

A healthcare platform is defined as a comprehensive integration of hardware and software elements that collaborate to deliver a variety of healthcare services and applications to individuals, including healthcare professionals and patients, in order to facilitate efficient and widespread health promotion [27]. Numerous healthcare frameworks exist in the present day, integrating diverse technologies to monitor a variety of human biophysical symptoms and environmental data. This monitoring is accomplished using a variety of wireless communication techniques, including ZigBee, fifth generation (5G), Bluetooth, and Wi-Fi [27].

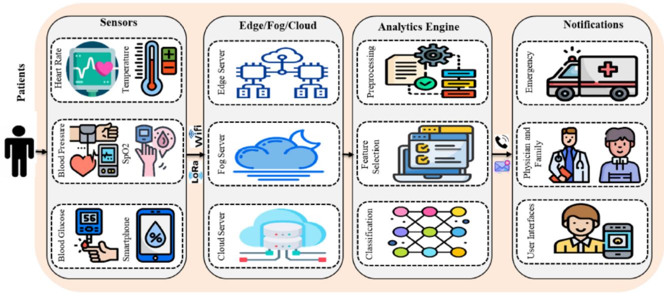


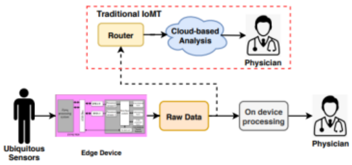
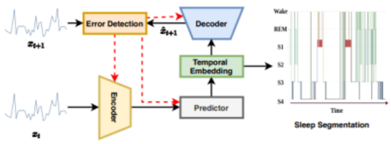
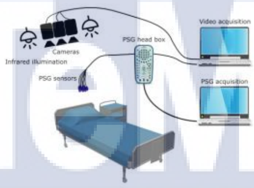
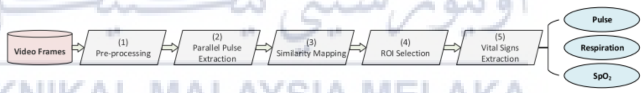
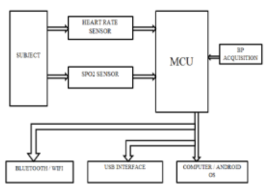
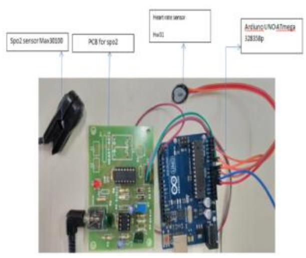
Figure 2.17: General pipeline of IoT-based smart healthcare systems [27]

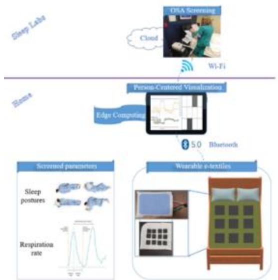
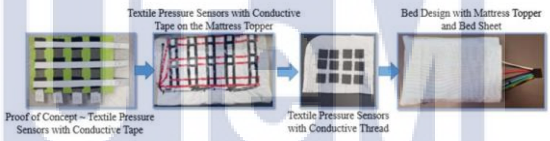
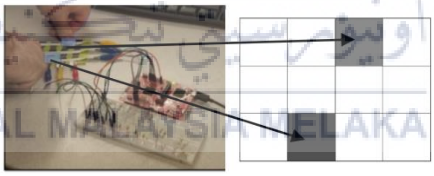
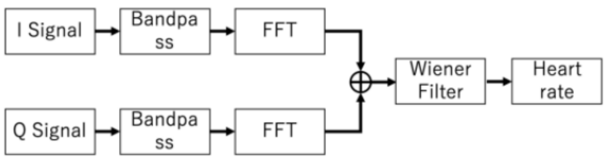
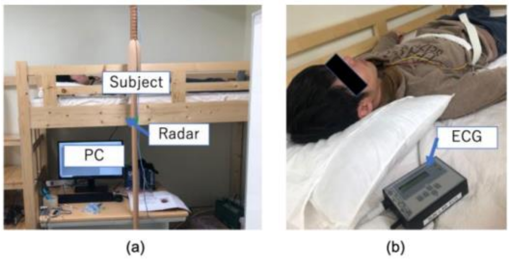
IoT technology plays a pivotal role in supporting healthcare systems by enabling individuals to receive real-time monitoring within the comfort of their smart homes, thereby reducing the need for hospital or clinic admissions and subsequently decreasing emergency costs [27]. Incorporating IoT technologies into the design of intelligent healthcare systems has numerous benefits. In hospital settings, they include improved accessibility, ensuring patient comfort and safety, and reducing patient burden. IoT simplifies data transfer and storage by facilitating the construction of networks comprised of smart devices, cloud applications, and solutions. The most promising IoT healthcare applications include remote monitoring, smart medical devices, smart homes, and wearables. Recent academic and industrial research efforts have concentrated on IoT interoperability, particularly in the healthcare domain, with a strong emphasis on standardizing communication protocols to ensure interoperability among disparate devices, networks, and data structures [28] [29].

To assure Quality of Service (QoS) in healthcare systems, IoT should integrate a number of factors. Among these are the standardization of dependable communication protocols, the improvement of mobile and peripheral devices, and the use of low-cost and low-power embedded processors [30] [31]. The IoT communication architecture is an essential enabling mechanism for decentralized pervasive healthcare applications [32] [33].

2.6 The process flow of the previous paper

Table 2.5: Previous work product and working system.

	Name of project	Model/product/illustration project
1	A Smart IoT System for Continuous Sleep State [14]	 Figure 2.18: IoMT framework for sleep continuous monitoring [14]  Figure 2.19: IoMT The proposed framework [14]
2	Camera-Based Vital Signs Monitoring During Sleep A Proof of Concept Study [13]	 Figure 2.20: Illustration of the camera setup [13]  Figure 2.21: Processing framework from the video data [13]
3	Design and Development of Wearable Device for Continuous Monitoring of Sleep APNEA Disorder [19]	 Figure 2.22: Block diagram of sleep apnea monitoring device [19]  Figure 2.23: Wearable continuous sleep apnea detector [19]

	Name of project	Model/product/illustration project
4	Distinguish Obstructive and Central Sleep Apnea by Portable Peripheral Arterial Tonometry [23]	 Figure 2.24: The WatchPAT system is depicted [23]
5	SleepSmart: Smart Mattress Integrated with e-Textiles and IoT Functions for Sleep Apnea Management [34]	 Figure 2.25: General Diagram of the System [34]  Figure 2.26: The Design Process of Cushion Cover [34]  Figure 2.27: Monitoring Sensor Location and Pressure Changes [34]
	Name of project	Model/product/illustration project
6	Precise Heart Rate Measurement Using Non- contact Doppler Radar Assisted by Machine Learning Based Sleep Posture Estimation [35]	 Figure 2.28: Process of heart rate measurement for radar signal [35]  Figure 2.29: Experimental environment [35]

<table>
<tr><th></th><th>Name of project</th><th>Model/product/illustration project</th></tr>
<tr><td>7</td><td>Rhythm Monitor A Wearable for Circadian Health Monitoring [25]</td><td>

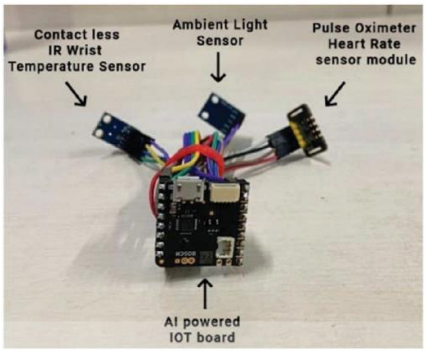

Figure 2.30: Rhythm monitor architecture diagram [25]


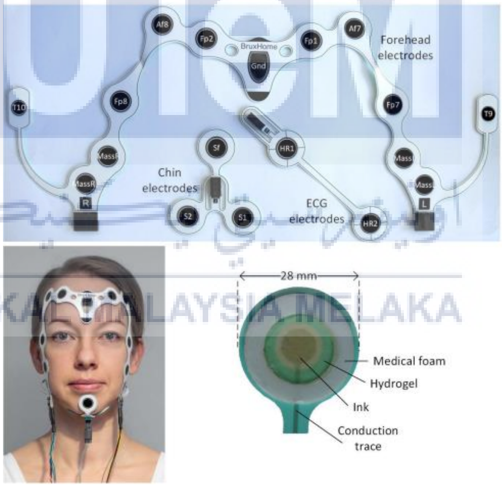
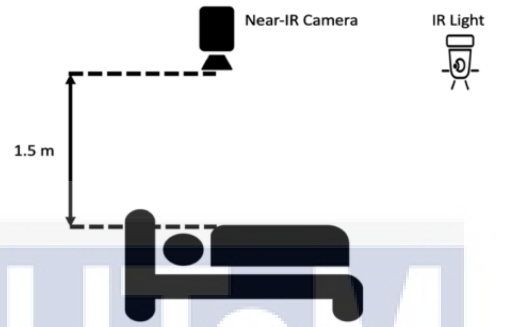
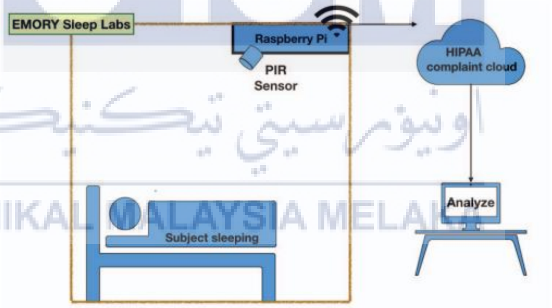
Figure 2.31: Device Prototype [25]
</td></tr>
<tr><td>8</td><td>Self-Applied Electrode Set Provides a Clinically [36]</td><td>


Figure 2.32: The forehead ambulatory electrode set (AES) [36]
</td></tr>
</table>

	Name of project	Model/product/illustration project
9	Validation of Dozee Ballistocardiography based Device for Contactless and Continuous Heart Rate [37]	 Figure 2.33: Working Principle of Dozee [37]
10	Vision Based Heart and Respiratory Rate Monitoring [38]	 Figure 2.34: Data collection setup [38]
11	Obstructive Sleep Apnea Classification in a Mixed-Disorder Elderly Male Population Using a Low-Cost Off-Body Movement Sensor [39]	 Figure 2.35: Illustration of the data acquisition setup [39]

2.7 Comparison of previous paper

Table 2.6:Improvement for previous project

No.	Name of project	Summarize	Advantage	Disadvantage	Improvement
1	A Smart IoT System for Continuous Sleep State[14]	IoT sleep tracking uses self-supervised representation learning and unsupervised segmentation to detect sleep instantly, with security and decentralised learning.	• Affordable: Compared to typical sleep monitoring methods, it's affordable. • Privacy: The system secures sleep data.	• Low-cost OSA monitoring in elderly men with an off-body movement sensor and Raspberry Pi. • High compliance: Allows long-term OSA monitoring and assessment..	• Improve sleep sensor and algorithm accuracy. • User-friendly interface: Make devices and applications simple to understand sleep data.
2	Camera-Based Vital Signs Monitoring During Sleep A Proof of Concept Study [13]	NIR and PPG camera for sleep apnea diagnosis. 8 patients completed comprehensive polysomnography. The camera detected pulse and respiration within 2 BPM with 92% and 91% accuracy.	• Comfortable Sleep Monitoring: Camera-based technology allows patients sleep comfortably without cords or sensors. • Cost-Effective: Camera-based sleep disorder diagnosis and monitoring may be cheaper.	• Less Accuracy: Camera-based sleep measurement may be less accurate than traditional methods. • Individual Variations: Sleep issues and conditions may alter system effectiveness.	• Improve Accuracy: Improve the camera-based system's data analysis methods and procedures. • More Parameters: Broaden the system's sleep data collection.
3	Design and Development of Wearable Device for Continuous Monitoring of Sleep APNEA Disorder [19]	The Design of Wearable Smart Products Based on Big Data studied the popularity of wearables. Surveys show that wristbands and health wearables are popular and affordable, and AI, cloud, and big data improved products.	• Innovation and market response: The initiative creates wearable technologies to meet market demands and grow the sector. • Advancing the industry: Big data, cloud technology, and artificial intelligence boost wearable technology.	• Data security and privacy concerns: Wearable gadgets may collect and use huge data. • Ethics: To retain user trust, data ethics, openness, and informed permission must be addressed.	• Design wearable electronics with user comfort, simplicity, and customization in mind. • Acquire user feedback: To improve the design and include people in the development process.

No.	Name of project	Summarize	Advantage	Disadvantage	Improvement
4	Distinguish Obstructive and Central Sleep Apnea by Portable Peripheral Arterial Tonometry [23]	This study studies sleep apnea and cardiovascular illness. Finger pulse waves detect sleep apnea using PAT. Central and obstructive sleep apnea were detected 66% and 100% by an algorithm. Therapy can benefit from this improvement.	• Sleep Apnea Types: The initiative created algorithms to distinguish central and obstructive sleep apnea. • Reliable Results: Several facilities and patients tested the project algorithms to ensure their accuracy in recognizing and distinguishing sleep apnea.	• Low Central Sleep Apnea Data: The study's central sleep apnea event count was low. • Certain Medications: Patients receiving heart failure-related vasoactive medications were excluded from the trial.	• To better understand and treat central sleep apnea, include more patients in studies. • Algorithm Transparency: Share the study's algorithms to improve algorithm development and cooperation.
5	SleepSmart: Smart Mattress Integrated with e-Textiles and IoT Functions for Sleep Apnea Management [34]	URI's "SleepSmart" uses sensory mattress toppers to detect OSA, with three stages: Sensory first, OSA-tested sensors, and an OSA/sleep quality app.	• Comfortable Monitoring: SleepSmart monitors and detects sleep apnea. • Early Detection: By continuously monitoring your sleep, SleepSmart can detect sleep apnea early on.	• SleepSmart requires a sensor-equipped mattress topper. • Comfort Issues: The mattress topper's sensors may disturb certain sleepers.	• Improve Sensor Integration: Connect sensors and electronics for more accurate data. • Focus on Comfort: Improve user experience by considering thickness and flexibility.
6	Precise Heart Rate Measurement Using Non- contact Doppler Radar Assisted by Machine Learning Based Sleep Posture Estimation [35]	Doppler radar and machine learning measure sleep and heart rate without touching the patient, improving patient comfort and privacy. Algorithms estimate patient sleep stability, predicting better heart rate and sleep position.	• Non-contact Monitoring: Doppler radar technology permits heart rate monitoring without physical touch, making it pleasant and non-invasive. • Privacy Preservation: Non-contact, wearable-sensor-free monitoring protects patient privacy.	• Environmental Factors: Wall materials, room size, and radio waves impact radar-based system performance. • Data Interpretation Challenges: Users and caretakers may need training to understand data and make informed health decisions.	• Better flexibility: Improve the system's flexibility. • Easier to Use: Make the system simpler and more integrated with other health apps to provide users a complete health picture.

No.	Name of project	Summarize	Advantage	Disadvantage	Improvement
7	Rhythm Monitor A Wearable for Circadian Health Monitoring [25]	Rhythm Monitor tracks heart rate, wrist and ambient temperature, light exposure, and exercise to improve circadian health and avoid health concerns.	• Health Monitoring: The initiative tracks the individual's circadian rhythm-related physical indicators to provide a holistic perspective of their health. • Convenient: As a wearable device, it makes health monitoring accessible to anyone.	• Privacy Concerns: Continuous health tracking collects and processes sensitive personal health data. • Adherence: Device success depends on user compliance.	• Data Security Enhancements: Improve data encryption and privacy to reduce privacy issues. • User-friendly Interface: Make the device's interface more intuitive to help users comprehend and act on health information.
8	Self-Applied Electrode Set Provides a Clinically[36]	A self-applied electrode set (AES) was developed to assess brain activity during HSAT for OSA diagnosis, and 38 OSA suspects had one-night HSAT with AES. HSAT ranks OSA severity lower than AES, suggesting it may improve home OSA diagnosis.	• Improved accuracy: EEG, EOG, and EMG recordings enable the AES diagnose sleep apnea by assessing sleep quality and identifying particular sleep disorder patterns.	• Limited size options: The AES only provides one size, which may not suit all users and cause pain.	• Multiple sizes: Offering several electrode set sizes would increase comfort and usability for persons with different facial shapes and sizes.
9	Validation of Dozee Ballistocardiography based Device for Contactless and Continuous Heart Rate[37]	Dozee is a touchless HR and RR detector that provides accurate long-term hospital and home vital sign monitoring, helping patients identify health issues early.	• Contactless Monitoring: The Dozee device monitors vital signs without physical contact or attachments. • Cost-effectiveness: The Dozee device is cheaper than other monitoring methods.	• Limitations: The Dozee only measures heart rate and respiration rate, neither blood pressure or oxygen saturation.	• Evaluate other devices: To understand the Dozee device's strengths and shortcomings, compare it to other monitoring techniques.

No.	Name of project	Summarize	Advantage	Disadvantage	Improvement
10	Vision Based Heart and Respiratory Rate Monitoring [38]	Infrared video can be used to measure sleep-related respiratory and heart rates, but its accuracy needs improvement. Non-contact sleep respiration rate monitoring can detect sleep disorders.	• Convenient and accessible: Anyone may do it at home with cheap infrared cameras. • Home use: This technology could be used to develop a home sleep monitoring system to make sleep health tracking easier.	• Less accurate heart rate estimate: This method's heart rate monitoring during sleep is less accurate than respiratory rate estimation. • Effect of blanket thickness: Motion tracking may be influenced by blanket thickness.	• Movement interference: Body motions might affect respiratory and heart rate measures. • User-friendly interface: Create a simple sleep tracking interface.
11	Obstructive Sleep Apnea Classification in a Mixed-Disorder Elderly Male Population Using a Low-Cost Off-Body Movement Sensor [39]	This experiment classified older men's obstructive sleep apnea with 91% accuracy using a cheap off-body movement sensor. It might be used for home and clinical monitoring and assessment.	• Low-cost solution: An off-body movement sensor and Raspberry Pi can monitor older men's OSA. • High compliance: The sensor's simplicity and ease of use encourage high compliance, allowing long-term OSA monitoring.	• Small study size: 32 older men may limit generalisation. • No standard: The logistic regression model accurately identified OSA, however the research did not compare its findings to PSG.	• Increase sample size: Use a bigger and more varied sample to make the results more generalizable and relevant to a wider population. • Explore more: New attributes from movement data or other sources may improve categorisation accuracy and system performance.

2.8 Summary of Past Related Paper

An extensive review of numerous scholarly articles shows that various technologies are being applied to Internet of Things (IoT) based sleep monitoring. Each of these technologies demonstrates different strengths and limitations and varies in accuracy and utility. Table 5 provides an organized overview, comparing the method and technique mentioned in various journals, broken down by their respective authors.

Table 2.7: Literature review summarization

Ref	Method used				Technique			Continuos	Non continuos
	CAM	PIR	Heart rate	Textile	HSAT	PAT	PSG		
1[14]	✓		✓				✓	✓	
2[13]	✓		✓				✓	✓	
3[19]			✓				✓	✓	
4[23]			✓		✓	✓			✓
5[34]				✓					✓
6[35]			✓					✓	
7[25]			✓						✓
8[36]			✓		✓		✓	✓	
9[37]			✓		✓		✓	✓	
10[38]	✓		✓				✓	✓	
11[39]		✓					✓	✓	
Project	✓				✓			✓	

Note: CAM = camera, PIR = pir motion sensor, Heart Rate = Heart rate sensor, Textile = pressure sensor, HSAT = Home Sleep Apnea Testing, PAT = peripheral arterial tonometry, PSG = Polysomnography.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodologies used to create the proposed IoT-based sleep monitoring system. This includes an explanation of the system development process flow, the selection of hardware and software, and the proposed system's working flow.

3.2 Methodology

The system utilizes a Raspberry Pi 4B, a power supply, and a night vision infrared camera for hardware development. Python programming plays a pivotal role, enabling tasks like pose detection, voice assistance, and accuracy assessment. ThingSpeak is chosen platform for creating and managing the system's dashboard, offering enhanced data visualization and monitoring capabilities.

3.3 Hardware requirement

The achievement of this project's study heavily relies on the hardware infrastructure employed. Each hardware component assumes a distinct and pivotal role in facilitating the research inquiry. The specific hardware elements utilized in this project are depicted in Figure 3.1, meticulously chosen to support the development and implementation of the study objectives.

In this project, the Raspberry Pi 4B is chosen as the single-board computer, offering extensive support for multiple programming languages such as Python, C, C++, and more. With the Raspberry Pi 4B's versatile capabilities and multi-programming language compatibility, this project can be successfully executed.

3.4 First phase: Gathering Movement Data through Hardware and System

Figure 3.1 illustrates the block diagram of the initial phase of a sleeping pattern monitoring system. This diagram comprises two main sections: sleep posture detection and image processing. The sleep posture detection section incorporates a webcam, mini-PIR sensor, and Raspberry Pi. In contrast, the image processing section includes Raspberry Pi and machine learning using TensorFlow.

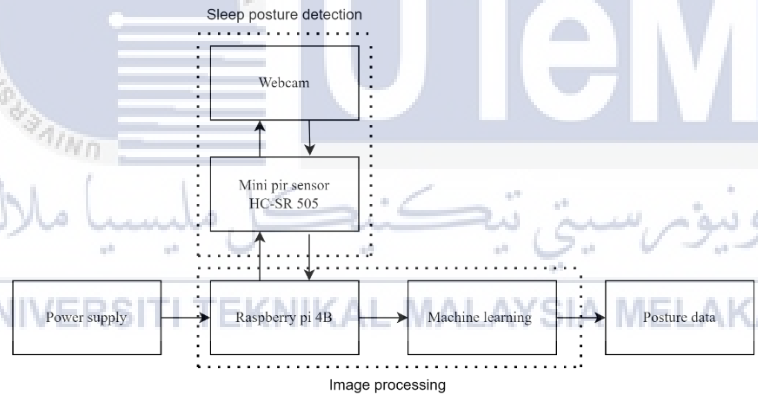


Figure 3.1: Block diagram for collecting posture data

Figure 3.2 illustrates the hardware connectivity arrangement for this system. The central component of the system is the Raspberry Pi 4B microcontroller. Additional components, including the Mini PIR sensor (HC-SR505) and Webcam, are connected to the Raspberry Pi 4B on GPIO 14 and the USB port, respectively. Once the Raspberry Pi 4B is programmed and the necessary libraries are installed, the mini-PIR sensor and Webcam will be detected by the system and activated accordingly.

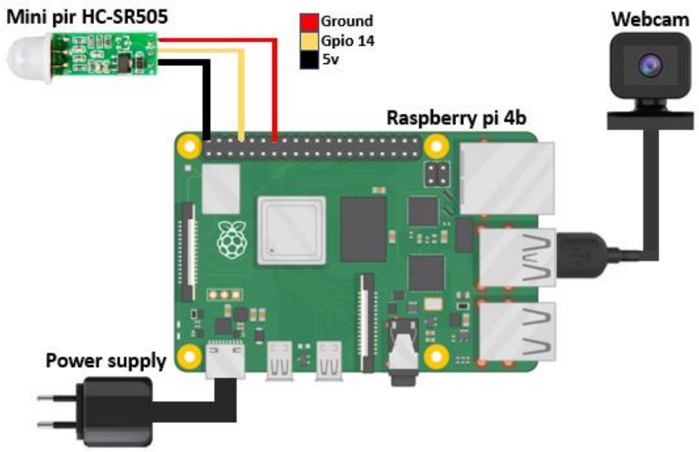


Figure 3.2: The circuit design for collecting movement data

Figure 3.3 illustrate the positioning of each component and subject. The Mini Pir sensor will be put together with the Webcam. Webcam and PIR sensor will be positioned 3 meters beside the subject due to the spec of the PIR sensor. The sensing range is 3 meters. The raspberry pi will also be put together with the Pir sensor and Webcam.

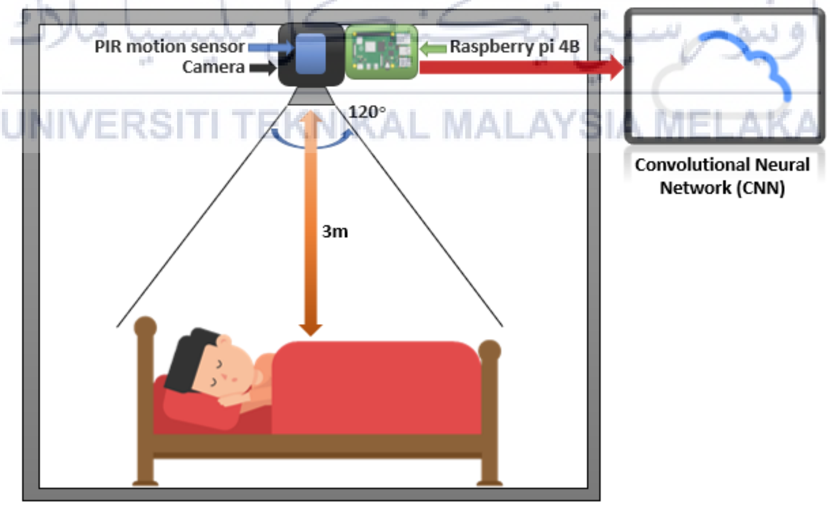


Figure 3.3: First phase illustration of sleep monitoring

3.5 Second phase: Developing Hardware and Designing the System

Figure 3.4 depicts the block diagram of the finalized system design and hardware development. The diagram is divided into three main sections: sleep posture detection, image processing, and user interface. Notably, in this finalized block diagram, the mini PIR sensor and webcam have been omitted. This removal is attributed to the completion of data collection. Instead, a night IR sensor has been incorporated to enable the system to operate during the night, utilizing the previously gathered data.

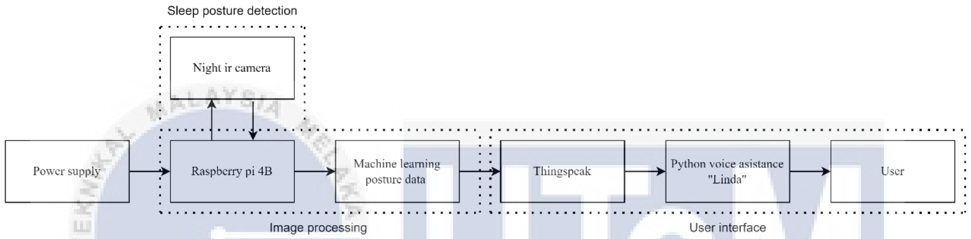


Figure 3.4: Block diagram of second phase system design

Figure 3.5 illustrates the physical connections to the Raspberry Pi. The USB microphone will be connected to one of the USB outlets, while an auxiliary speaker will be connected to the auxiliary outlet. The night IR camera will be plugged into the dedicated camera port. Lastly, the 3.5-inch display and the ice tower fan will be connected to the GPIO (General Purpose Input/Output) pins of the Raspberry Pi.

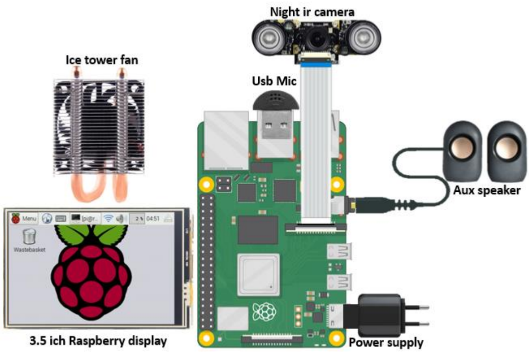


Figure 3.5: The circuit of second phase system design

Figure 3.6 depicts the arrangement of each component and subject in the system. The night IR camera, ice tower fan, and 3.5-inch display will be housed in a single case attached to a tripod. This assembly will be positioned 3 meters beside individual. The speaker will be placed below the tripod, along with the power supply.

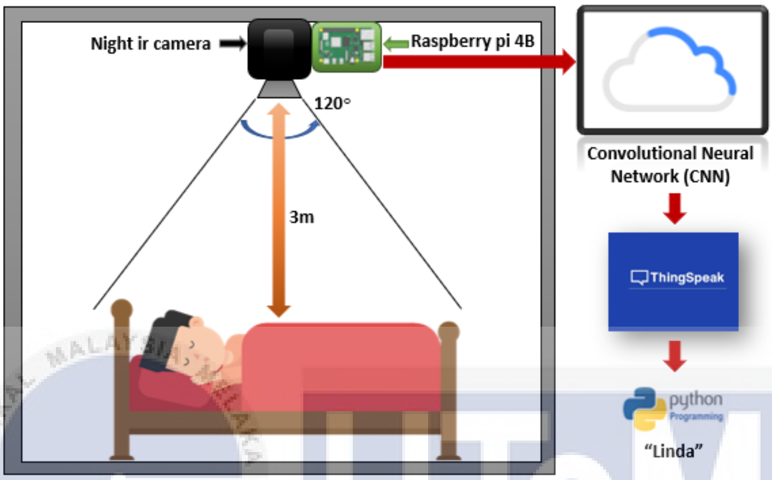


Figure 3.6: Second phase illustration of sleep monitoring

3.5.1 Raspberry pi 4B

The Raspberry Pi 4 Model B, released by the Raspberry Pi Foundation in June 2019, is a compact computer known for its impressive performance. It features a quad-core 64-bit ARM Cortex-A72 CPU clocked at 1.5 GHz, surpassing its predecessors. With memory options ranging from 2GB to 8GB LPDDR4-3200 SDRAM, USB and USB 3.0 ports, Wi-Fi, Bluetooth, micro-HDMI ports, and a camera interface, it offers flexibility and connectivity. Powered by a microSD card and Raspberry Pi OS, this versatile device can run different Linux distributions and even supports Windows 10 IoT Core.

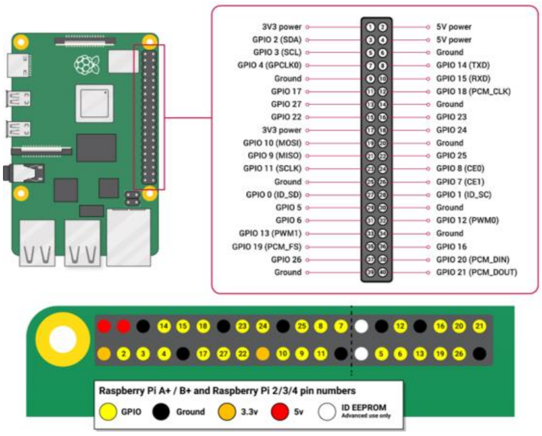


Figure 3.7: Raspberry pi io pins

The Raspberry Pi 4's GPIO pins make connecting sensors, LEDs, and other electronic components easy, allowing users to bring their creative projects to life. The Raspberry Pi 4 sparks creativity and offers limitless possibilities, from building media centers to home automation systems. It's an accessible and enjoyable tool for learning about computers, programming, and electronics, making technology available to everyone. Combining performance, flexibility, and a user-friendly interface, the Raspberry Pi 4 is popular among hobbyists, educators, and tech enthusiasts.

Raspberry Pi will be performing a lot of different tasks, from basic data preprocessing to running a machine learning model to communicating with an external app. It's a powerful little device that's capable of handling complex operations, making it a good fit for this project.

3.5.2 Mini pir sensor HC-SR505

The HC-SR505 Mini PIR Motion Sensor utilizes infrared technology with high sensitivity and reliability for automatic control. Its small size and low-power operation mode makes it widely used in various automatic electronic equipment, particularly battery-powered products. This sensor can accurately detect motion by sensing changes in infrared radiation, allowing for seamless integration into automation systems. It finds applications in home automation, security systems, lighting control, robotics, and other battery-powered devices, providing efficient and precise motion detection for enhanced automation and convenience.

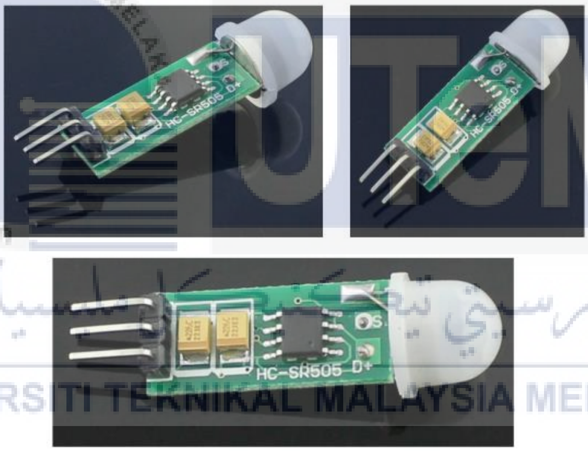


Figure 3.8: HC-SR505 Mini PIR Motion Sensor

Table 3.1: Mini pir motion sensor specifications

Information	Description
Operating voltage range	DC4.5-20V
Quiescent Current	<60uA
Trigger reusable trigger	(default)
Delay Time	The default 8S + -30%
Board Dimensions	10*23mm
Sensing distance	3 meters

3.5.3 Web cam

A 1080P HD USB webcam can be utilized in sleep monitoring applications by capturing high-resolution video of a person's sleep patterns. Placed in a suitable position, the webcam records the individual's movements throughout the night, allowing for detailed analysis of their sleep quality and patterns. The high resolution of the webcam enables the detection of even subtle movements, providing valuable insights into restless sleep or frequent changes in sleep positions. By processing the captured video feed with computer vision algorithms, sleep monitoring systems can extract relevant data such as sleep duration, restless periods, and sleep disturbances. This information can evaluate sleep quality, identify potential sleep disorders, and suggest personalized sleep improvement strategies. By leveraging the high-resolution video capabilities of the webcam, sleep monitoring systems can provide a non-intrusive and effective means of tracking and analyzing sleep patterns to enhance overall sleep health.

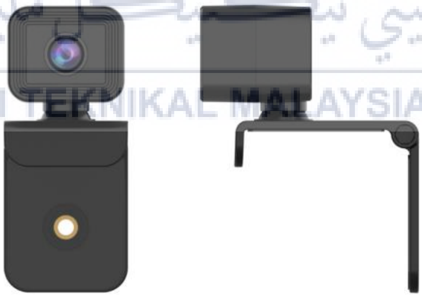


Figure 3.9: 1080P HD USB

Table 3.2: Usb webcam specification

Information	Description
Resolution	1920*1080 P
View Angle	120º Large wide-angle lens
Video Resolution	1920*1080 P
Mic	Built-in MIC
Fixed Focus	Yes

3.5.4 Night Infrared (IR) Camera for Raspberry Pi - 5MP

The integration of the Night IR Camera into the development of a Sleeping Pattern Monitoring System significantly augments the project's capabilities. With its 5-megapixel resolution and advanced IR features, the camera extends beyond conventional sleep pattern monitoring, ensuring enhanced security in low-light conditions. Moreover, it broadens functionality to encompass wildlife observation, catering specifically to users with outdoor sleeping arrangements. The camera's capacity for ambient monitoring contributes to a comprehensive assessment of factors influencing sleep quality. Additionally, its application in astrophotography introduces a visually soothing component to the bedtime experience, thereby incorporating both practical and recreational features into the sleep environment.

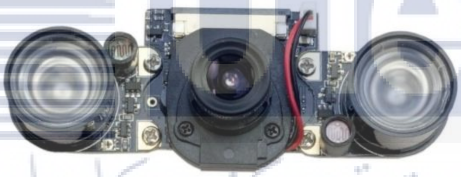


Figure 3.10 : Night Infrared (IR) Camera

Table 3.3: Night Infrared (IR) Camera specification

Feature	Description
Resolution	5 Megapixels (2592 x 1944 pixels)
Sensor Type	High-fidelity IR-sensitive CMOS sensor
Lens Type	Wide-angle lens with adjustable focus
Infrared LEDs	Integrated infrared LEDs for superior night vision
IR Cut Filter	Automatic IR cut filter ensuring seamless day-to-night transitions
Frame Rate	Up to 30 frames per second (fps)
Field of View (FOV)	Broad-angle FOV for comprehensive scene coverage

3.6 Software requirement

3.6.1 Raspberry pi software

Raspberry Pi OS (64-bit), the official operating system for Raspberry Pi computers, is specifically designed to harness the full potential of 64-bit architecture. Offering improved performance, expanded memory addressing capabilities, and support for resource-intensive tasks enables users to tackle demanding applications such as media streaming and data analysis. While retaining its user-friendly nature, the OS comes pre-installed with software like Python and various educational tools. Compatible with GPIO pins and a wide range of software frameworks, Raspberry Pi OS (64-bit) caters to diverse projects in fields like home automation, robotics, and server applications, combining accessibility with the benefits of 64-bit computing.

Figure 3.11: Raspberry pi imager

3.6.2 Python

Python is a highly regarded and versatile programming language renowned for its simplicity and readability. Its clean syntax and extensive library support make it well-suited for various domains, including web development, data analysis, machine learning, and more. Python boasts a thriving ecosystem of libraries and frameworks, such as Django and TensorFlow, empowering developers to build complex applications efficiently. It's dynamic typing, automatic memory management, and support for multiple programming paradigms contribute to its flexibility and accessibility, appealing to novice and experienced programmers. Moreover, Python's cross-platform compatibility facilitates seamless execution across different operating systems. Python's widespread adoption can be attributed to its user-friendly nature, elegant readability, and robust community support, rendering it a prime choice for diverse applications.

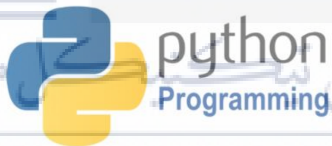


Figure 3.12: Python programming language

Table 3.4: List of libraries

Pose detection		
Library	Alias	Purpose
cv2	OpenCV	Open-Source Computer Vision Library. Used for image and video processing, including capturing frames from a webcam, image manipulation, and drawing on images.
mediapipe	mp	MediaPipe is a library for building multimodal (e.g., hands, face, and pose) pipelines. In this code, it's used for pose estimation, specifically for detecting the position of body parts in a video stream.
math		Standard Python library for mathematical operations. Used for calculating angles and performing other mathematical calculations.

Library	Alias	Purpose
time		Standard Python library for handling time-related functions. Used for tracking elapsed time, timing intervals, and sleep detection.
requests		HTTP library for sending HTTP requests. Used for sending data to ThingSpeak, an Internet of Things (IoT) platform.
Voice assistance		
webbrowser		Provides a high-level interface to allow displaying Web-based documents to users. Used to open URLs for playing music and opening Python code.
requests		A popular HTTP library for sending HTTP requests. Used for fetching news, weather, prayer times, and ThingSpeak data.
BeautifulSoup		A library for pulling data out of HTML and XML files. Used for scraping news data from HTML content.
gTTS		Google Text-to-Speech API wrapper for Python. Used for converting text to speech for audio output.
os		Provides a way of interacting with the operating system. Used for system-level operations, such as stopping music.
speech_recognition	sr	Library for performing speech recognition. Used for listening to user commands and processing them.
datetime		A module to work with dates and times. Used for getting the current date and time.
time		Standard Python library for handling time-related functions. Used for timing intervals, waiting, and sleep detection.
dateutil		A library extending the capabilities of datetime. Used for parsing dates and calculating time differences.
threading		Provides support for threading. Used for running functions concurrently, such as handling alarms and reminders.
pygame		A set of Python modules designed for writing video games. Used for playing audio files in the background.

Library	Alias	Purpose
mixer		A module in the pygame library for handling sound mixing. Used for initializing and playing audio files.
subprocess		Provides a way to spawn new processes, connect to their input/output/error pipes, and obtain their return codes. Used for opening Python code in a separate process.
psutil		Cross-platform library for retrieving information on running processes and system utilization. Used for stopping a Python script process.
timedelta		Represents the difference between two dates or times. Used for setting alarms and reminders with specified time intervals.
Confusion matric method		
pandas	pd	A data manipulation and analysis library. Used for reading and working with Excel data.
sklearn.metrics		Part of scikit-learn, a machine learning library. Used for calculating the confusion matrix.
seaborn	sns	A data visualization library based on Matplotlib. Used for creating visualizations of the confusion matrix.
matplotlib.pyplot	plt	A 2D plotting library. Used for creating plots, including the confusion matrix visualization.

3.6.3 ThingSpeak

ThingSpeak, a product of MathWorks, stands out as a pivotal platform in the Internet of Things (IoT) landscape, facilitating the efficient collection, analysis, and visualization of data from diverse interconnected devices. Through its user-friendly interface, users can create channels to link with sensors and devices, enabling real-time data processing with customizable MATLAB analytics. This platform's unique features include interactive capabilities, triggering automated responses based on predefined conditions. Notably, ThingSpeak accessibility, offering both free and premium plans, has contributed to its widespread adoption across applications such as industrial automation, weather monitoring, and healthcare. In essence, ThingSpeak serves as a comprehensive and user-friendly tool for individuals and organizations seeking to harness the power of IoT for data-driven decision-making.

Figure 3.13 : ThingSpeak application

3.6.4 Tensor flow

TensorFlow, an open-source machine learning library, was developed by the Google Brain team and has gained significant popularity due to its capabilities and flexibility. The library employs tensors as its fundamental data structure, enabling the representation of data as vectors and matrices of potentially higher dimensions. It utilizes a dataflow graph to express computations based on the dependencies between individual operations, thereby facilitating efficient calculation and the possibility for parallelism and distributed execution.

Figure 3.14: Tensor Flow library

The recent addition of "eager execution" in TensorFlow 2.0 has made the platform more approachable for beginners and more intuitive for research and development, enabling operations to be computed as they are called within Python. TensorFlow supports a multitude of machine learning and deep learning algorithms, with high-level APIs for the construction and training of neural networks.. Furthermore, TensorFlow models can be deployed for inference on a wide variety of platforms, including servers, mobile devices, and even browsers using TensorFlow.js. Lastly, TensorFlow boasts a vibrant and making it a comprehensive and dynamic ecosystem for machine learning development and deployment.

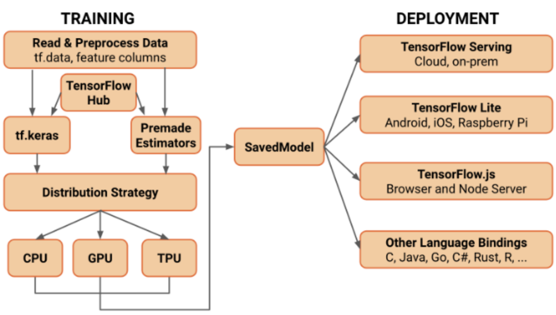


Figure 3.15: New architecture of TensorFlow 2.0

3.6.5 Autodesk Tinkercad

The integration of Autodesk Tinkercad version 3.6.5 has proven to be instrumental in the meticulous development of the Sleeping Pattern Monitoring System using the Internet of Things (IoT). The platform's advanced features, embedded within its user-friendly interface, facilitate the detailed design of a customized physical case to house critical components of the sleep monitoring system. Leveraging Tinkercad drag-and-drop functionalities allows for the seamless integration of diverse hardware elements, ensuring precision in accommodating sensors and the Raspberry Pi.

Figure 3.16: Autodesk Tinkercad design

The platform's distinct advantage extends to its support for electronics design, enabling a visualized layout planning process. This feature proves instrumental in optimizing the spatial arrangement of components within the case, prioritizing both functional efficacy and aesthetic coherence. Tinkercad iterative design capabilities have significantly expedited the refinement process, contributing to the seamless development of the physical enclosure for this IoT-centric sleep monitoring initiative. Regular reference to the official Autodesk Tinkercad documentation ensures staying abreast of the latest features and updates, underscoring the reliability and efficacy of this indispensable tool in realizing project goals.

3.7 The working flow of the proposed system

3.7.1 Sleep monitoring flowchart

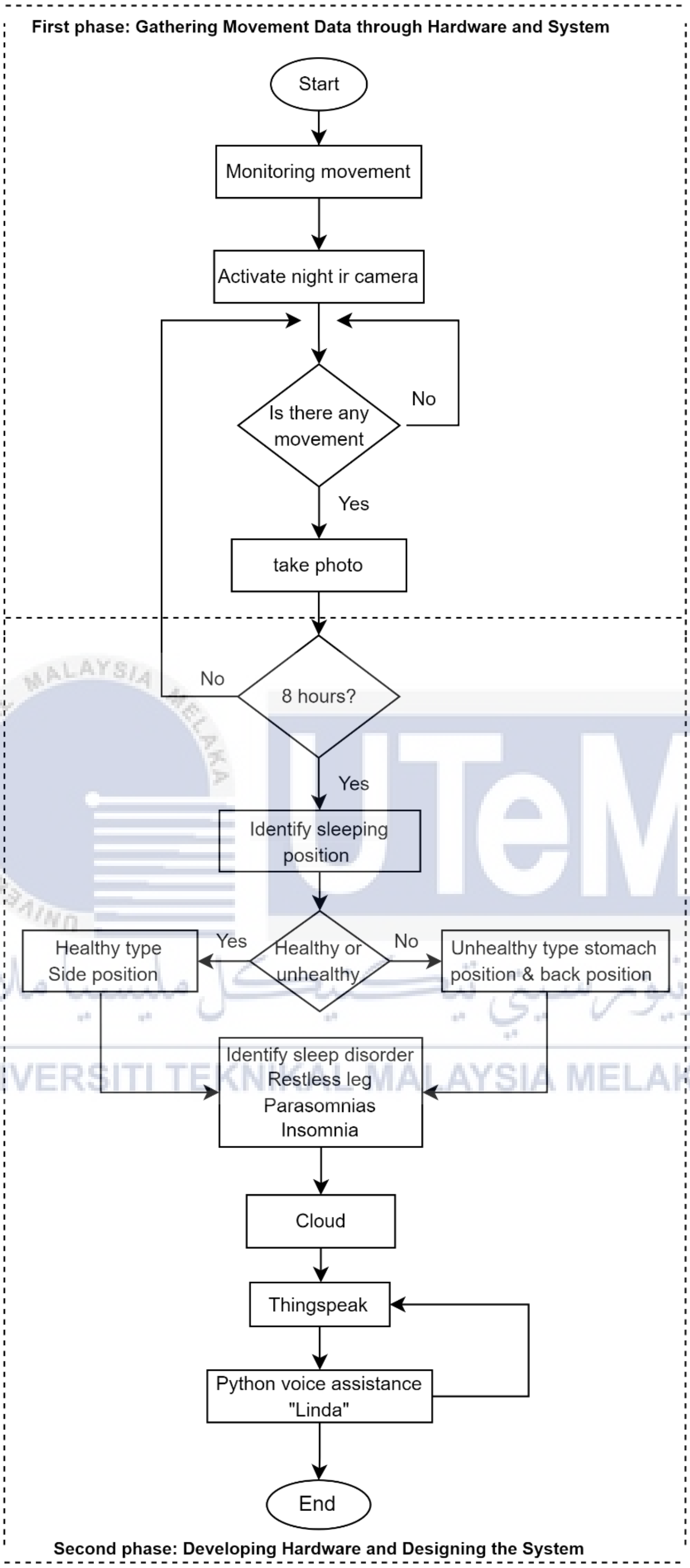


Figure 3.17: Flowchart of sleeping monitoring system

The system is structured in two distinctive phases. In the initial phase, the system commences with continuous movement monitoring, deploying a night infrared camera to enhance visibility in low-light conditions when no movement is detected. Upon movement detection, a photo is captured to serve as a comprehensive record. After an 8-hour duration, the system proceeds to the second phase, where it conducts a detailed analysis of the captured photo. This involves categorizing the sleeping position as either healthy (side position) or unhealthy (stomach or back position), and identifying specific sleep disorders such as restless leg syndrome, parasomnias, or insomnia.

The integration with cloud platforms and Thingspeak facilitates seamless data storage and analysis, ensuring the collected information, including sleep positions and identified sleep disorders, is efficiently transmitted for comprehensive examination. Additionally, the project incorporates a Python voice assistance program named "Linda" to provide articulate and user-friendly feedback or assistance based on the results of the sleep pattern analysis.

The formalized structure of this two-phase system aligns with the overarching goal of developing an innovative sleeping pattern monitoring system using IoT, promising not only technical excellence in movement data acquisition and sleep pattern analysis but also a user-friendly experience with the integration of cloud-based storage and voice-assisted feedback.

3.7.2 Block diagram of sleep posture detection

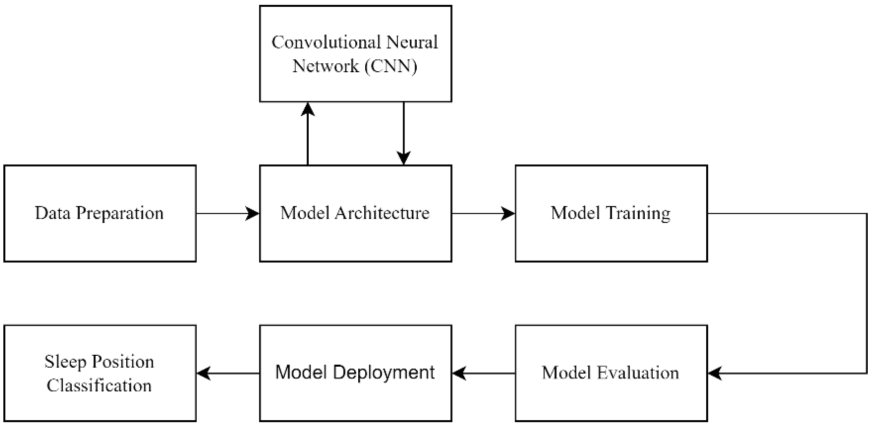


Figure 3.18: Application of TensorFlow in posture identification

Table 3.5: Block diagram explanation

Block diagram	Explanation
Data Preparation	This constitutes the initial phase where the collected image or video data is loaded into the TensorFlow environment. Necessary preprocessing steps, including image resizing or video frame extraction, are executed during this stage to ensure data compatibility with the upcoming model.
Model Architecture Definition	After data preparation, the architecture of the machine learning model is defined. This project which involves image and video processing, a Convolutional Neural Network (CNN) is typically chosen due to its proficiency in identifying spatial patterns within images.
Model Training	The training phase involves feeding the labeled dataset through the designed model. The performance of the model is continuously assessed, and its parameters are adjusted accordingly with the assistance of optimization algorithms provided by TensorFlow.

Block diagram	Explanation
Model Evaluation	Post-training, the model's performance is scrutinized by testing it on a separate dataset that was not part of the training process. This step serves as a proxy for the model's potential performance on new, unseen data in the future. The test data will be taken and tested on 10 people.
Model Deployment	Once the model demonstrates satisfactory performance, it is deployed onto the Raspberry Pi. Notably, TensorFlow has a Raspberry Pi-compatible version which facilitates this step.
Sleep Position Classification	Upon deployment, the model is utilized to classify sleeping positions. The Raspberry Pi interfaces the image or video data captured by the webcam with the deployed TensorFlow model, resulting in a prediction of the individual's sleeping position.

3.7.3 Voice assistance "Linda"

"Linda" is a sophisticated voice assistant meticulously designed to provide a seamless and intuitive interaction experience. Named after its distinctive personality, "Linda" is a fusion of cutting-edge technology and thoughtful planning, offering a range of functionalities to assist users in various tasks. In creating "Linda," the aim was to develop a voice assistant that seamlessly integrates into users' lives, providing both utility and a touch of sophistication. As "Linda" evolves, it promises to be a reliable and intelligent digital companion, assisting users in navigating the complexities of daily tasks through intuitive voice commands.

Table 3.6: Detailed Overview of the Voice Assistant (Linda)

Stage	Description
Conceptualization and Planning	In the pursuit of developing a sophisticated digital assistant, meticulous planning and ideation were paramount. The initial phase involved conceptualizing the desired functionalities, encompassing tasks ranging from real-time data retrieval to entertainment and time management.
Technology Stack and Architecture	The foundation of this voice assistant project rests upon the robust capabilities of Python. A carefully chosen set of libraries and APIs were instrumental in enhancing its features. Key components include speech recognition, text-to-speech conversion, and seamless integration with external APIs for comprehensive information retrieval.
Speech Recognition Implementation	Employing the SpeechRecognition library, the voice assistant is adept at understanding and interpreting spoken commands from the user. This foundational element ensures fluid and intuitive interaction

Stage	Description
Task Execution Mechanism	Each voice command triggers a specific function, allowing the assistant to execute tasks such as music playback, news reading, information provision, and alarm setting. The implementation of threading ensures concurrent task management, providing a responsive and dynamic user experience.
API Integration for Real-Time Data	Real-time data retrieval is facilitated through the integration of APIs such as News API for current headlines, OpenWeatherMap API for weather updates, and Aladhan API for accurate prayer times. The secure management of API keys is a critical aspect of this integration.
Natural Language Processing (NLP) for Enhanced Interaction	A rudimentary form of Natural Language Processing (NLP) has been implemented to extract pertinent information from user commands. This includes setting reminders with specific texts and times, adding a layer of intelligence to the assistant's functionality.
Iterative Development and Continuous Improvement	The project has undergone multiple iterations to refine features, address bugs, and elevate the overall user experience. Valuable feedback from testing phases has played a pivotal role in shaping the continuous improvement process.

Table 3.7: Available Commands Voice

Command	Description
"Linda"	Trigger phrase to activate the assistant.
"Read top news"	Reads the latest top news.
"Play music"	Plays acoustic music.
"Stop music"	Stops the currently playing music.
"What is restless leg"	Explains restless legs syndrome.
"What is parasomnia"	Explains parasomnia.
"What is insomnia"	Explains insomnia.

Command	Description
"What is the reference for all the information"	Provides the information reference source.
"Tell me the date and time"	Provides the current date and time.
"Weather"	Provides the current weather information.
"Prayer times"	Provides the prayer times for the day.
"Set an alarm for [time]"	Sets an alarm for the specified time.
"Set a reminder [text] at [time]"	Sets a reminder with specific text at the specified time.
"Stop alarm"	Stops the currently active alarm.
"Stop reminder"	Stops the currently active reminder.
"Sleep data"	Provide a conclusion from collected data and give recommendation.
"Exit"	Exits the voice assistant.

Figure 3.19: Voice Assistance "Linda"

3.7.4 Designing a User-Friendly Custom Project Casing

Within the dynamic landscape of technological progress, the deliberate design of a user-friendly custom project casing plays a pivotal role in shaping an enhanced user experience. This section explores the intricacies of "Designing a User-Friendly Custom Project Casing," emphasizing the convergence of precision engineering and intuitive design. The goal is to produce a protective casing that not only ensures the security of project components but also introduces an unparalleled level of usability. Throughout this discussion, our focus remains on attaining a meticulous equilibrium between form and function, creating a casing that embodies tailored excellence and redefines benchmarks in project design and usability standards.

3.7.4.1 Modular Design Elements for Enhanced Functionality and Aesthetics in Raspberry Pi Case

In the meticulous design process of a custom Raspberry Pi case using TinkerCAD, deliberate partitioning optimizes 3D printing quality and streamlines assembly. Each component serves specific functions, contributing to an efficient and well-rounded design. This modular approach ensures optimized 3D printing and guarantees that each part is purposeful, enhancing both functionality and aesthetics. Compartmentalization facilitates customization, efficient assembly, and an enhanced user experience with the final product.

Table 3.8: Explanation for each case part

Part	Explanation
Raspberry Pi Lower Cover	Functioning as a secure housing unit for the Raspberry Pi, this part shields the internal components from external elements, maintaining a compact and organized internal arrangement.
Tripod Mounting Feature	Incorporating a tripod mounting capability, this component offers versatile placement options, allowing users to position the Raspberry Pi setup in diverse environments.
Ice Cold Raspberry Pi Fan Cover	This component is designed to facilitate efficient cooling for the Raspberry Pi, promoting optimal performance and longevity.
LCD Back Cover	Dedicated to safeguarding the LCD display, this component protects against potential damage or scratches, thereby ensuring the longevity and clarity of the display during operation.
Raspberry Pi Upper Part Cover	Providing easy access to the internal components of the Raspberry Pi, this part ensures simplified maintenance and adjustments without necessitating the disassembly of the entire case.
LCD Front Bezel Cover	This component serves to enhance the overall aesthetic appeal of the case with a polished front bezel, providing a sleek and professional appearance for the entire project.

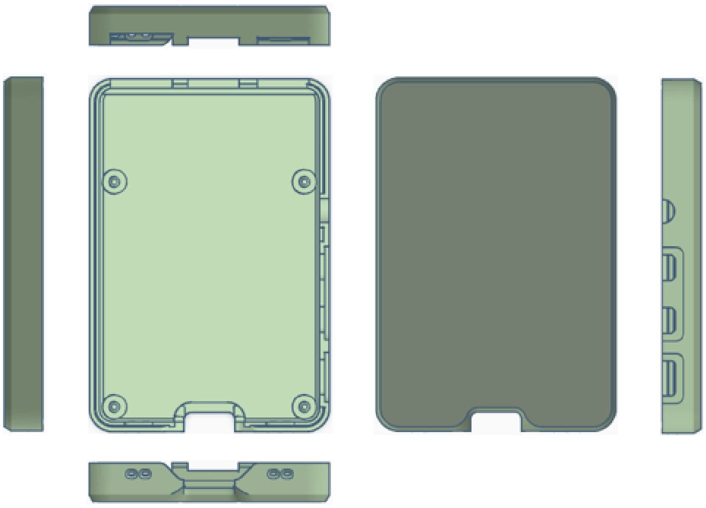


Figure 3.20: Raspberry pi lower cover

Figure 3.21: Tripod mounting

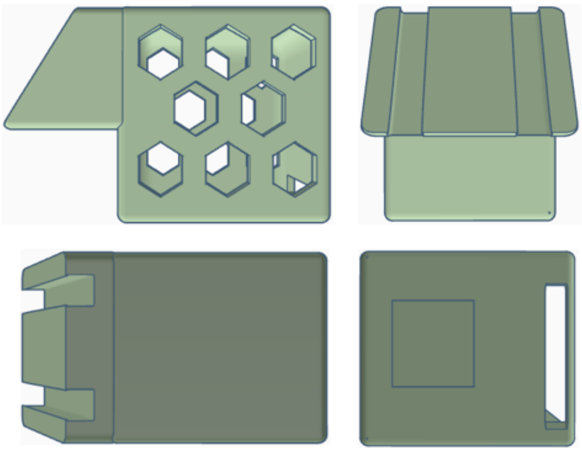


Figure 3.22: Ice cold raspberry pi fan cover

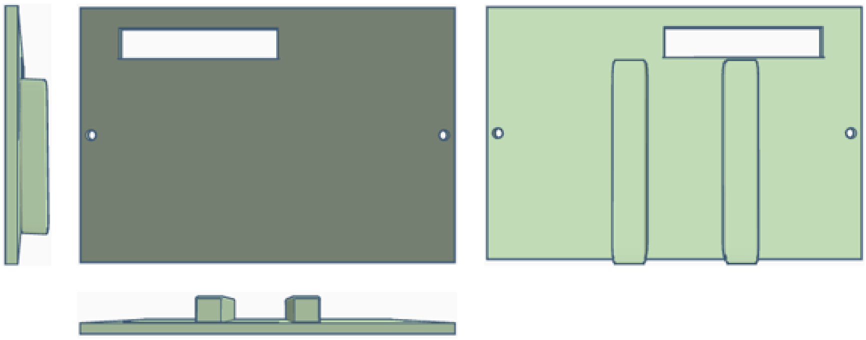


Figure 3.23: Lcd back cover

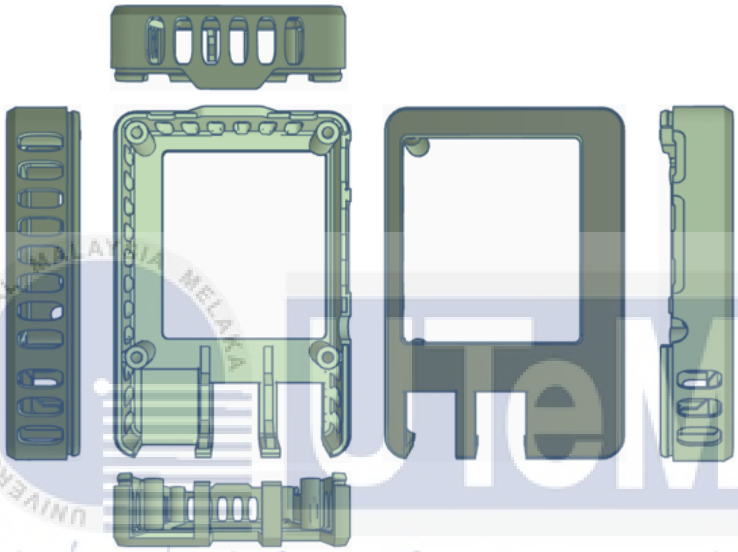


Figure 3.24: Raspberry pi upper part cover

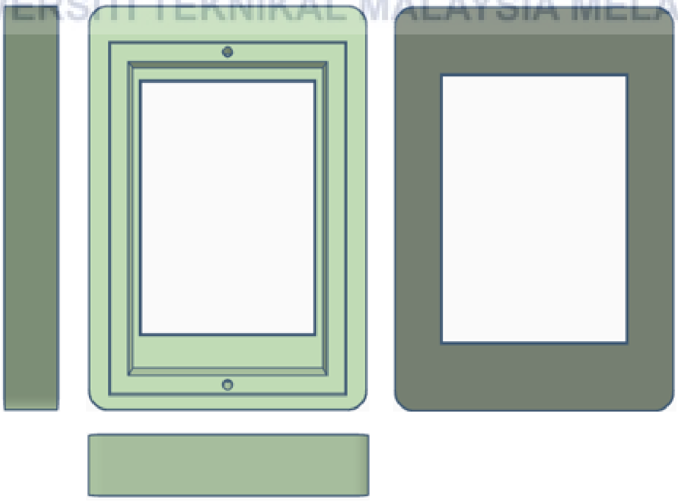


Figure 3.25: Lcd front bezel cover

3.7.5 Connectivity with Thingspeak

In this section, the integration process with ThingSpeak, a robust platform designed for real-time data visualization and analysis, will be explored. The fusion of the Python environment with ThingSpeak not only facilitates seamless data transmission but also empowers users to monitor and analyze information with precision. This subsection provides a systematic guide, delineating the essential steps for creating a ThingSpeak channel, retrieving imperative API keys, and configuring a Python script for efficient data transmission.

Table 3.9: Create account on Thingspeak

Task	Description
Create a ThingSpeak Account	Commence by navigating to the ThingSpeak website (https://thingspeak.com/) and enrolling in a complimentary account.
Sign In	Log in to the newly created ThingSpeak account using the designated credentials.
Create a Channel	Access the "Channels" section and select "My Channels". Initiate the channel creation process by selecting the "New Channel" button.
Channel Configuration	Populate essential details such as the channel name, description, and field labels to effectively organize data.
Save the Channel	Preserve the configured settings by selecting the "Save Channel" option.
Get Channel API Key	Navigate to the "API Keys" tab and document the Write API Key; a critical element for ensuring secure and authorized data transmission.

Task	Description
Install Requests Library	Execute the command pip install requests in your terminal to install the necessary requests library.
Write Python Script	Develop a Python script to generate or fetch data, replacing placeholders with the actual Channel ID and Write API Key.
Run the Python Script	Execute the Python script to initiate the seamless transmission of either simulated or real-time data to the designated ThingSpeak channel at regular intervals.

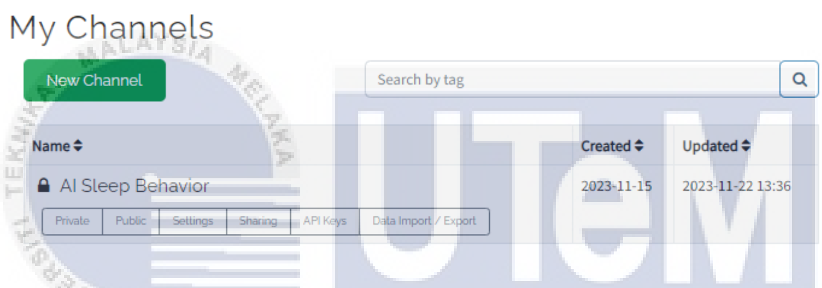


Figure 3.26: New channels

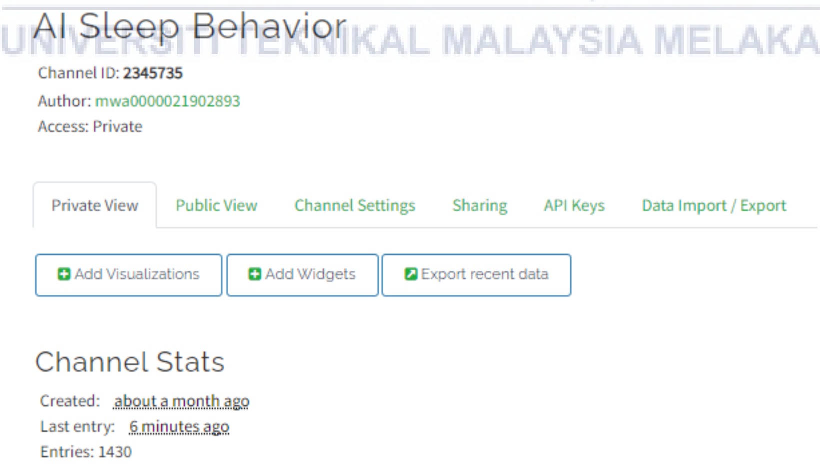


Figure 3.27: Private view channel

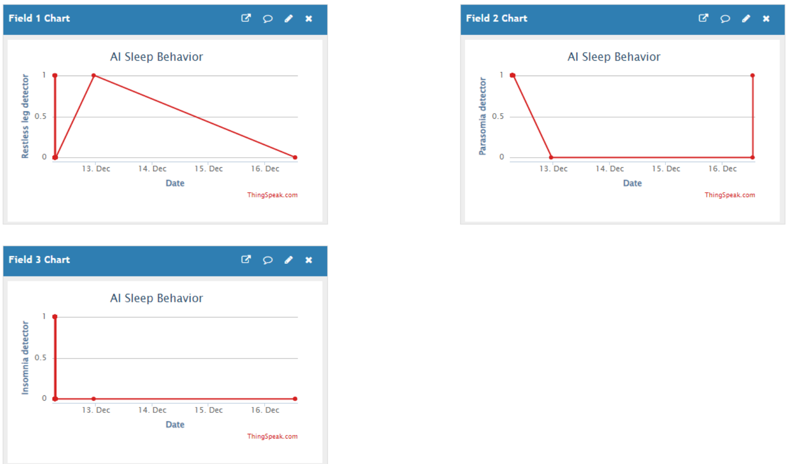


Figure 3.28: Graph of sleep disorder

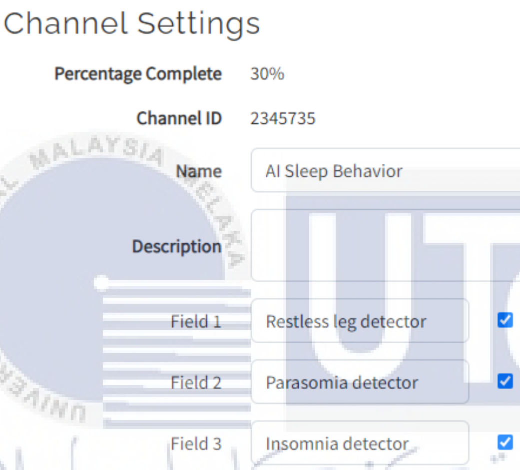


Figure 3.29: Channel setting

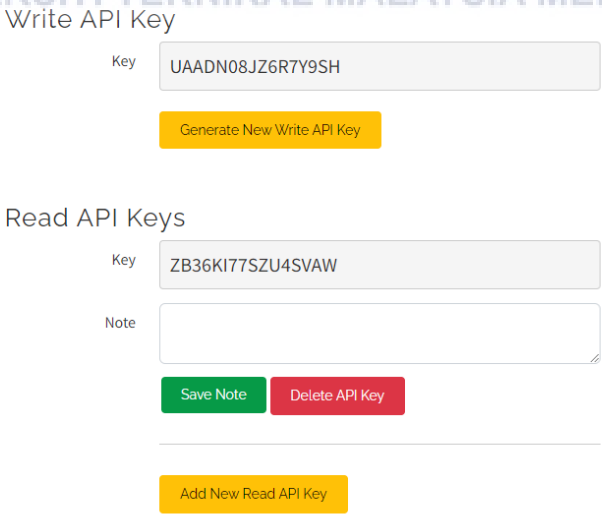


Figure 3.30: Api thingspeak keys

3.8 Summary

This chapter details the methods utilised to fulfil the objectives of this work. A flowchart shows the project's workflow to provide a clear picture of the process. The software and hardware used in this project are also discussed. This chapter also discusses the predicted results of monitoring sleep quality with Thingspeak, which can provide graphs for type of sleep disorder.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, the deployment of the Raspberry Pi-based system is comprehensively examined, encompassing hardware configuration, software integration, and real-world testing. The core components, namely the Raspberry Pi 4B, a night IR camera, and a dedicated power supply, are strategically employed. Python programming plays a crucial role in implementing functionalities such as pose detection, voice assistance, and the assessment of system accuracy through machine learning. The integration with ThingSpeak, a real-time data visualization platform, is meticulously detailed, covering the creation of channels and the configuration of Python scripts. Real-world testing involves a cohort of 10 users, offering a robust evaluation of the system's reliability, accuracy, and user-friendliness across diverse scenarios. The ensuing results, inclusive of accuracy metrics derived from confusion matrix analysis, furnish valuable insights into the practical implications of the developed system.

4.2 Condition set for sleep disorder

Sleep disorder, a prevalent sleep disorder characterized by recurrent breathing interruptions, presents substantial health implications that are frequently underestimated. This study concentrates on the meticulous detection of specific movement patterns within predefined timeframes, encompassing restless leg, parasomnia, and insomnia. There were 3 conditions were set for each sleep disorder:

1) Within 30 seconds[6], if there is too frequent detection of movement (categorized as restless leg[5]).
2) Within 1 minute[40], if there is still movement (categorized as parasomnia[5]).
3) Within 2 minutes[40], if it doesn't return to a healthy position (categorized as insomnia[5]).

4.3 Explanation of the Confusion Matrix

A Confusion Matrix, often referred to as an error matrix, is a matrix that provides information about the classification results of a Machine Learning model compared to the actual outcomes. Currently, the system is designed to identify sleep disorders, including sleep disorder variants such as Restless Leg, Parasomnia, and Insomnia. There are four categories in the confusion matrix:

1) Sleep disorders:
   a) **True Positive (TP)**: The system successfully detects the presence of sleep disorder, Restless Leg, Parasomnia, and Insomnia.
   b) **True Negative (TN)**: It correctly says "no" when there's no sign of sleep disorder.
   c) **False Positive (FP)**: Occasionally, the system might say there's sleep dissorder when it's not there.
   d) **False Negative (FN)**: There are times when the system misses detecting sleep disorder that is happening.

Comprehending these categories is crucial for assessing the effectiveness of the Sleeping Pattern Monitoring System. The primary objective is to minimize instances where the system inaccurately identifies a specific sleep position or overlooks sleep disorders.

This continuous evaluation ensures the system consistently provides accurate information about sleep patterns and associated issues.

4.4 Accuracy sleep disorder detection

In the domain of sleep disorder diagnostics, precision is paramount, particularly in addressing distinctive conditions such as restless leg syndrome (RLS), parasomnia, and insomnia. Each of these disorders presents unique challenges, underscoring the critical importance of accurate identification. Accurate recognition of symptoms is crucial for the formulation of personalized treatment plans, particularly in the case of RLS. In the broader context of parasomnia and insomnia, characterized by diverse and occasionally overlapping manifestations, precise detection is foundational to preventing misdiagnoses and ensuring targeted interventions.

The determination of accuracy in sleep disorder diagnostics is contingent on meticulous analysis. If the values fall below 1 or exceed 1, it signals that the system is not accurate. True Positives and True Negatives are examined for correct identifications and exclusions, while efforts are made to minimize False Positives and False Negatives, thereby ensuring a precision level that justifies the characterization of the diagnostic outcomes as accurate.

4.4.1 Restless leg confusion matrix

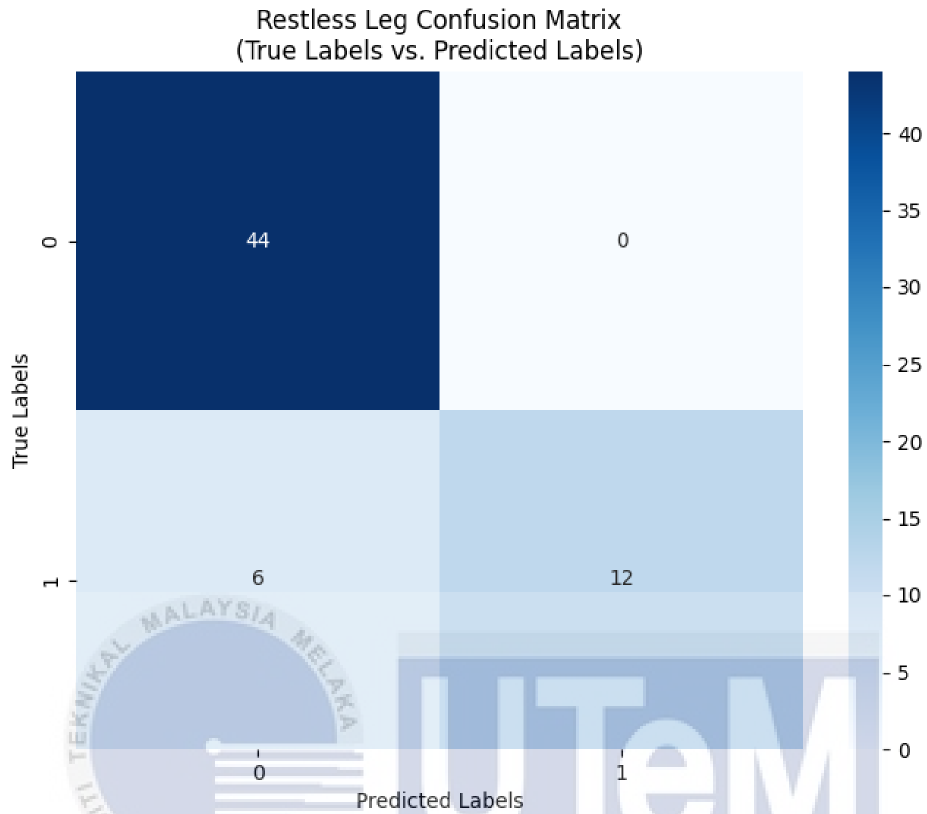


Figure 4.1: RLS confusion matrix

Table 4.1: RLS accuracy matrix

Information	Calculation method
• True Positive (TP): 12 • True Negative (TN): 44 • False Positive (FP): 0 • False Negative (FN): 6	$Accuracy = \frac{(\mathrm{TP} + \mathrm{TN})}{(\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN})}$ $Accuracy = \frac{(12 + 44)}{(12 + 44 + 0 + 6)}$ $Accuracy = 0.9032$ Conclusion: The detection is accurate.

4.4.2 Parasomnia confusion matrix

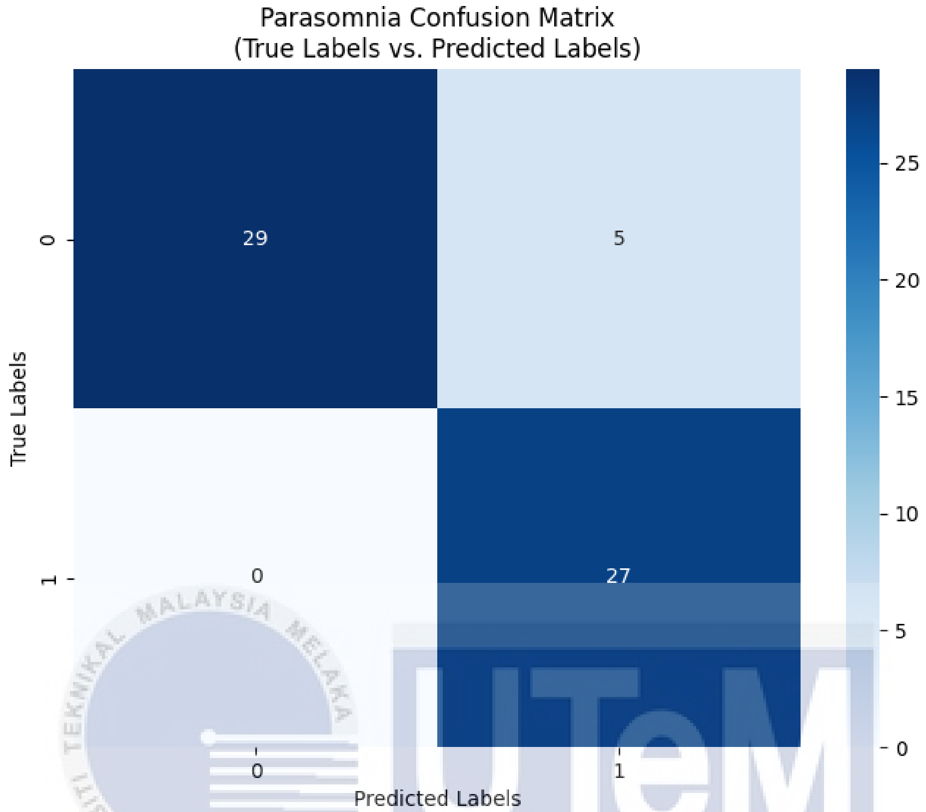


Figure 4.2: Parasomnia confusion matrix

Table 4.2: Parasomnia accuracy matrix

Information	Calculation method
• True Positive (TP): 27 • True Negative (TN): 29 • False Positive (FP): 5 • False Negative (FN): 0	$Accuracy = \frac{(\mathrm{TP} + \mathrm{TN})}{(\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN})}$ $Accuracy = \frac{(27 + 29)}{(27 + 29 + 5 + 0)}$ $Accuracy = 0.9180$ Conclusion: The detection is accurate.

4.4.3 Insomnia confusion matrix

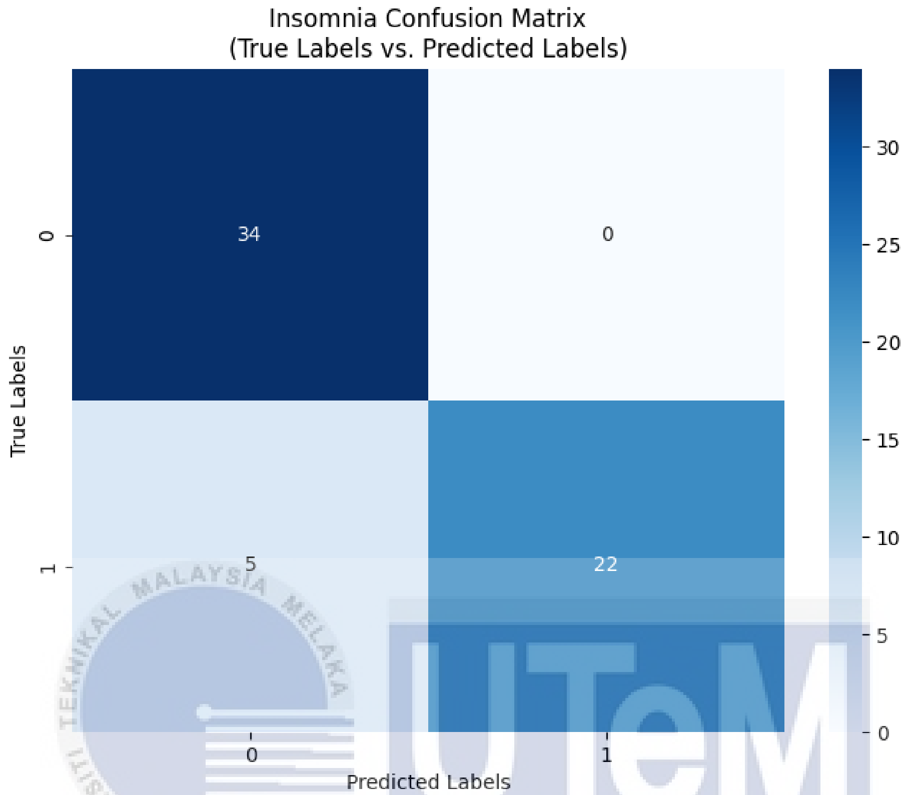


Figure 4.3: Insomnia confusion matrix

Table 4.3: Insomnia accuracy matrix

Information	Calculation method
• True Positive (TP): 22 • True Negative (TN): 34 • False Positive (FP): 0 • False Negative (FN): 5	$Accuracy = \frac{(\mathrm{TP} + \mathrm{TN})}{(\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN})}$ $Accuracy = \frac{(22 + 34)}{(22 + 34 + 0 + 5)}$ $Accuracy = 0.9180$ Conclusion: The detection is accurate.

4.5 Reliability sleep disorder system

The importance of understanding and optimizing sleep patterns has gained considerable traction. The advent of sophisticated sleep monitoring systems has opened new avenues for unraveling the intricacies of our nightly rest. This study delves into the reliability of an innovative sleep monitoring system, a technological designed to meticulously capture and analyze individual sleep patterns. The research is undergoing by an extensive testing phase involving ten diverse participants, each contributing a unique dataset. This diverse cohort enables a variable examination of the system's performance across a spectrum of sleep profiles, offering insights into its reliability and effectiveness.

Through an examination of individual narratives and empirical data, this study endeavors to bridge the gap between technology and its impact on the daily lives of users. The goal is to contribute to the ongoing evolution of our understanding of sleep health. This involves providing not only an overview of the monitoring system's capabilities but also offering insights into how technology can empower individuals to enhance their overall well-being through the cultivation of improved sleep habits.

4.5.1 Comprehensive analysis of individual sleep data: insights from 10 participants

This section delves into a comprehensive analysis of individual sleep data, drawing insights from a diverse group of 10 participants. Through meticulous examination and interpretation of each participant's sleep metrics, this analysis aims to unveil patterns, variations, and key observations that contribute to a nuanced understanding of the reliability of the sleep monitoring system. By dissecting the intricacies of sleep parameters such as restless leg, parasomnia, and insomnia across the participant cohort, this section provides valuable insights into the efficacy and performance of the monitoring system in capturing and representing individual sleep patterns. The collective examination of these 10 sets of data serves as a pivotal component in evaluating the robustness and practical applicability of the sleep monitoring system in diverse sleep scenarios.

Table 4.4: Research Period

Time of Data Collection	Duration of Research	Commencement Date	Conclusion Date
10:00 PM to 6:00 AM	10 days	December 9, 2023	December 18, 2023

Table 4.5: Participant information

Participant	Start Date	End Date
1	December 09, 2023, 10:00 PM	December 10, 2023, 6:00 AM
2	December 10, 2023, 10:00 PM	December 11, 2023, 6:00 AM
3	December 11, 2023, 10:00 PM	December 12, 2023, 6:00 AM
4	December 12, 2023, 10:00 PM	December 13, 2023, 6:00 AM
5	December 13, 2023, 10:00 PM	December 14, 2023, 6:00 AM
6	December 14, 2023, 10:00 PM	December 15, 2023, 6:00 AM
7	December 15, 2023, 10:00 PM	December 16, 2023, 6:00 AM
8	December 16, 2023, 10:00 PM	December 17, 2023, 6:00 AM

Participant	Start Date	End Date
9	December 17, 2023, 10:00 PM	December 18, 2023, 6:00 AM
10	December 18, 2023, 10:00 PM	December 19, 2023, 6:00 AM

4.5.1.1 Analysis participant 1

Participant 1 exhibits a sleep pattern characterized by restless leg symptoms accounting for 17.27% of the observed data. To address leg discomfort, it is recommended to encourage side sleeping and consider the use of a supportive pillow. Additionally, the high occurrence of parasomnia at 49.19% suggests the need for a consistent bedtime routine to address abnormal sleep behaviors. For the 33.54% incidence of insomnia, exploring stress management techniques and maintaining a regular sleep schedule may contribute to improved sleep quality.

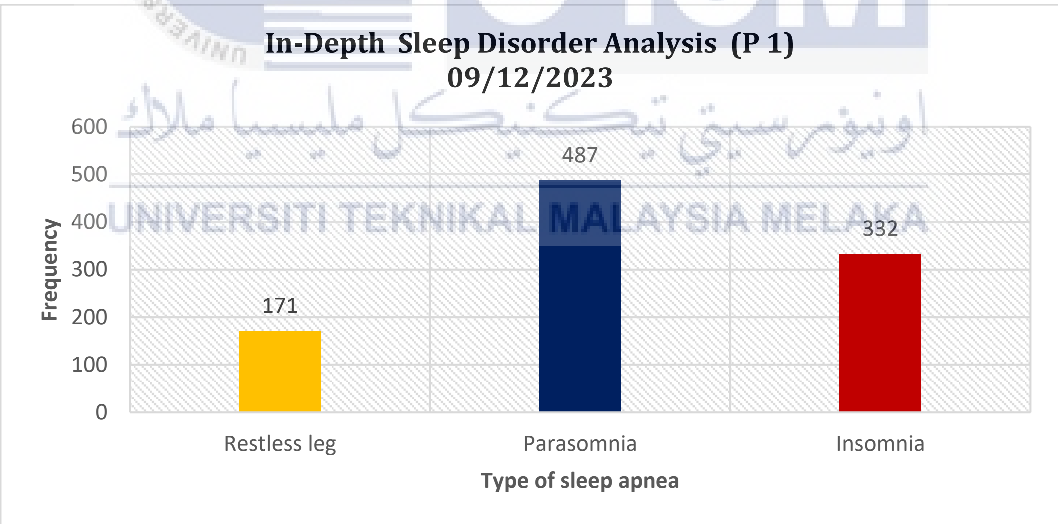


Figure 4.4: In-Depth Sleep Disorder Analysis (P 1)

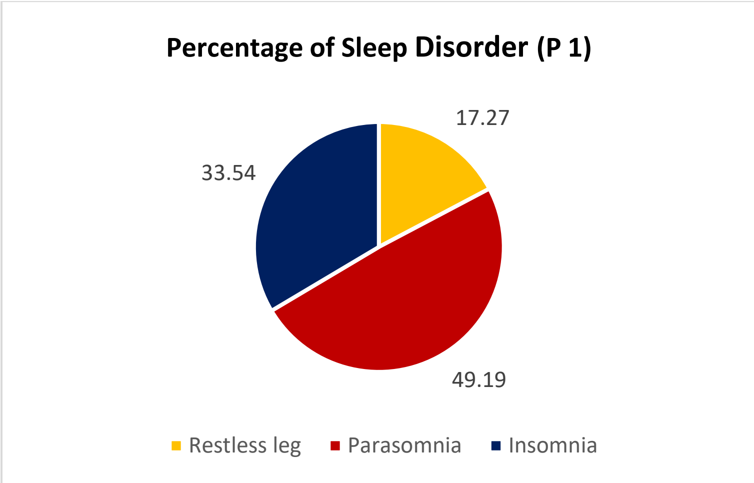


Figure 4.5: Percentage of Sleep Disorder (P 1)

4.5.1.2 Analysis participant 2

For Participant 2, restless leg symptoms constitute 20.81% of the data, indicating a potential source of discomfort during sleep. To address this, suggesting side sleeping and providing support with a body pillow may be beneficial. The prevalence of parasomnia at 33.71% suggests the importance of developing a relaxing pre-sleep routine and limiting screen time before bedtime. Additionally, with insomnia accounting for 45.47%, recommendations include encouraging a calming bedtime routine and considering mindfulness practices.

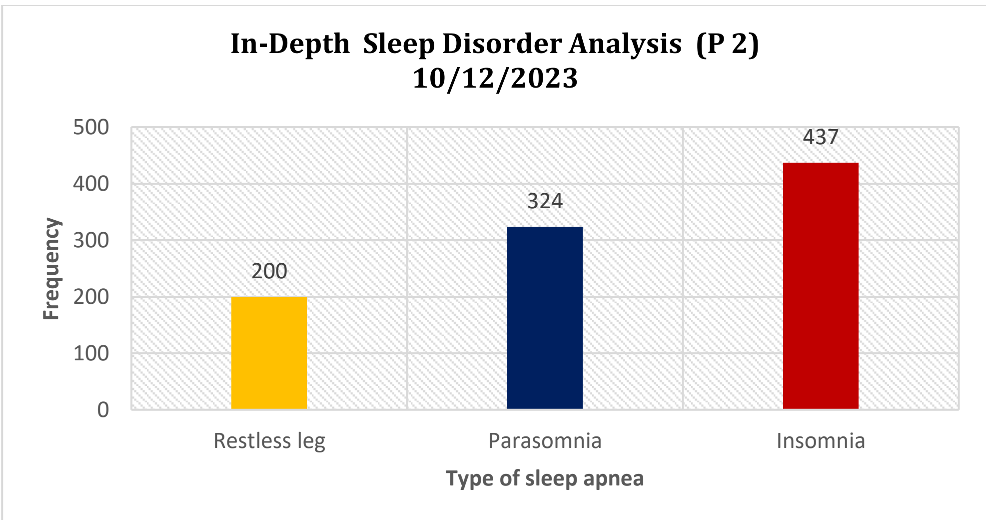


Figure 4.6: In-Depth Sleep Disorder Analysis (P 2)

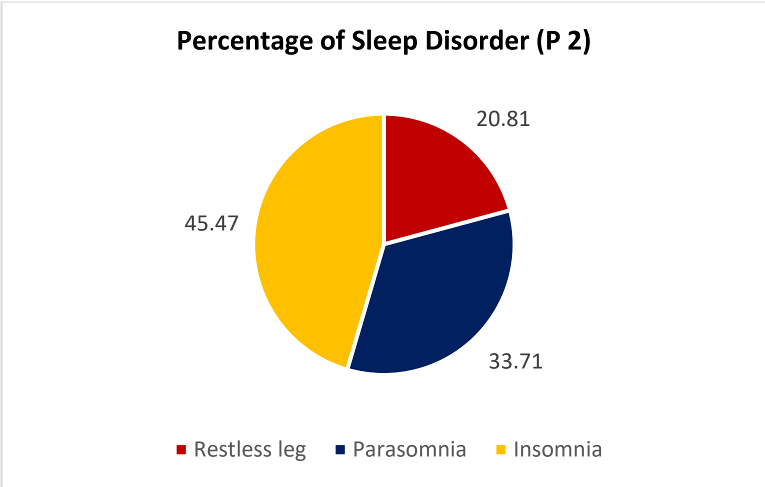


Figure 4.7: Percentage of Sleep Disorder (P 2)

4.5.1.3 Analysis participant 3

Participant 3 presents a sleep pattern where restless leg symptoms are prominent at 29.26%. Encouraging side sleeping, along with evaluating mattress and pillow support, may alleviate leg discomfort. The lower incidence of parasomnia at 14.11% suggests exploring stress reduction techniques and adopting sleep hygiene practices. However, with insomnia at 56.64%, recommendations include suggesting a consistent sleep schedule and stress management strategies.

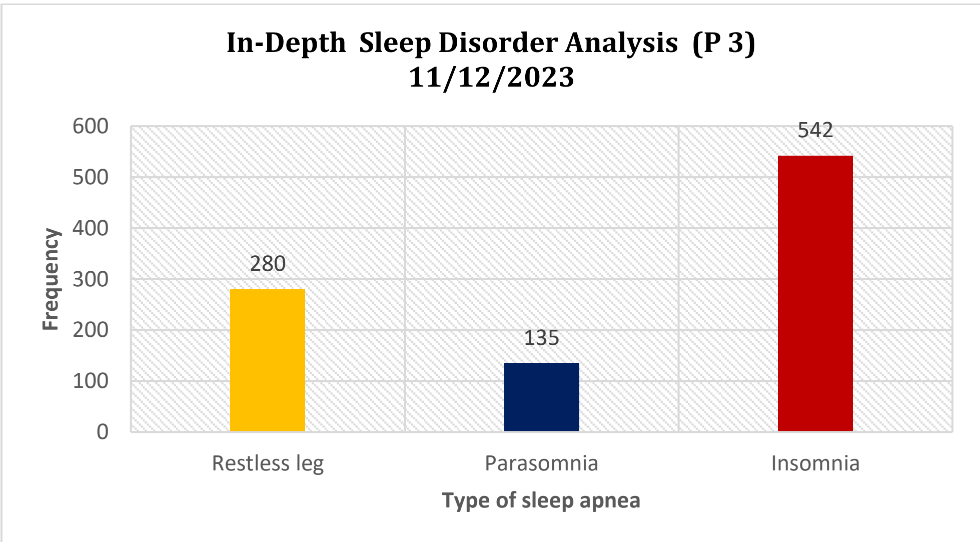


Figure 4.8: In-Depth Sleep Disorder Analysis (P 3)

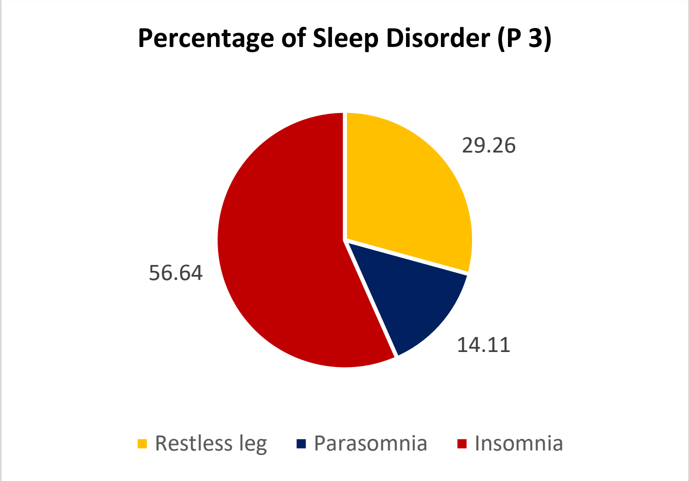


Figure 4.9: Percentage of Sleep Disorder (P 3)

4.5.1.4 Analysis participant 4

In the case of Participant 4, restless leg symptoms contribute to 24.51% of the data, emphasizing the potential benefits of side sleeping and assessing pillow and mattress comfort. The prevalence of parasomnia at 41.85% suggests the importance of a calming pre-sleep routine and considering professional sleep evaluation. Additionally, addressing insomnia at 33.64% involves exploring stress reduction techniques and maintaining a regular sleep pattern.

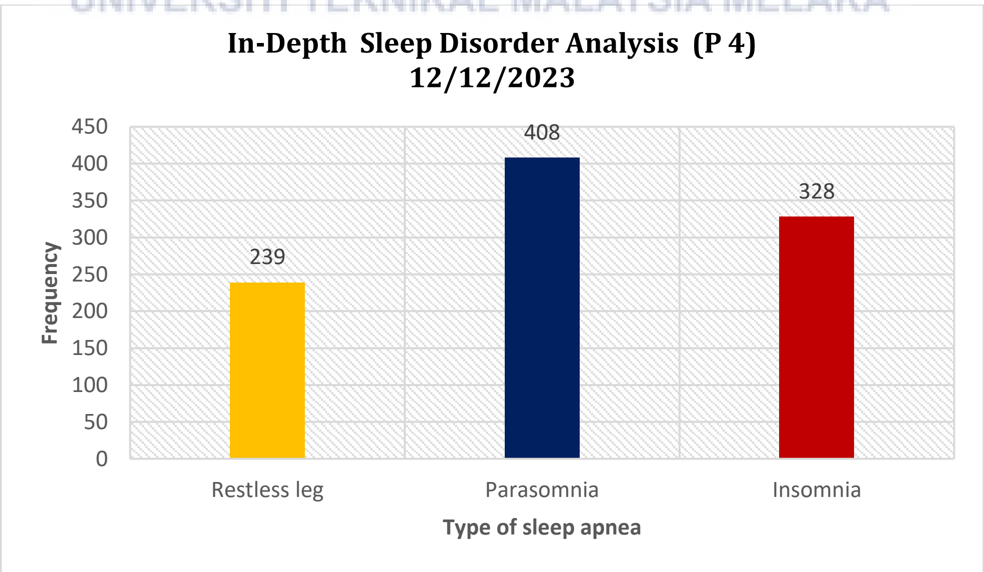


Figure 4.10: In-Depth Sleep Disorder Analysis (P 4)

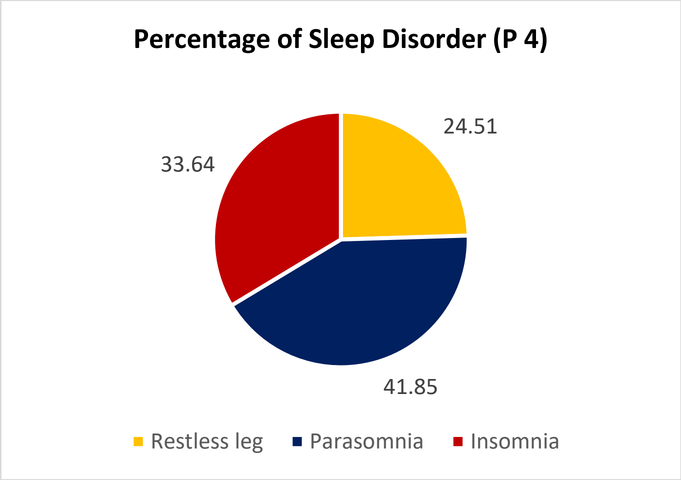


Figure 4.11: Percentage of Sleep Disorder (P 4)

4.5.1.5 Analysis participant 5

Participant 5 displays a sleep pattern with restless leg symptoms at 25.44%. Recommendations include proposing side sleeping and evaluating the overall sleep environment. With parasomnia at 38.68%, developing a consistent pre-sleep routine and limiting caffeine intake before bedtime may contribute to better sleep quality. Furthermore, for the 35.88% incidence of insomnia, encouraging relaxation techniques and maintaining a consistent sleep schedule is recommended.

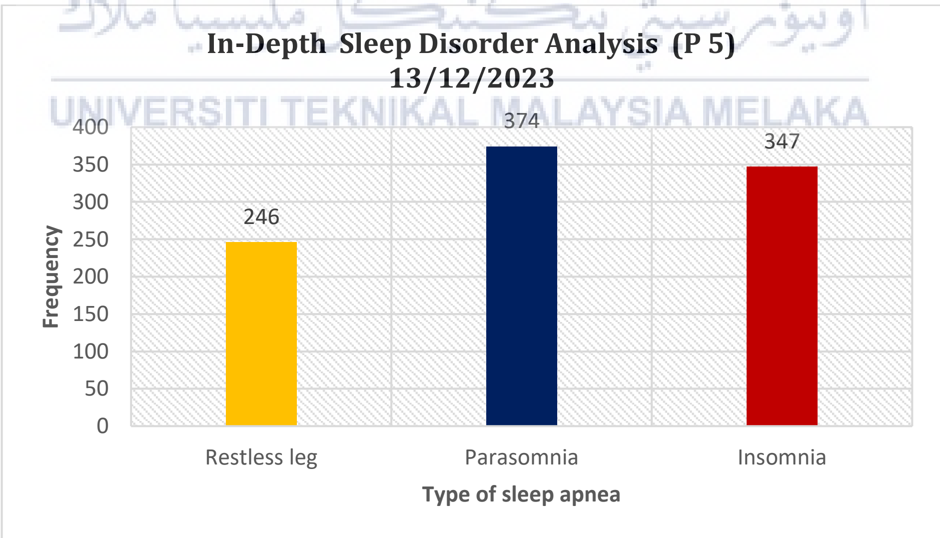


Figure 4.12: In-Depth Sleep Disorder Analysis (P 5)

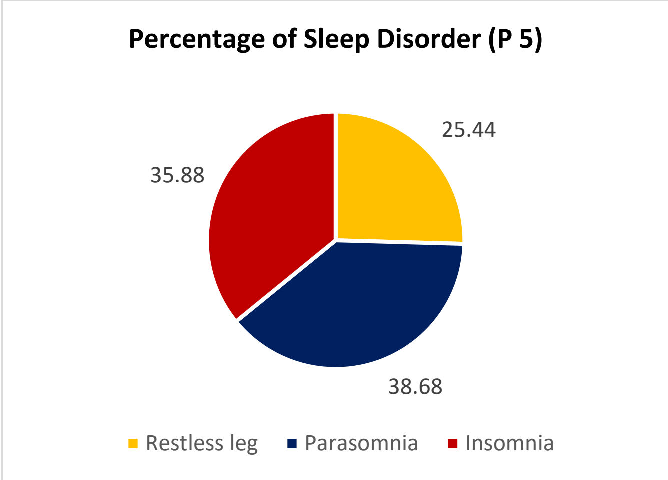


Figure 4.13: Percentage of Sleep Disorder (P 5)

4.5.1.6 Analysis participant 6

For Participant 6, the data indicates restless leg symptoms at 8.60%. Suggesting side sleeping and assessing mattress and pillow support may address leg discomfort. However, the high prevalence of parasomnia at 67.79% suggests the need to explore stress management and mindfulness techniques, possibly requiring professional evaluation. With insomnia at 23.61%, encouraging a calming bedtime routine and limiting stimulating activities before sleep is recommended.

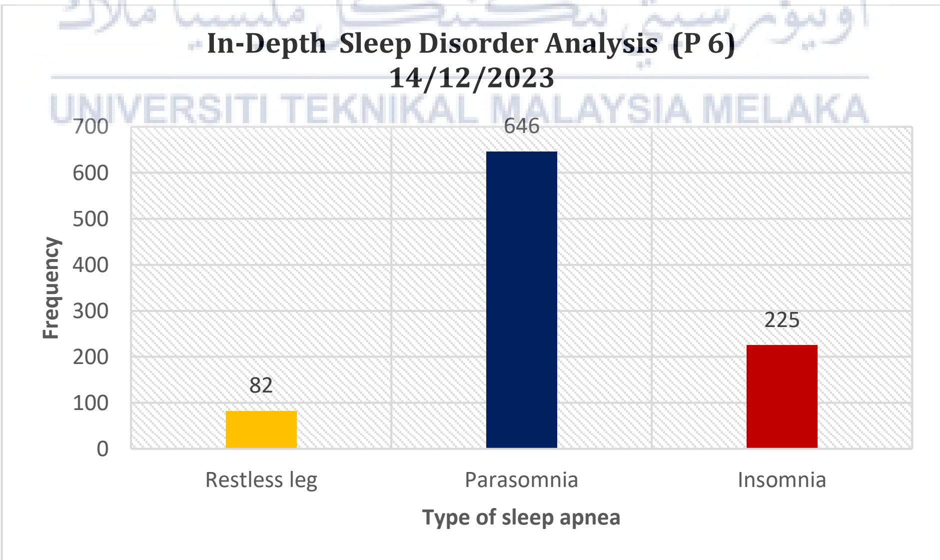


Figure 4.14: In-Depth Sleep Disorder Analysis (P 6)

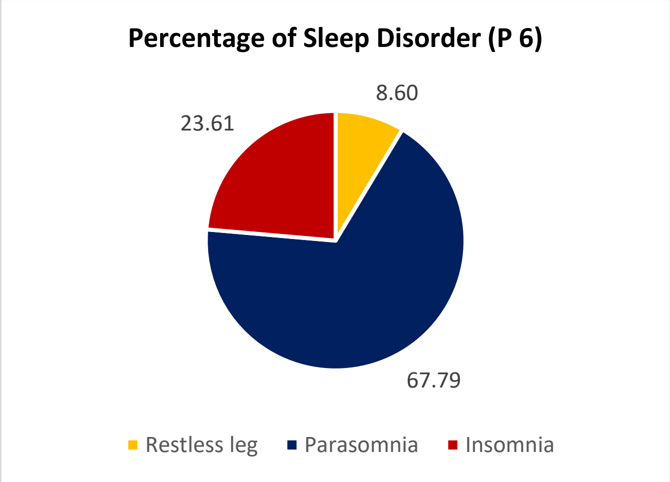


Figure 4.15: Percentage of Sleep Disorder (P 6)

4.5.1.7 Analysis participant 7

Participant 7 exhibits restless leg symptoms at 12.08%, highlighting the potential benefits of side sleeping and assessing the sleep environment. The prevalence of parasomnia at 45.55% suggests the importance of a relaxing pre-sleep routine and considering professional evaluation. Additionally, addressing insomnia at 42.37% involves exploring stress management strategies and maintaining a consistent sleep schedule.

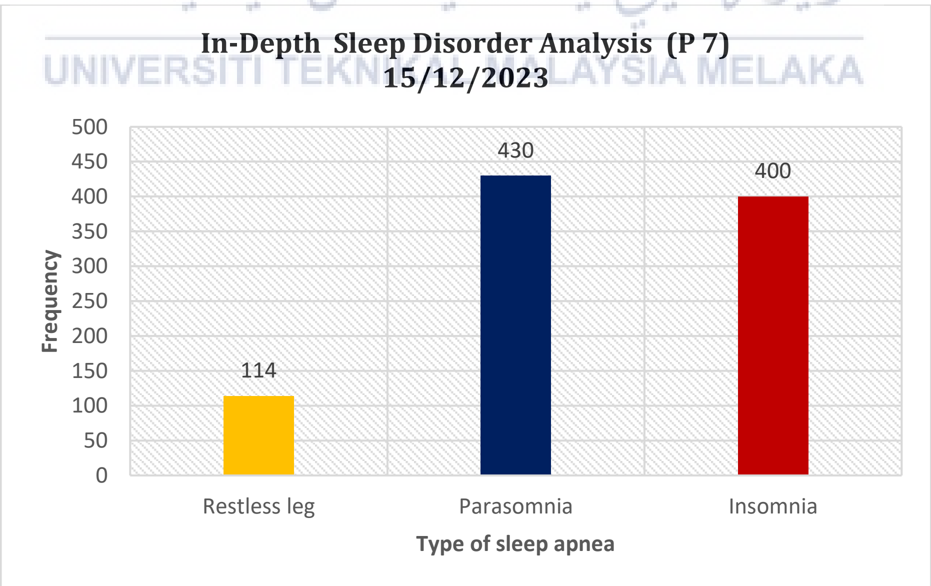


Figure 4.16: In-Depth Sleep Disorder Analysis (P 7)

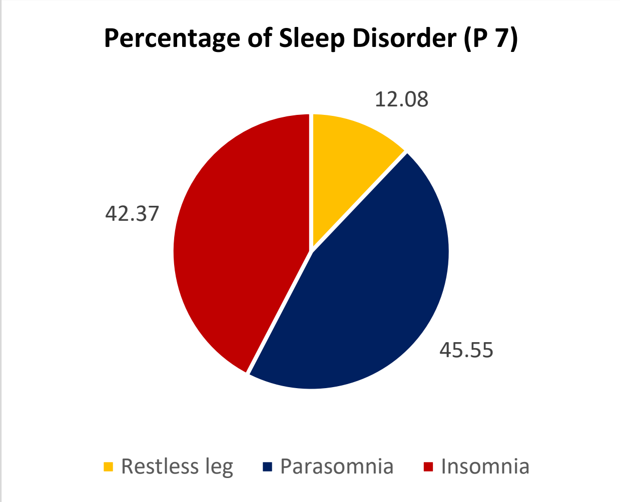


Figure 4.17: Percentage of Sleep Disorder (P 7)

4.5.1.8 Analysis participant 8

In the case of Participant 8, restless leg symptoms contribute to 28.83% of the data, emphasizing the potential benefits of side sleeping and assessing mattress and pillow comfort. With parasomnia at 40.59%, recommendations include developing a calming pre-sleep routine and considering sleep hygiene practices. Additionally, addressing insomnia at 30.57% involves encouraging stress reduction techniques and maintaining a regular sleep pattern.

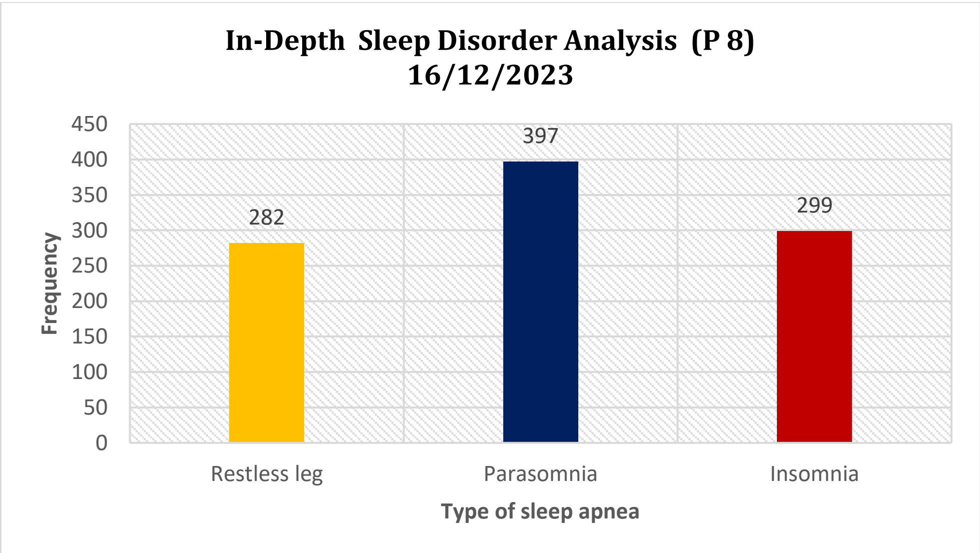


Figure 4.18: In-Depth Sleep Disorder Analysis (P 8)

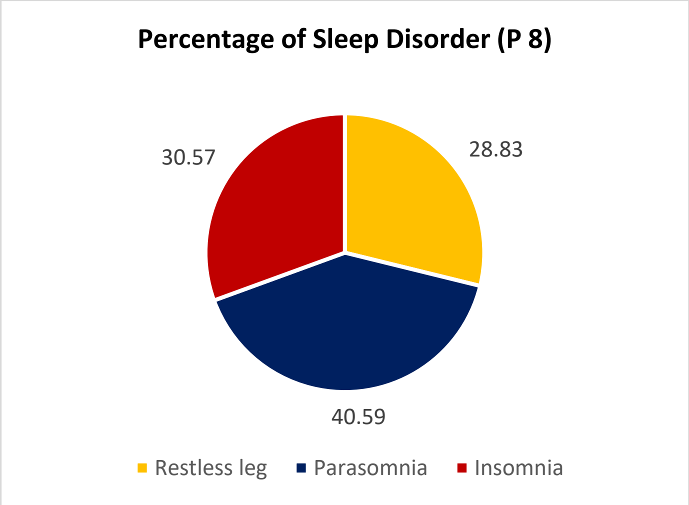


Figure 4.19: Percentage of Sleep Disorder (P 8)

4.5.1.9 Analysis participant 9

Participant 9 presents a sleep pattern with restless leg symptoms at 18.87%. Recommendations include suggesting side sleeping and assessing mattress and pillow support. With parasomnia at 40.30%, exploring stress reduction techniques and adopting sleep hygiene practices may contribute to better sleep quality. Addressing insomnia at 40.83% involves encouraging relaxation techniques and maintaining a consistent sleep schedule.

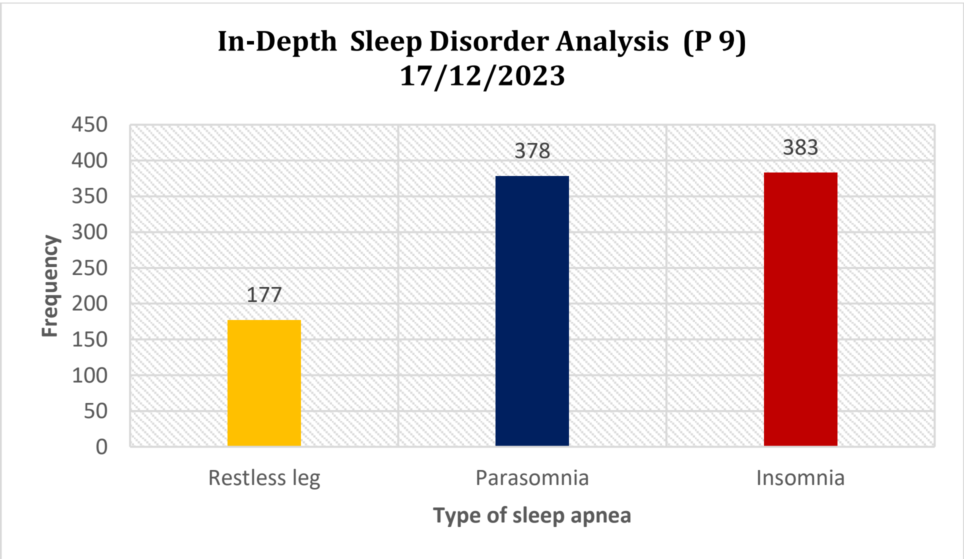


Figure 4.20: In-Depth Sleep Disorder Analysis (P 9)

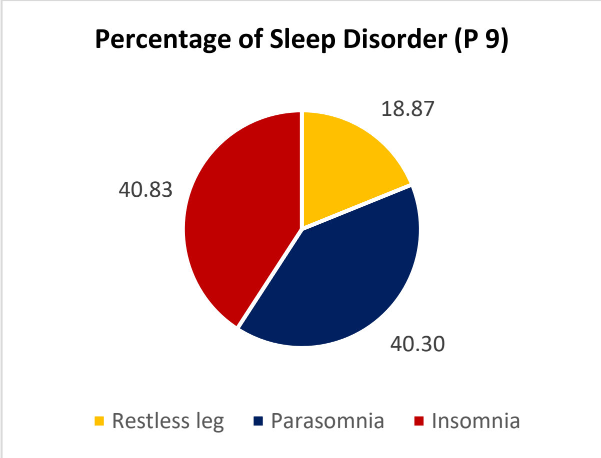


Figure 4.21: Percentage of Sleep Disorder (P 9)

4.5.1.10 Analysis participant 10

For Participant 10, restless leg symptoms contribute significantly at 48.85%. Recommendations include proposing side sleeping and assessing mattress and pillow comfort. With parasomnia at 34.43%, developing a calming pre-sleep routine and limiting screen time before bedtime may contribute to improved sleep quality. Additionally, for the 16.72% incidence of insomnia, exploring stress management strategies and maintaining a consistent sleep pattern is recommended.

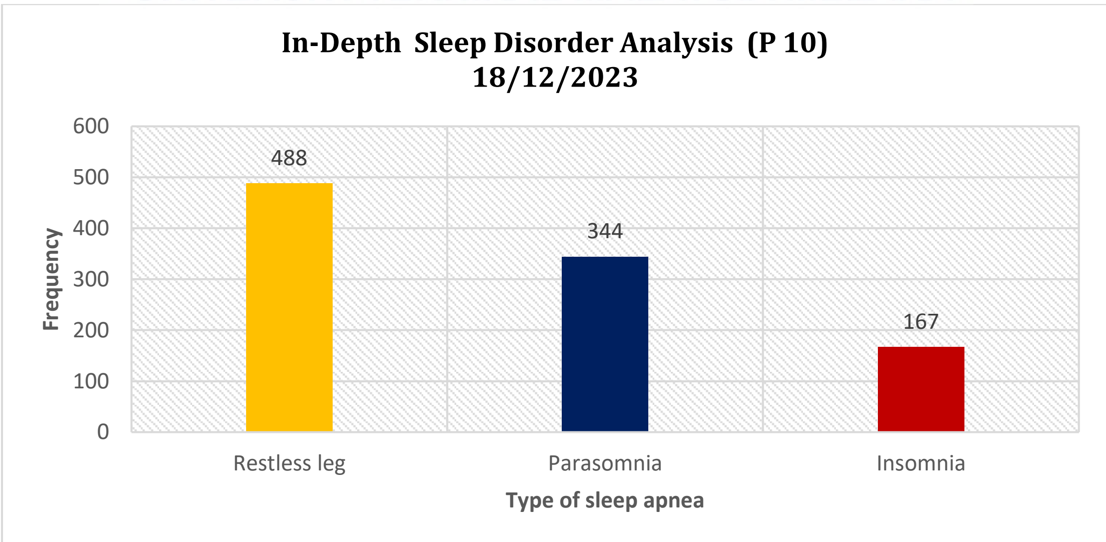


Figure 4.22: In-Depth Sleep Disorder Analysis (P 10)

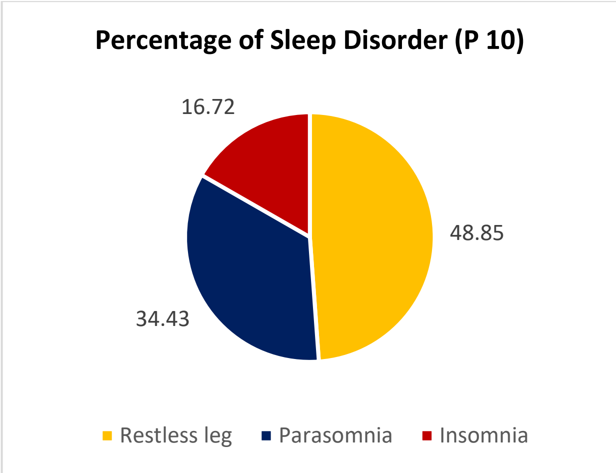


Figure 4.23: Percentage of Sleep Disorder (P 10)

4.6 Sleep position detection

Three distinct sleep positions, namely back [9], side [9], and stomach [9] positions, have been identified through the utilization of the Mediapipe library. Analysis indicates that the optimal sleeping posture among these is the side position. This finding is based on comprehensive data collected and processed by the aforementioned library, highlighting the significance of adopting a side sleeping position for enhanced sleep quality.

Figure 4.24: Back position

Figure 4.25: Side position

Figure 4.26: Stomach position

In conclusion, the research conducted through the application of the Mediapipe library has successfully identified three primary sleep positions back, side, and stomach. The analysis has clearly indicated the side sleeping position as the most favorable for achieving optimal sleep quality. This conclusion is substantiated by robust data collection and processing methodologies, highlighting the importance of adopting a side sleeping posture for individuals seeking to enhance their overall sleep experience [9].

4.7 Comprehensive sleep disorder scenario

Sleep disorders are prevalent conditions that can significantly impact an individual's overall well-being. Understanding and identifying specific sleep-related issues is crucial for effective diagnosis and intervention. This report presents scenarios based on three distinct sleep disorders: restless leg syndrome, parasomnia, and insomnia. Each scenario outlines the detection of these disorders within different sleeping positions to shed light on potential challenges in initiating or maintaining sleep, as well as the occurrence of abnormal behaviors during sleep.

4.7.1 Scenario 1: All sleep disorders detected

In this scenario, the monitoring system successfully detects the presence of all three sleep disorders restless leg syndrome, parasomnia, and insomnia. This comprehensive identification provides valuable insights into the complex interplay of these disorders during the sleep cycle. Understanding and addressing these simultaneous occurrences are essential for developing targeted interventions to improve sleep quality and overall health.

Figure 4.27: Scenario back A

4.7.2 Scenario 2: Restless Leg Detected

This scenario focuses on the detection of restless leg syndrome during sleep. The monitoring system identifies the specific leg movements associated with this neurological condition. The differentiation between scenarios back B and side A emphasizes the importance of considering different sleeping positions when assessing and addressing restless leg syndrome. This information aids in tailoring interventions to minimize discomfort and improve the sleep experience for individuals with this disorder.

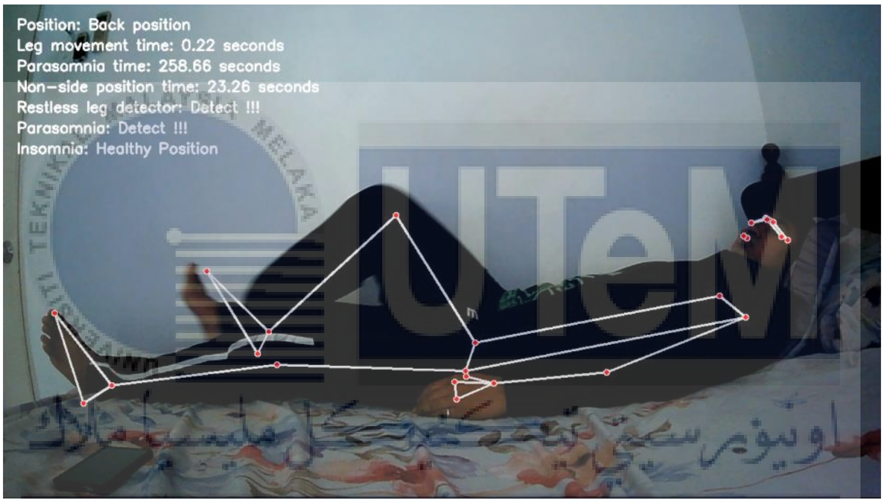


Figure 4.28: Scenario back C

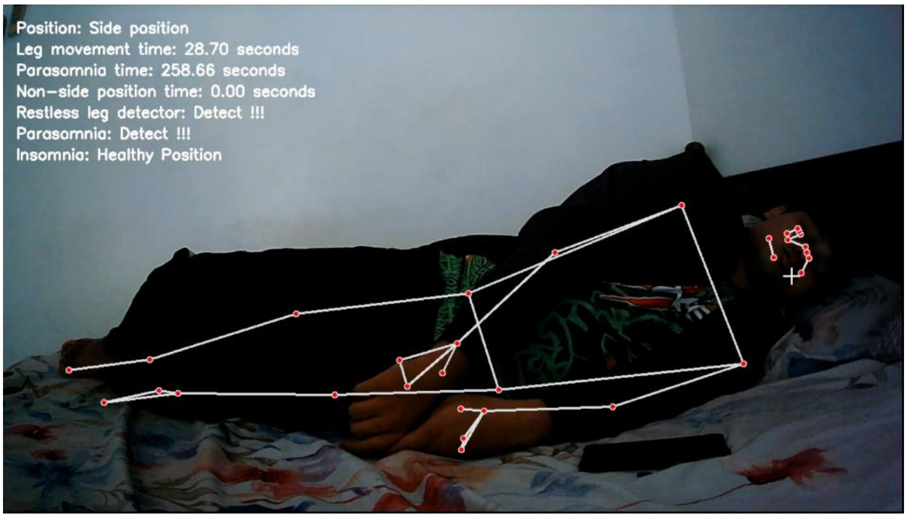


Figure 4.29: Scenario side B

4.7.3 Scenario 3: Parasomnia Detected

The scenarios presented here highlight the detection of parasomnia, encompassing abnormal behaviors such as sleepwalking, night terrors, and REM behavior disorder. Recognizing parasomnia is crucial for understanding the potential disruptions it may cause during sleep. The diverse sleeping positions in the scenarios emphasize the need for a comprehensive approach to address various parasomnias effectively.

Figure 4.30: Scenario back B

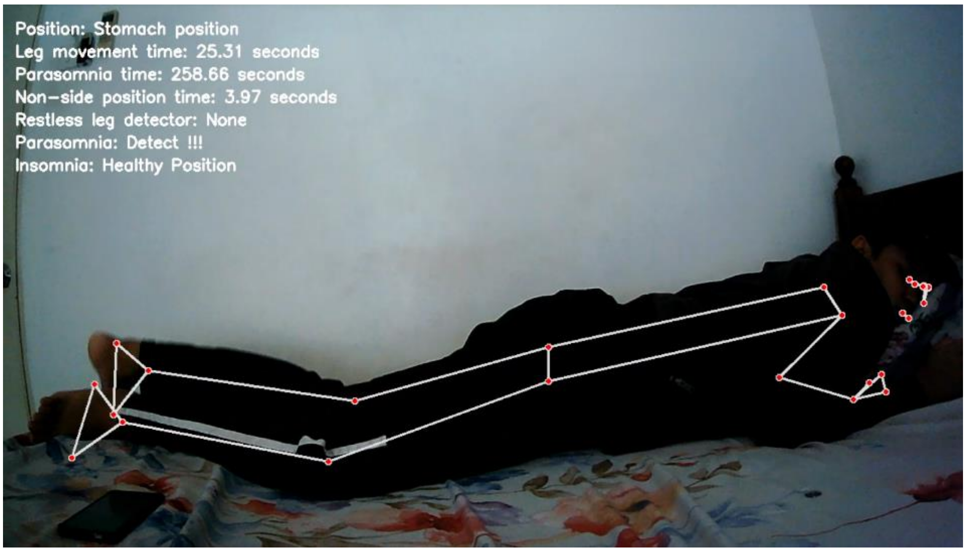


Figure 4.31: Scenario stomach A

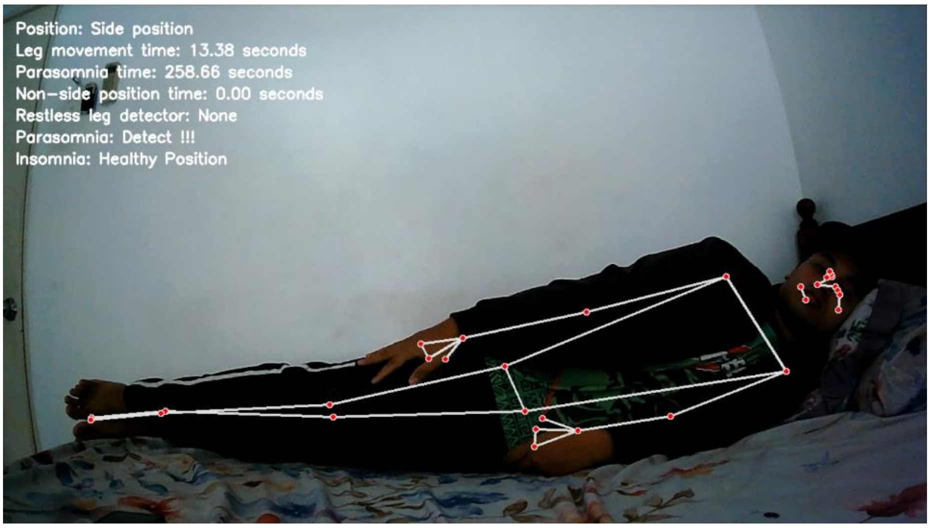


Figure 4.32: Scenario side A

4.7.4 Scenario 4: Insomnia Detected

This scenario centers on the detection of insomnia, a sleep disorder characterized by challenges in initiating or maintaining sleep. The monitoring system identifies instances where an individual fails to return to a healthy sleeping position within the specified time frame, indicating potential difficulties associated with insomnia. This information is instrumental in tailoring interventions to address the underlying factors contributing to sleep disturbances in individuals with insomnia.

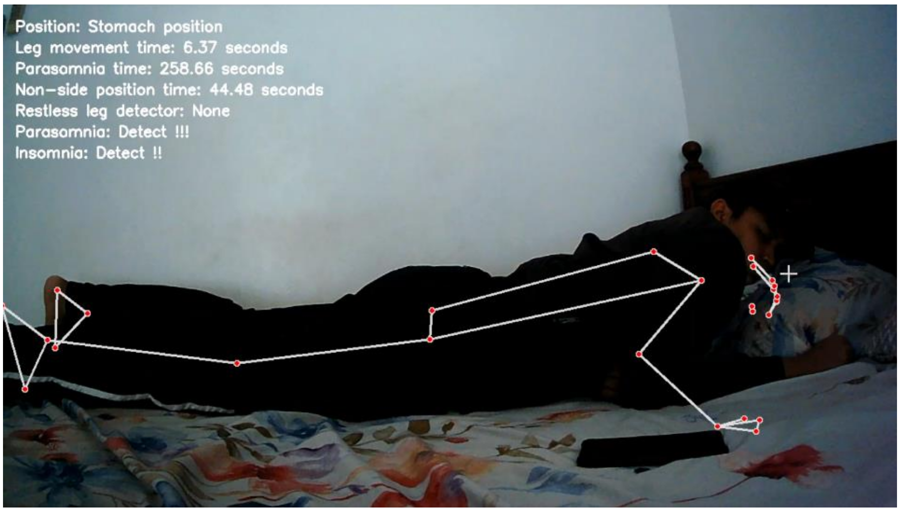


Figure 4.33: Scenario stomach B

4.7.5 Scenario 5: Blanket Presence Test

This unique scenario evaluates the system's detection capabilities in the presence of a blanket during sleep. The objective is to assess the system's robustness in real-world conditions, considering the common practice of individuals using blankets during sleep. Key parameters include monitoring for restless leg syndrome, parasomnia, and insomnia while accounting for the additional variable of the blanket. The results of this test provide crucial insights into the system's adaptability and effectiveness in practical, everyday scenarios, ensuring its reliability in diverse sleep environments.

Figure 4.34: Scenario blanket A

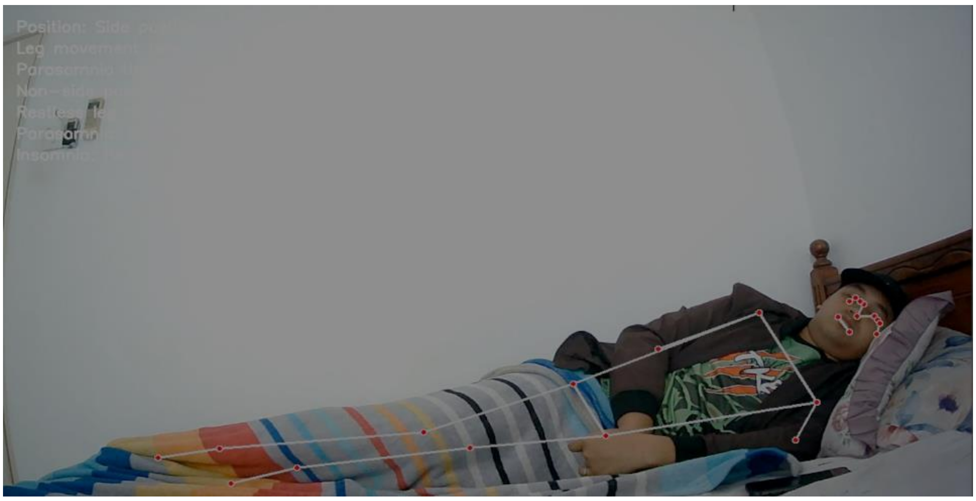


Figure 4.35: Scenario blanket B

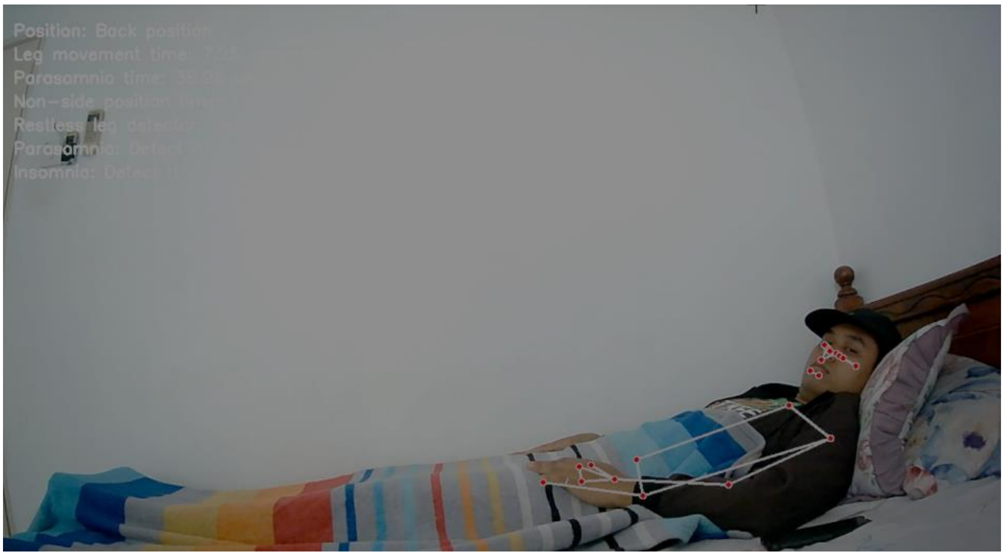


Figure 4.36: Scenario blanket C

4.8 Command Execution, API Integration, and User Interaction

The voice assistant script has demonstrated noteworthy proficiency in executing a diverse array of commands with precision. Employing the speech recognition capabilities facilitated by the speech_recognition library and the Google Speech Recognition service, the script accurately interprets voiced commands, ensuring a high level of user command comprehension. An integral aspect of the script is its seamless integration with various external Application Programming Interfaces (APIs), including but not limited to the News API, OpenWeatherMap API, Aladhan API for prayer times, and ThingSpeak for sleep data analysis. This integration is pivotal for retrieving real-time data and furnishing the user with accurate and up-to-date information.

A salient feature of the script is its adept utilization of multithreading, enabling concurrent execution of tasks such as playing music, setting alarms, and handling reminders. This concurrent processing capability enhances the user experience by allowing the assistant to perform multiple tasks simultaneously. The script is equipped with robust error-handling mechanisms, offering informative messages in case of anomalies such as API request failures or invalid commands. Furthermore, the script provides articulate and informative feedback to the user, contributing to a positive and intuitive user experience.

In terms of security considerations, prudent attention has been given to safeguarding API keys. However, a cautious approach is advised regarding the utilization of os.system to mitigate potential security risks. While the script proficiently executes commands, prospective improvements could center on enhancing code readability and documentation. Augmenting the script with additional comments and comprehensive documentation would elucidate the purpose of distinct sections and functions, fostering ease of maintenance and modification. Rigorous testing, particularly for components interfacing with external APIs, remains imperative to ensure the reliability of individual functions and features. In summation, the voice assistant script has demonstrated competency in command execution, API integration, and user interaction, establishing a robust foundation for prospective refinements.

```
Listening for a command...
Recognizing the command...
You said: linda
Trigger phrase detected! How can I assist you?
Recognized command: linda
Listening for a command...
Recognizing the command...
You said: read top news
Fetching the latest top news...
Insect Compasses, Fire-Fighting Vines: 2023's Nature-Inspired Tech - Voice of America - VOA News. None
Recognized command: read top news
Listening for a command...
Recognizing the command...
You said: play music
Playing acoustic music: https://youtu.be/NP7xfIbnMuU
Recognized command: play music
Listening for a command...
Recognizing the command...
You said: stop music
Stopping music...
SUCCESS: The process "chrome.exe" with PID 10184 has been terminated.
SUCCESS: The process "chrome.exe" with PID 9580 has been terminated.
SUCCESS: The process "chrome.exe" with PID 21840 has been terminated.
SUCCESS: The process "chrome.exe" with PID 10880 has been terminated.
SUCCESS: The process "chrome.exe" with PID 6272 has been terminated.
SUCCESS: The process "chrome.exe" with PID 7084 has been terminated.
SUCCESS: The process "chrome.exe" with PID 11108 has been terminated.
SUCCESS: The process "chrome.exe" with PID 15568 has been terminated.
SUCCESS: The process "chrome.exe" with PID 18012 has been terminated.
SUCCESS: The process "chrome.exe" with PID 15112 has been terminated.
SUCCESS: The process "chrome.exe" with PID 12328 has been terminated.
SUCCESS: The process "chrome.exe" with PID 25556 has been terminated.
Recognized command: stop music
Listening for a command...
Recognizing the command...
You said: what is restless leg
Restless legs syndrome, also known as RLS, is a condition that causes an uncontrollable urge to 
the evening or nighttime hours when you're sitting or lying down.
Recognized command: what is restless leg
Listening for a command...
Recognizing the command...
You said: what is parasomnia
A parasomnia is a sleep disorder that involves unusual and undesirable physical events or experi
rom sleep. If you have a parasomnia, you might have abnormal movements, talk, express emotions, 
Recognized command: what is parasomnia
Listening for a command...
Recognizing the command...
You said: what is insomnia
Insomnia is a common sleep disorder. It can cause trouble falling asleep, staying asleep, or get
 can interfere with your daily activities and may make you feel sleepy during the day.
Recognized command: what is insomnia
Listening for a command...
Recognizing the command...
You said: what is the reference for all this information
Recognized command: what is the reference for all this information
Listening for a command...
Recognizing the command...
You said: what is the reference for all the information
The information provided is based on the National Institute of Health.
Recognized command: what is the reference for all the information
Listening for a command...
Recognizing the command...
You said: tell me the date and time
The current time is 12:14 AM and the date is 2023-12-27.
You said: what is the weather today
The current weather in Melaka is 26.13 degrees Celsius with scattered clouds.
Recognized command: what is the weather today
Listening for a command...
Recognizing the command...
You said: can you provide me period times
Recognized command: can you provide me period times
Listening for a command...
Recognizing the command...
You said: provide me prayer times
Prayer times for Melaka today:
Fajr: 06:10
Sunrise: 07:12
Dhuhr: 13:11
Asr: 17:31
Sunset: 19:11
Maghrib: 19:11
Isha: 20:13
Imsak: 06:00
Midnight: 01:11
Firstthird: 23:11
Lastthird: 03:12
```

Figure 4.37: Voice assistant response

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the project has successfully achieved its stipulated objectives and realized the outlined scope, culminating in the development of an advanced sleep monitoring system powered by Internet of Things (IoT) technologies. The meticulous design and execution of the system, centered around the Raspberry Pi microcontroller, underscore its technological prowess and effectiveness in capturing comprehensive motion data during sleep. The algorithm crafted for personalized feedback exhibits a keen understanding of sleep patterns, offering users tailored recommendations based on insightful data analysis.

Furthermore, the system's performance has undergone rigorous evaluation, affirming its commendable reliability and accuracy in delivering meaningful insights into users' sleep behaviors. The seamless integration with TensorFlow, coupled with the implementation of a cloud-based database for efficient data storage, aligns with the project's scope and contributes to a seamless user experience. The provision of a user-friendly mobile application or web interface empowers users to effortlessly access and customize their sleep data.

The testing phase, involving ten users, serves to further validate the system's reliability and accuracy, marking the successful culmination of the project's endeavors. In essence, this project has not only met but surpassed its objectives and scope, presenting a sophisticated sleep monitoring system that integrates cutting-edge technology, algorithmic sophistication, and user-centric design. Looking forward, the insights gained from this project serve as a robust foundation for the continuous advancement of sleep monitoring technology, promising enhancements in overall sleep health for individuals.

5.2 Future works

Looking forward, the sleep monitoring project presents opportunities for growth and improvement. One crucial aspect to focus on in the future is the algorithm that provides personalized feedback. By tweaking its settings and incorporating advanced machine learning techniques, the aim is to make it even better at understanding individual sleep patterns. This ongoing refinement ensures the algorithm keeps improving, making the entire system more adaptable and effective.

Another important area for development is expanding the system's compatibility with different Internet of Things (IoT) devices and sensors. Integrating emerging technologies like wearable devices or smart mattresses will allow for the collection of a broader range of sleep-related data. This not only helps understand sleep better but also positions the system as a versatile solution for monitoring various aspects of sleep health.

There will also be a continued prioritization of user experience by refining the mobile app or web interface. Adapting these interfaces based on user feedback and preferences is key to making the overall experience better. Exploring features like personalized sleep coaching or real-time alerts for irregular sleep patterns will add practical value, giving users insights and guidance for better sleep. This dual focus on improving the algorithm and user experience underscores the commitment to keeping the system relevant and effective in the ever-evolving landscape of sleep monitoring technology.

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APPENDICES

Appendix A Raspberry pi code

```
import time
import cv2
import RPi.GPIO as GPIO
from datetime import datetime
import threading

# We're using the BCM GPIO numbering
GPIO.setmode(GPIO.BCM)

# GPIO 14 is set up as an input. It's pulled up to stop false signals
GPIO.setup(14, GPIO.IN, pull_up_down=GPIO.PUD_DOWN)

# Set up the webcam
camera = cv2.VideoCapture(0)

# Global variables to track motion state
motion_detected = False
motion_start_time = None

# Counter for captured images
image_count = 0

def motion_detected_handler(channel):
    global motion_detected, motion_start_time, image_count
    if GPIO.input(channel):
        if not motion_detected:
            motion_detected = True
            motion_start_time = time.time()
            print("Motion Detected!")
    else:
        if motion_detected:
            motion_detected = False
            motion_duration = time.time() - motion_start_time
            if motion_duration > 5:
                # Capture a frame from the webcam
                ret, frame = camera.read()
                if ret:
                    image_count += 1
                    # Save the frame as an image file with incremented name
                    cv2.imwrite(f'motion_detected_{image_count}.jpg', frame)
                    print(f'Image Captured: motion_detected_{image_count}.jpg')
            print("Motion Ended. Duration:", motion_duration, "seconds")
```

```
def sensor_monitor():
    GPIO.add_event_detect(4, GPIO.BOTH, callback=motion_detected_handler,
bouncetime=200)

    try:
        while True:
            time.sleep(1)

    except KeyboardInterrupt:
        print("Quit")
        GPIO.cleanup()
        camera.release()

# Start the sensor monitoring thread
sensor_thread = threading.Thread(target=sensor_monitor)
sensor_thread.start()

# Main thread continues here
while True:
    # Perform other tasks or wait for user input
    pass
```

Appendix B Gant Chart

No	PSM 2 Project Activity	Expected	Week													
		Actual	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Meeting with supervisor	Expected														
		Actual														
2	Meeting with JK PSM	Expected														
		Actual														
3	Result of 3d printing	Expected														
		Actual														
4	New 3d design (final design)	Expected														
		Actual														
5	Claiming process	Expected														
		Actual														
6	Finishing process of Casing	Expected														
		Actual														
7	Complete Chapter 2: Adding new statistic	Expected														
		Actual														
8	Complete Chapter 3: Methodology	Expected														
		Actual														
9	Collecting data	Expected														
		Actual														
10	Complete Chapter 4: Result	Expected														
		Actual														
11	Submit report	Expected														
		Actual														
12	Preparation for presentation	Expected														
		Actual														

Development of Sleeping Pattern Monitoring System using Internet of Things

by Muhammad Nur Ikhwan Md Shahrum

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