DEVELOPEMENT OF SMART HOME CONTROLLER WITH EEG AND IoT INTEGRATION

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

Faculty of Electronics and Computer Technology and Engineering
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DEDICATION

Specially dedicated to

My beloved mother and father,

Rushiza Binti Abdul Halim and Mazlan Bin Amin

To my supervisor,

TS. KHAIRUL AZHA BIN A AZIZ

My family,

Mohamad Ilham, Fatini and Amer Fariq

My friends,

Especially Sharveen and Ahmad basyir

Thanks for all the encouragement and support

Jazakallahu khairan khatirah

ABSTRACT

The integration of Electroencephalography (EEG) technology with the Internet of Things (IoT) offers a novel approach to smart home automation, enabling users to control devices using brainwave signals. This project aims to develop a smart home controller that leverages EEG and IoT to enhance accessibility, particularly for individuals with mobility impairments. The system utilizes an EEG headset to capture brain activity, which is then processed by a microcontroller and converted into digital commands. These commands are transmitted via the Blynk IoT platform, allowing real-time monitoring and control through a smartphone application.The experimental phase involved analyzing EEG attention levels to determine appropriate thresholds for activating and deactivating smart home devices. Results indicate that the system successfully responds to predefined attention values, enabling hands-free control of appliances such as lamps. However, challenges such as signal inconsistencies, environmental factors, and individual variations in EEG response were observed. Additionally, minor technical issues, including delays in data processing and limited independent control of multiple devices, were noted.Despite these limitations, the project demonstrates the feasibility of EEG-based smart home automation. Future enhancements will focus on improving signal accuracy through advanced machine learning algorithms, addressing privacy concerns with secure data transmission, and expanding functionality to include additional smart home appliances. The successful implementation of this technology could revolutionize home automation, providing an intuitive and accessible solution for a broader range of users.

ABSTRAK

Integrasi teknologi Electroencephalography (EEG) dengan Internet of Things (IoT) menawarkan pendekatan inovatif dalam automasi rumah pintar, membolehkan pengguna mengawal peranti menggunakan isyarat gelombang otak. Projek ini bertujuan untuk membangunkan pengawal rumah pintar yang menggabungkan EEG dan IoT bagi meningkatkan kebolehaksesan, terutamanya bagi individu yang mengalami masalah pergerakan. Sistem ini menggunakan alat EEG untuk menangkap aktiviti otak, yang kemudiannya diproses oleh mikropengawal dan ditukar kepada arahan digital. Arahan ini dihantar melalui platform Blynk IoT, membolehkan pemantauan dan kawalan masa nyata melalui aplikasi telefon pintar.Fasa eksperimen melibatkan analisis tahap perhatian EEG untuk menentukan ambang yang sesuai bagi mengaktifkan dan menyahaktifkan peranti rumah pintar. Hasil kajian menunjukkan bahawa sistem ini berjaya bertindak balas terhadap nilai perhatian yang telah ditetapkan, membolehkan kawalan bebas tangan terhadap peranti seperti lampu. Walau bagaimanapun, cabaran seperti ketidakkonsistenan isyarat, faktor persekitaran, dan variasi individu dalam tindak balas EEG turut diperhatikan. Selain itu, terdapat beberapa isu teknikal seperti kelewatan pemprosesan data dan kawalan peranti yang terhad secara individu.Meskipun terdapat kekangan, projek ini membuktikan kebolehlaksanaan automasi rumah pintar berasaskan EEG. Penambahbaikan masa hadapan akan memberi tumpuan kepada meningkatkan ketepatan isyarat melalui algoritma pembelajaran mesin yang lebih maju, menangani isu keselamatan data, serta memperluaskan fungsi untuk merangkumi lebih banyak peranti rumah pintar. Kejayaan pelaksanaan teknologi ini berpotensi merevolusikan automasi rumah, menyediakan penyelesaian yang lebih intuitif dan mudah diakses oleh pelbagai lapisan pengguna.

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Alhamdulillah, In the name of Allah, the Most Merciful and Graceful we glory Allah S.W.T and ask blessing and salute on noble prophet Muhammad S.A.W his companion‘s and who those follow him upholding the cause of right religion.

First of all, I feel grateful to Merciful Allah S.W.T for giving me guidance and opportunity to finish this final year project within the time given. I would like to thank my supervisor, TS. KHAIRUL AZHA BIN A AZIZ for assisting me to finish this project and for her knowledge, sharing, suggestion and support during the completion of this thesis.

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LIST OF ABBREVIATIONS

Iot	-	Internet of Thing
EEG	-	Electroencephalogram
IDE	-	Integrated Developement Enviroment
BCI	-	Brain Computer Interface

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CHAPTER 1

INTRODUCTION

1.1. Background

The evolution of smart home technology has been remarkable, driven by the increasing demand for more efficient, convenient, and secure living environments. The integration of Internet of Things (IoT) technologies has revolutionized how we interact with our homes, enabling devices to communicate with each other and be controlled remotely through internet-connected systems. This integration has laid the groundwork for advanced home automation, allowing for real-time monitoring and control of various home systems such as lighting, heating, security, and entertainment.

In recent years, the incorporation of Electroencephalography (EEG) technology into smart home systems has opened new avenues for enhancing user interaction. EEG is a non-invasive method of recording electrical activity of the brain, often used in medical and research settings to study brain functions and diagnose conditions.By leveraging EEG technology, it becomes possible to interpret neural signals to control devices, offering a hands-free and intuitive method of managing smart home environments.

The convergence of EEG and IoT in smart home systems aims to create a more seamless and natural interaction between users and their home environments. This development is particularly beneficial for individuals with mobility impairments or disabilities, as it provides an alternative means of interaction that does not rely on traditional manual controls.

In a typical setup, an EEG headset captures the user's brain activity and translates specific patterns into commands that can be understood by the IoT-enabled devices in the home. For example, a user could potentially control lighting, adjust the thermostat, or operate household appliances simply by thinking about the desired action. This kind of integration requires sophisticated signal processing algorithms and machine learning techniques to accurately interpret EEG signals and ensure reliable communication with the smart home system.

Research and development in this field focus on improving the accuracy of EEG signal interpretation, enhancing the usability of the interface, and ensuring the security and privacy of the user data. Effective integration of EEG with IoT involves addressing challenges such as minimizing signal noise, developing user-friendly interfaces, and ensuring that the system is adaptable to different users and environments.

In conclusion, the development of a smart home controller using EEG and IoT integration represents a significant advancement in home automation technology. It promises to offer enhanced convenience, accessibility, and efficiency, potentially transforming the way we interact with our living spaces. As technology continues to evolve, further innovations in this area are likely to emerge, pushing the boundaries of what is possible in smart home environments.

1.2. Problem statement

In recent years, the concept of smart homes has evolved rapidly, driven by advancements in Internet of Things (IoT) technology. These systems offer increased convenience, security, and energy efficiency through interconnected devices. However, the interaction with these systems is primarily reliant on traditional input methods such as mobile apps, voice commands, and physical switches. This limitation poses a significant accessibility challenge for individuals with physical disabilities, and even for able-bodied users, it may not always offer the most intuitive or seamless experience.

To address this gap, the integration of Electroencephalography (EEG) technology with IoT-enabled smart home systems presents a promising solution. EEG devices, which measure electrical activity in the brain, can provide a novel and direct method of controlling smart home environments. This integration could enable users to operate various home appliances and systems using brain signals, enhancing accessibility and user experience.

Despite the potential benefits, several challenges need to be addressed in developing an effective EEG-IoT integrated smart home controller. These challenges include ensuring the accuracy and reliability of EEG signal interpretation, maintaining user privacy and data security, achieving real-time processing, and designing a user-friendly interface that accommodates a wide range of user needs and preferences.

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1.2.1 Problem statement relate to societal and global issue

A smart home controller that integrates with EEG and IoT improves the quality of life for those with mobility limitations, such as the elderly or those with severe physical disabilities, therefore addressing important societal and global challenges. This technology encourages increased independence and autonomy by enabling hands-free manipulation of household appliances and systems using brainwave signals. This possibly lowers healthcare expenses by decreasing the need for ongoing carer help. Furthermore, as smart homes proliferate, this innovation can help create more inclusive living spaces by guaranteeing that all population segments have access to technology breakthroughs, therefore closing the digital gap and promoting social justice.

1.2.2 Problem statement related to environment and sustainability

EEG headset control for smart home using Blynk IoT can be realized based on online enabled home automation of energy use and waste in an environmentally friendly beneficial way. This technology allows us to activate household appliances by the power of our thoughts. This optimizes energy management; it enables lighting, heating and cooling systems to be adjusted only when they are required. And it's a tailored approach to cut the total carbon footprint of a household by reducing that wasteful energy use. This can drive broader social changes towards environmental behaviour - as state-of-the-art IoT technologies are adopted; the use of EEG-activated automation in smart houses will redefine the criteria for what it is to be green and energy-efficient.

1.3. Project Objective

- Develop a smart home controller that integrates EEG technology and IoT.
- Enable users to control smart home devices using brainwave signals.
- To create a user-friendly interface within the Blynk app for real-time monitoring and control only by using smartphone.

1.4. Job Scope

a) In this works, the project will only focus on the following scopes:

- Develop communication protocols for Blynk IoT to interface with the smart home controller by using Blynk IoT platform.
- Write and maintain code for the smart home controller software.
- Conduct extensive testing of the EEG signal processing and IoT integration.
- Create comprehensive documentation for system architecture, code, and user manuals.
- Create Smart Home controller that can be control by EEG signal and IoT integration.

Provide real-time responses to facilitate user interaction.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This part had shown a lot of research had been done in order to get a suitable technique related to this project that is smart home controller with EEG and IoT integration because it still has many ways needed to be improve based on the existing method to facilitate our generation. The research also will related with my own project and maybe will be use that method to my project.

2.2 Electroencephalography (EEG)

The study by C. Sun and C. Mou, provides a comprehensive review of EEG signal processing techniques, focusing on preprocessing, feature extraction, and classification methods. The authors analyzed 61 research articles retrieved from major academic databases and identified key trends and challenges in the field. They highlighted the importance of preprocessing methods, particularly channel selection and data augmentation, and noted the growing use of deep learning techniques. The study emphasizes the need for innovative methods to address the challenges of EEG signal processing, including low spatial resolution, low signal-to-noise ratio, dimensionality disaster, non-stationariness, and subject-specificity[1].The review by A. Chaddad, Y. Wu, R. Kateb, and A. Bouridane covers various aspects of EEG signal processing, including signal acquisition, denoising, feature engineering, and classification. The authors discuss the significance of EEG in brain-related research and highlight the complexity of EEG signals. They present a detailed examination of denoising techniques, feature engineering methods, and machine learning algorithms used in EEG signal processing. The study identifies current limitations and future research directions, including the need for more advanced preprocessing methods and the integration of EEG with other imaging modalities[2].

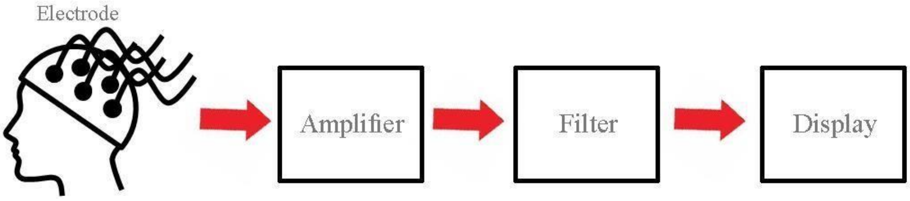

Figure 2. 1 EEG system

The research by K. Erat, E. B. Şahin, F. Doğan, N. Merdanoğlu, A. Akcakaya, and P. O. Durdu focuses on EEG signal processing for brain-computer interface (BCI) applications. The authors discuss the challenges of EEG signal processing, including noise interference, nonlinearity, and individual variations. They present a detailed analysis of various preprocessing and feature extraction methods, including time-frequency analysis, high-order spectral analysis, and nonlinear dynamic analysis. The study highlights the potential of machine learning and deep learning algorithms for EEG signal processing and emphasizes the need for more advanced methods to improve BCI performance.

These studies collectively demonstrate the ongoing efforts to improve EEG signal processing techniques, addressing the challenges posed by the unique characteristics of EEG signals. They highlight the importance of preprocessing methods, the growing use of deep learning, and the need for more advanced feature extraction and classification methods to enhance the accuracy and reliability of EEG signal processing[3].

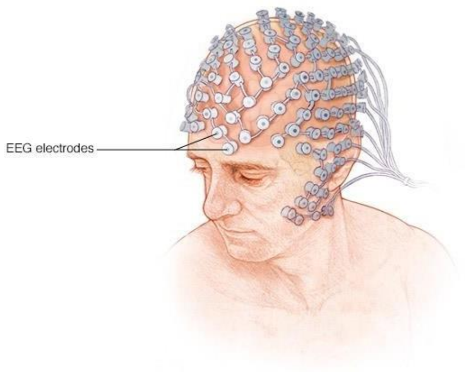

Figure 2. 2 EEG

2.3 Neuron activities

Neuronal activity plays a crucial role in various aspects of brain function, including myelin regeneration, brain organoid development, and large-scale recording in freely-moving mice. A recent study by Xie et al. (2023) demonstrated that neuronal activity can stimulate the formation and regeneration of myelin, improve conduction speed and neural signal processing ability, maintain axonal integrity, and support axonal nutrition. The authors discussed the latest research progress on neuronal activity's effects on myelin regeneration, including direct or indirect stimulation methods and related neural signaling pathways such as glutamatergic, GABAergic, cholinergic, histaminergic, purinergic and voltage-gated ion channel signaling[4].

In another study, Birey et al. (2023) reviewed the use of brain organoids for neuroscientific research[5]. They found that neuronal activity is a key determinant of function in brain organoids and analyzed the number of articles describing activity assays using whole cell patch clamp, calcium imaging, or extracellular activity measurements[5]. The authors showed that calcium imaging and patch clamp were the most frequently used assays, with whole mount organoids being the most used approach for calcium imaging and extracellular activity, while patch clamp was mainly performed in organoid sections[5].

Furthermore, Xie et al. (2023) introduced a new method for acquiring simultaneous volumetric neuronal activity patterns from freely-moving mice using the calcium sensor CaMPARI[6]. This method enables large-scale recording across multiple brain regions at single-cell resolution without mounting the animal's head under a microscope, tethering it, or attaching a miniaturized imaging device to its skull[6]. The authors demonstrated the advantages of CaMPARI-based recording for detecting activity from brain volumes larger than 6 mm3 and validated its accuracy by comparing the results to recordings with the widely-used GECI, jGCaMP7s[6].

These three studies highlight the importance of neuronal activity in various aspects of brain function and introduce new methods for studying it, including the regulation of myelin regeneration, the analysis of neuronal activity in brain organoids, and large-scale recording in freely-moving mice using the CaMPARI sensor.

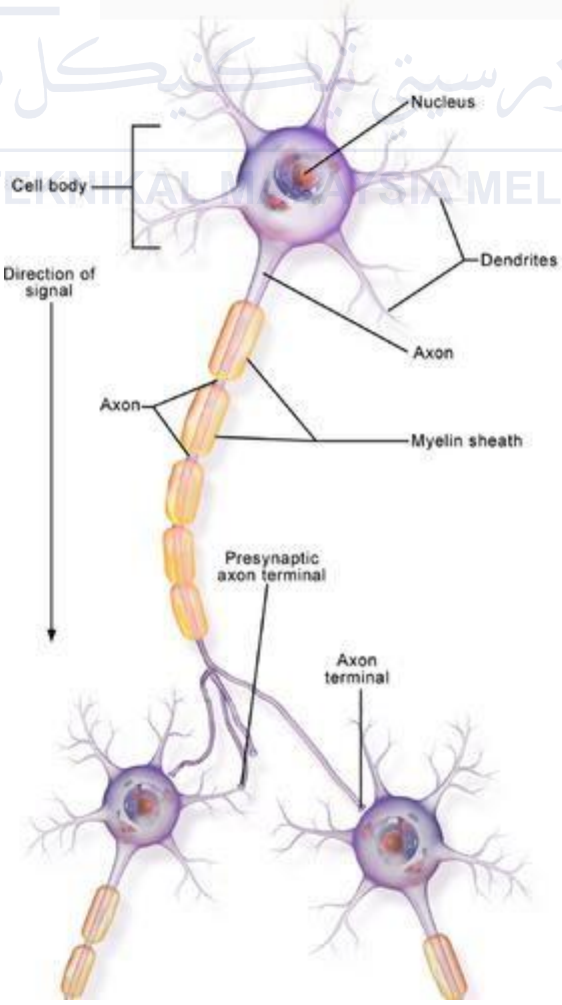

Figure 2. 3 Neuron struct

2.4 Brain wave

The study by Borghini et al. analyzed the correlation between brainwave activity and reaction times during a cognitive task. The researchers found that the power of specific brainwaves, such as Theta and Beta waves, was positively correlated with response times. This suggests that the longer the time required for a subject's reaction, the greater the mental workload generated in the specific frequency range. The study also reported that the majority of subjects exhibited statistically significant correlations between Theta wave power in the frontal lobe and response time[7].Seifi Ala et al. conducted a systematic review to evaluate the effects of binaural beat stimulation on brainwave entrainment. The review included 14 studies that investigated the effects of binaural beats on EEG parameters. The results showed inconsistent findings, with five studies reporting results in line with the brainwave entrainment hypothesis, eight studies reporting contradictory results, and one study reporting mixed results. The review highlighted the need for a comprehensive theoretical and methodological debate about the definition of brainwave entrainment and its operationalization[8].

Lersch et al. investigated the effects of binaural beats on cognitive performance using EEG. The study found that binaural beats in the frequency range of the human EEG did not elicit brainwave entrainment effects. The results suggested that the inconsistency in research outcomes might be attributable to specifics in the approaches to EEG measurement and analysis. The study emphasized the need for further systematic and more standardized approaches to basic research in this field[9].

The reviewed studies demonstrate the complexity of the relationship between brainwave activity and reaction times. While Borghini et al. found positive correlations between Theta wave power and response times, Seifi Ala et al. highlighted the need for a comprehensive definition and operationalization of brainwave entrainment. Lersch et al.

showed that binaural beats do not necessarily elicit brainwave entrainment effects. These findings underscore the importance of methodological standardization and a deeper understanding of the underlying mechanisms to better understand the effects of brainwave entrainment on cognitive performance. The summary of brain wave have been show at Table 2.1.

Table 2. 1 Summary of brain waves

Waveform	**Frequency (Hz)**	**Location**	**Mental State**	**Activities**
Gamma	25 – 100+	- Somatosensory cortex	Excited	- Concentration - Higher learning
Beta	12.5 – 30	- Both side of brain - Symmetrical distributon - Most evident frontally	Active	- Awake - Thinking - Talking
Alpha	7.5 – 12.5	-Posterior regions of head - Central sites (C3-C4) at rest	Relaxed	- Listening music -Watching TV - Meditating
Theta	4 – 7.5	- Where not related to task of hand	Drowsy	- Pre-sleep/ Semi-awake
Delta	0.5 – 3.5	- Frontally in adults - Posteriorly in children	Sleep	- Sleep - Healing
Mu	7.5 – 12.5	- Sensorimotor cortex	Relaxed	- Resting of motor neurons

2.4.1 Beta wave

The beta wave is the fastest of all waves, while having a very small amplitude. Although beta waves have a frequency range of 12.5 to 30 Hz, they can be further classified as High Beta (20.5-28 Hz), Low Beta (12.5-16 Hz), and Beta (16.5-20 Hz). This "fast" wave, which denotes arousal and is indicative of a highly engaged mind, occurs when people are actively involved in tasks and conversations[10].Shown at Figure 2.4

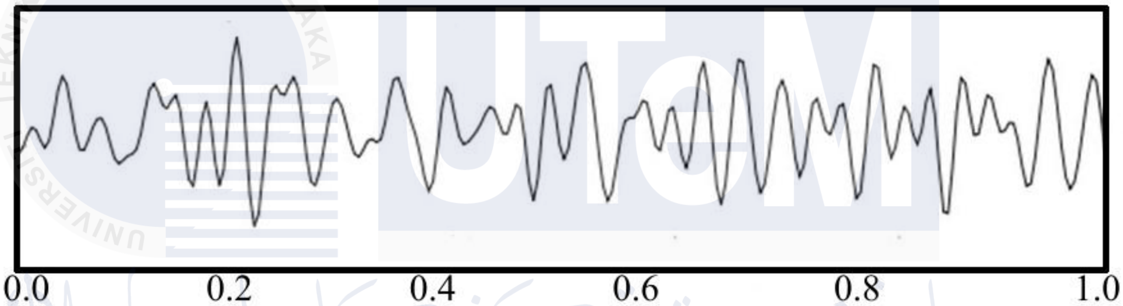

Figure 2. 4 Beta wave (Cvijetic, 2013)

2.4.2 Alpha wave

Because Hans Berger was the one who identified the Alpha wave, it is often referred to as Berger's wave. Non-arousal is represented by this wave. In comparison to the beta wave, it has a slower brainwave but a larger amplitude. The frequency range of alpha waves is 7.5–12.5 Hz. Furthermore, the mind is at ease and in its typical resting condition

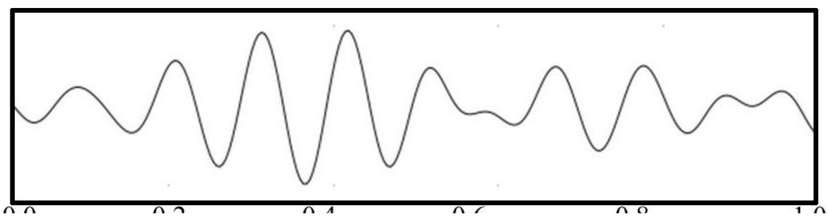

Figure 2. 5 Alpha wave (Cvijetic, 2013)

in this state. When individuals watch TV, meditate, or listen to music, this wave happens[10].

2.4.3 Theta wave

Theta wave is the following brain wave type in frequency sequence. In comparison to the Alpha wave, the Theta wave is slower in frequency and has an even larger amplitude. Theta waves typically have frequencies between 4 and 7.5 Hz. Individuals are in a hypnoidal state, also known as the theta state, which is a pre-sleep or semi-awake condition.

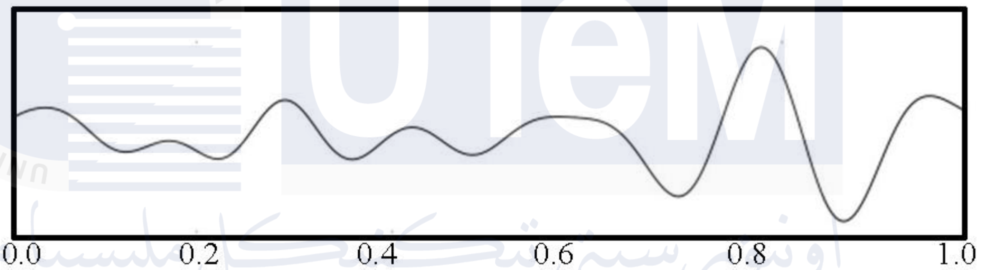

Figure 2. 6 Theta wave (Cvijetic, 2013)

2.4.4 Delta wave

Delta wave comes next. The delta wave is the slowest frequency and has the largest amplitude. Delta waves typically have frequencies between 0.5 and 3.5 Hz. It is the most profound brainwave stage connected to deep sleep deprivation. Furthermore, it is crucial for the immune system's and health's recovery. Babies typically exhibit the Delta wave.

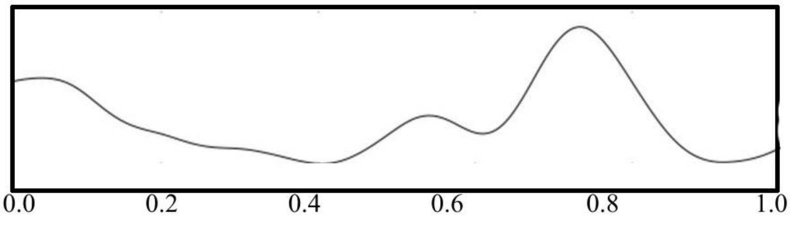

Figure 2. 7 Delta wave (Cvijetic 2013)

2.4.5 Gamma wave and mu wave

Two more wave types than the ones mentioned above: mu and gamma. Gamma waves have a frequency between 25 and 100 Hz, with 40 Hz being the usual value. It often occurs in an aroused mental state, which is excellent for learning. Similar in frequency to the alpha wave (7.5–12.5 Hz), the mu wave is exclusive to the sensorimotor cortex and displays motor neurons in their resting state.

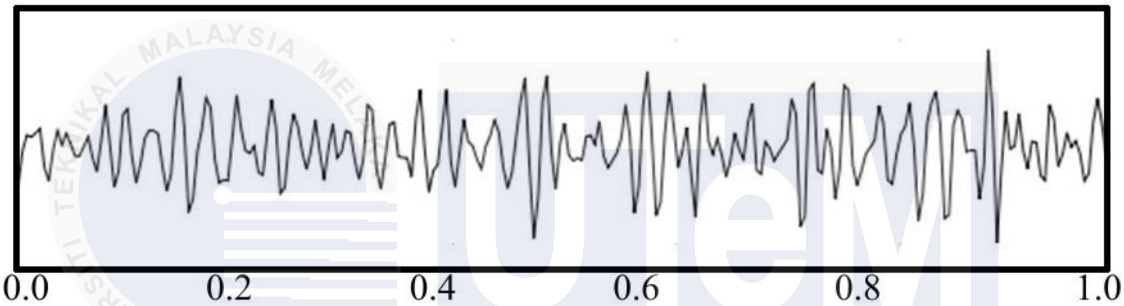

Figure 2. 8 Gamma wave (Cvijetic 2013)

2.5 Brain Computer Interface (BCI)

This systematic review by Cobos et al. analyzed the quality of BCI systems, identifying efficiency and usability as the most commonly used quality characteristics. The study highlights the need for a comprehensive model that covers the research gap in BCI system quality improvement. The authors emphasize the importance of considering user experience and satisfaction in the design and evaluation of BCI systems[11].

This comprehensive review by Yutaka Watanobe et al. covers various aspects of BCI systems, including techniques, datasets, feature extraction methods, evaluation measurement matrices, existing BCI algorithms, and classifiers. The study provides a taxonomy of BCI systems and discusses the challenges and limitations of BCI systems, along with possible solutions. The authors also highlight the need for standardized evaluation methods and the development of user-friendly BCI systems[12].

This review by Cobos et al. examines the different steps involved in designing a BCI system, including signal acquisition, preprocessing, feature extraction, classification, and control interface. The study discusses the advantages and drawbacks of various neuroimaging modalities and signal enhancement techniques used in BCI systems. The authors emphasize the importance of selecting appropriate signal processing methods based on the specific application and user requirements[13].

These references provide a comprehensive overview of the current state of BCI systems, highlighting advancements and challenges in the field. The studies emphasize the need for user-centric design, standardized evaluation methods, and the development of robust and reliable BCI systems. Future research should focus on improving the usability, efficiency, and accessibility of BCI systems to enhance their adoption and impact in various applications, such as assistive technology, rehabilitation, and entertainment.

Figure 2. 9 Brain computer interface

2.6 Research related to SMART HOME CONTROLLER WITH EEG AND IoT INTEGRATION

2.6.1 NeuroPhone: Brain-mobile phone interface using a wireless EEG headset

The NeuroPhone project introduces a brain-mobile phone interface using wireless EEG headsets for human-mobile interaction. Previous research mainly focused on expensive, wired EEG devices for higher quality signals, while consumer-oriented EEG headsets were cheaper but noisier and more geared towards gaming applications.Some related projects like wireless EEG headbands with limited electrodes or commercially available headsets with single electrodes were not suitable for applications like the NeuroPhone system.[14]

The NeuroPhone system stands out for its simplicity in engineering using affordable commercial components, opening up new opportunities in ubiquitous sensing and pervasive computing.Challenges in the project include developing practical and robust brain-mobile phone interfaces that can work not only in controlled settings but also in real-world scenarios, as well as addressing issues like power efficiency and resource limitations on mobile phones[14].

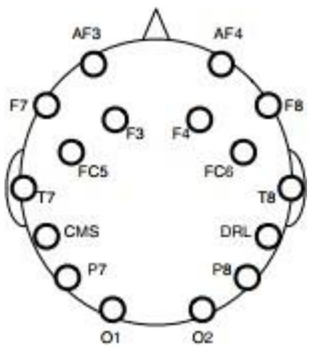

Figure 2. 10 Electrode position on the headset

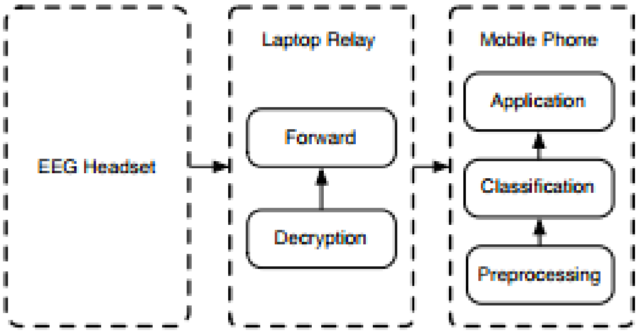

Figure 2. 11 NeuroPhone system architecture

The project focuses on developing a Brain Computer Interface (BCI) controlled robotic arm using EEG signals recorded from the human scalp, aiming to enable control through brain activity.An Emotiv EPOC headset with 14 electrodes is employed to detect and collect EEG signals for controlling the robotic arm based on human facial expressions[10]. Basically, the designed system consists of five steps as shown in Figure 2.12

Figure 2. 12 Block diagram of BCI robotic arm

The BCI robotic arm is designed to perform four movements, including making a fist, releasing a fist, flexion of elbow, and extension of elbow, with each movement corresponding to specific human expressions like left smirk, right smirk, raise brow, and look left-right.The system's performance was evaluated on 10 subjects, demonstrating an average accuracy exceeding 92%. Moreover, the study analyzed the impact of reducing the number of electrodes on the BCI system, determining that 7 electrodes are adequate for precise control of the robotic arm[10]. In the end, the system should work as shown in flow chart in Figure 2.13.

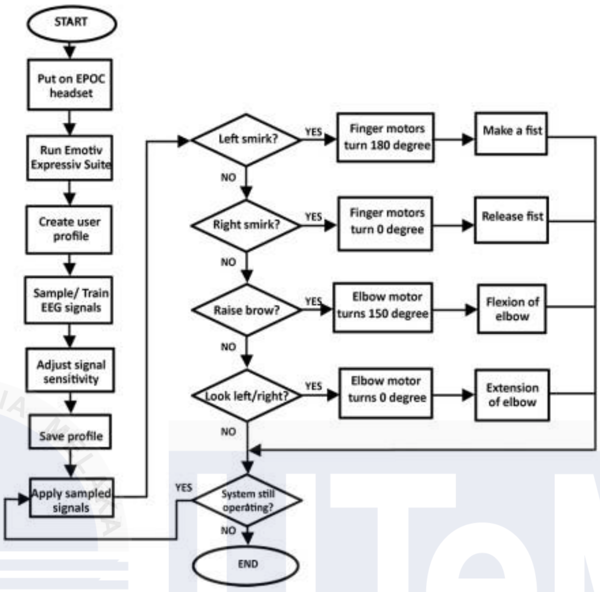

Figure 2. 13 Flowchart of BCI system

2.6.2 Design and Development of a Brain Computer Interface Controlled Robotic Arm

The project by K. Hong Way focuses on developing a Brain Computer Interface (BCI) controlled robotic arm using EEG signals recorded from the human scalp, aiming to enable control through brain activity.An Emotiv EPOC headset with 14 electrodes is employed to detect and collect EEG signals for controlling the robotic arm based on human facial expressions[10]. Basically, the designed system consists of five steps as shown in Figure 2.14.

Figure 2. 14 Block diagram of BCI robotic arm

The BCI robotic arm is designed to perform four movements, including making a fist, releasing a fist, flexion of elbow, and extension of elbow, with each movement corresponding to specific human expressions like left smirk, right smirk, raise brow, and look left-right.The system's performance was evaluated on 10 subjects, demonstrating an average accuracy exceeding 92%. Moreover, the study analyzed the impact of reducing the number of electrodes on the BCI system, determining that 7 electrodes are adequate for precise control of the robotic arm[10]. In the end, the system should work as shown in flow chart in Figure 2.15.

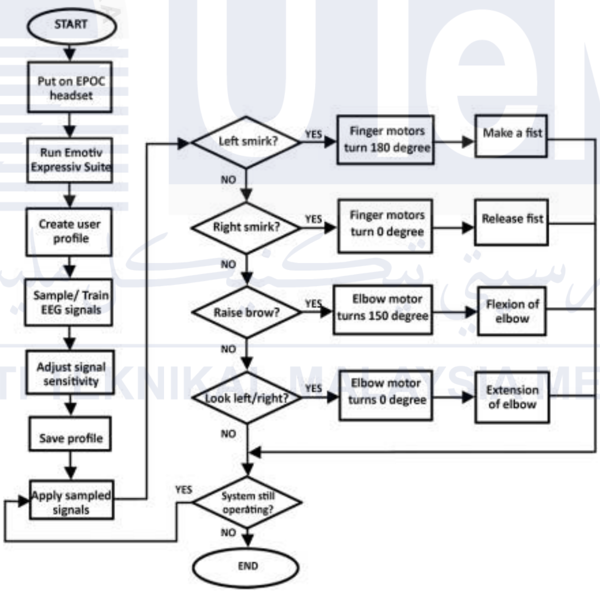

Figure 2. 15 Flowchart of BCI system

2.6.3 BRAIN COMPUTER INTERFACE BASED SMART HOME CONTROL USING EEG SIGNAL

The project aims to extract and identify the actual EEG signal related to user intention, defining events based on features like eye blinking or raising an eye for task execution. A smart home control system based on BCI using EEG signals is presented, allowing users to select and control home appliances in real-time through eye blinking features without physical activity, enhancing disabled individuals' lives .EEG signals are acquired using electrodes placed on the user's scalp, with pre-processing and signal conditioning to improve signal quality for feature extraction[15].Figure 2.16 depicts the block diagram of data transmission in the system.

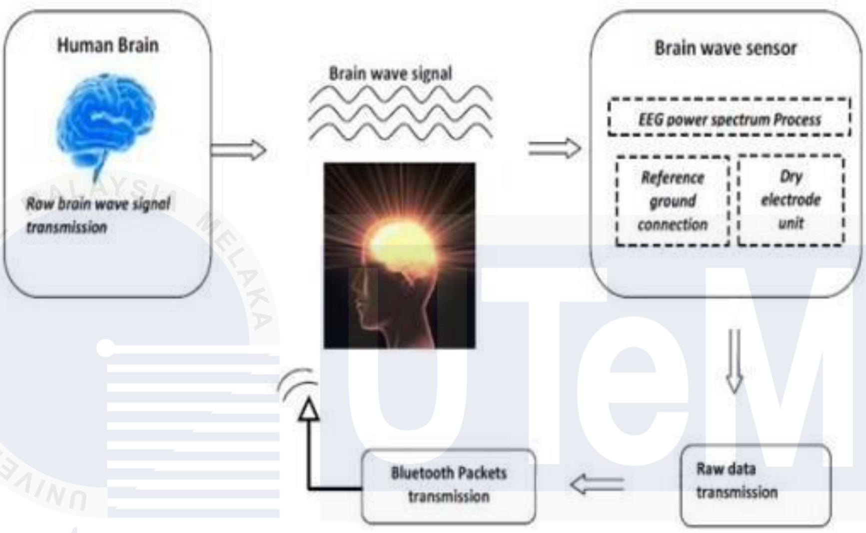

Figure 2. 16 Block diagram data transmission

The system integrates Arduino with relay modules and L298N for device operation, with a graphical user interface for user interaction and activation through eye blinks to control appliances. BCI-based systems, such as the presented home control system, can facilitate handicapped individuals by correlating brain activity with home appliance regulation, achieving high accuracy levels[15].Figure 2.17 show about the complete block diagram of smart home.

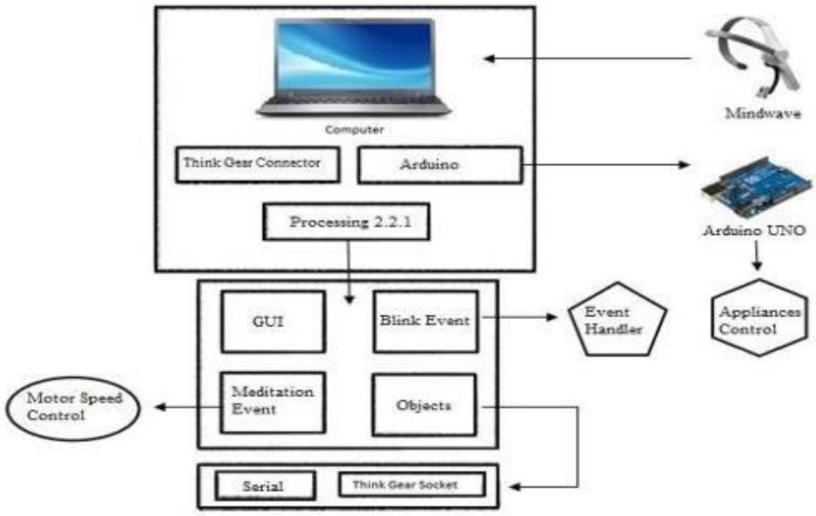

Figure 2. 17 Block diagram smart home

2.6.4 Development of IoT Smart Home Controller Using Biosensor

This research explores the creation and implementation of a smart home control system that leverages biosensor technology, specifically electroencephalogram (EEG) biosensors, in conjunction with the Internet of Things (IoT). The primary objective of this project is to develop a smart home controller that can interpret brain signals to operate various home appliances, thus enhancing the quality of life for all users, particularly those with physical disabilities.

The system utilizes the Neurosky Mindflex, a cost-effective EEG biosensor device, to capture electrical activity from the brain. These signals are then processed and classified using Arduino software, which acts as the intermediary between the biosensor and the home appliances. The processed brain signals are converted into commands that control the home appliances via the NODEMCU ESP8266 microcontroller. The appliances, such as lights and fans, can be turned on and off based on the user's mental states, such as attention and meditation levels[16].

One of the innovative aspects of this project is its integration with the ThingSpeak IoT platform, which allows for real-time data visualization and monitoring of the biosensor data. This platform enables users to observe the performance of the system remotely, providing insights into the efficiency and reliability of the home automation processes. The data collected and displayed include attention and meditation values, as well as the operational status of the connected appliances.

The project methodology involves several stages, including the setup of the EEG device, configuration of the microcontroller, and development of the control algorithms. It also includes rigorous testing and measurement phases to ensure the accuracy and responsiveness of the system. The comprehensive analysis provided in the report discusses the challenges faced during the development, such as signal noise and calibration issues, and proposes potential solutions for improving system performance[16].The flowchart of the project is shown below in Figure 2.18

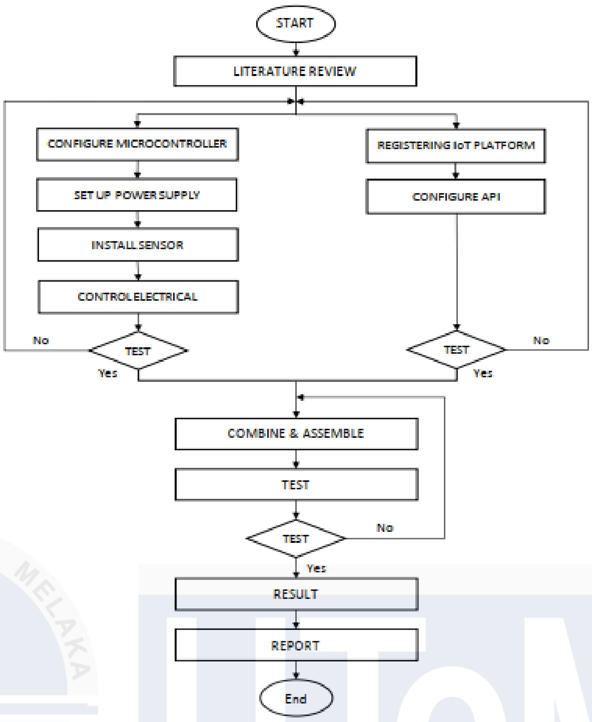

Figure 2. 18 Project flowchart

2.6.5 Hydroponics Using the Blynk Application

This is exposed through a study entitled "Monitoring pH in Hydroponics Using the Blynk Application." High technology is put to the test even in hydroponic agriculture without the use of soil but instead the use of mineral nutrient solutions in water. Hydroponics is a not-so-common means of growing crops, but it holds many advantages to itself, especially when utilized in areas where there is no ample space to spare, where traditional agriculture cannot be applied. This new method allows for the growth of a wide range of plants in vast, well-controlled environments. Urban towering house residents and urban-based small-scale farmers will find this method very useful to them. The constant conversion of agricultural lands into urban settlement and industrial areas characterizes agrarian Indonesia. Under such situations, innovative techniques like hydroponics provide an efficient means of using available limited space for agricultural production. However, hydroponic systems require meticulous monitoring of various parameters to ensure optimal plant growth, one of the most critical being the pH level of the nutrient solution[17].

This need is then answered by the research conducted by Miftahul Amin, Alfian Ma'arif, and Iswanto Suwarno, by developing an embedded system that integrates pH sensors with the Blynk application-an IoT platform.For that matter, the Blynk application helps in monitoring and controlling in real-time. This is a very good alternative in controlling the pH of hydroponics. The approach of the study involves the wick system method where a wick acts like an intermediary to draw nutrient solutions from the reserve to the roots of the plant.The experimental setup by the researchers gathered data every 30 minutes till 12 hours. The pH sensor reads the acidity levels and sends voltage values to the Blynk App, which converts it displaying it to pH values in real time. The results of the study indicate high accuracy in pH monitoring, with celery, tomato, and pakcoi plants showing accuracy values of 98.33%, 98.68%, and 98.45%, respectively show in Table 2.2,2.3,2.3.

Table 2. 2 Testing on Celery

Celery pH			
Research Tools	**Standard Measuring Instruments**	**Difference**	**Eror(%)**
6.47	6.5	0.03	0.46
6.63	6.5	0.13	2
6.63	6.5	0.13	2
6.42	6.5	0.08	1.23
6.34	6.5	0.16	2.46
6.51	6.5	0.01	0.15
6.63	6.5	0.13	2
6.42	6.5	0.08	1.23
6.30	6.5	0.20	3.07
6.55	6.5	0.05	0.76
6.59	6.5	0.09	1.38
6.42	6.5	0.08	1.23
6.51	6.5	0.01	0.15
6.42	6.5	0.08	1.23
6.38	6.5	0.12	1.8
6.63	6.5	0.13	2
6.38	6.5	0.12	1.84
6.47	6.5	0.03	0.46
6.59	6.5	0.09	1.38
6.34	6.5	0.16	2.46
6.68	6.5	0.18	2.77
6.68	6.5	0.18	2.77
6.68	6.5	0.18	2.77
6.34	6.5	0.16	2.46
Total		2.61	40.1
Average		0.10	1.67

$$\text{Accuracy} = \frac{1{,}67\ (\%)}{24}$$
$$= 100\% - 1.67\%$$
$$= 98.33\%$$

Table 2. 3 Testing on Pakcoi

Pakcoi pH			
Research Tools	**Standard Measuring Instruments**	**Difference**	**Eror(%)**
7.14	7.0	0.14	2
7.06	7.0	0.06	0.86
7.10	7.0	0.10	1.43
7.10	7.0	0.10	1.43
7.06	7.0	0.06	0.86
7.14	7.0	0.14	2
7.18	7.0	0.18	2.57
6.89	7.0	0.11	1.57
7.14	7.0	0.14	2
6.97	7.0	0.03	0.42
7.10	7.0	0.10	1.43
6.80	7.0	0.20	2.85
6.93	7.0	0.07	1
7.01	7.0	0.01	0.43
6.80	7.0	0.20	2.86
7.10	7.0	0.10	1.43
6.97	7.0	0.03	0.42
6.80	7.0	0.20	2.86
7.14	7.0	0.14	2
7.06	7.0	0.06	0.86
7.06	7.0	0.06	0.86
6.80	7.0	0.20	2.86
7.08	7.0	0.08	1.14
7.08	7.0	0.08	1.14
Total		2.59	37.28
Average		0.11	1.55

$$= 100\% - \frac{1.55(\%)}{24}$$
$$= 100\% - 1.55\%$$
$$= 98.45\%$$

Table 2. 4 Testing on Tomatoes

Tomatoes pH			
Research Tools	Standard Measuring Instruments	Difference	Eror(%)
6.46	6.5	0.04	0.61
6.42	6.5	0.08	1.23
6.52	6.5	0.02	0.30
6.30	6.5	0.20	3.07
6.48	6.5	0.02	0.30
6.32	6.5	0.18	2.76
6.54	6.5	0.04	0.61
6.34	6.5	0.16	2.46
6.32	6.5	0.18	2.76
6.52	6.5	0.02	0.30
6.38	6.5	0.12	1.84
6.46	6.5	0.04	0.61
6.40	6.5	0.10	1.53
6.34	6.5	0.16	2.46
6.46	6.5	0.04	0.61
6.42	6.5	0.08	1.23
6.52	6.5	0.02	0.30
6.32	6.5	0.18	2.76
6.46	6.5	0.04	0.61
6.38	6.5	0.12	1.84
6.52	6.5	0.02	0.30
6.48	6.5	0.02	0.30
6.59	6.5	0.09	1.38
6.40	6.5	0.10	1.53
Total		2.07	31.88
Average		0.08	1.32

$$= 100\% - \frac{1.32\ (\%)}{24}$$
$$= 100\% - 1.32\%$$
$$= 98.68\%$$

This research underscores the potential of IoT in enhancing the efficiency and effectiveness of hydroponic farming. By automating the monitoring process, the system reduces the need for manual checks, saving time and labor while ensuring that the plants receive the precise pH conditions required for optimal growth. The Blynk application, combined with the pH sensor and NodeMCU ESP8266 microcontroller, provides a seamless and user-friendly interface for farmers to monitor their crops remotely.The study's findings demonstrate that the integration of IoT with hydroponics can significantly improve the reliability and productivity of urban farming. It offers a practical solution for individuals and communities looking to adopt sustainable agricultural practices in urban settings. The real-time data provided by the Blynk application allows for timely interventions to maintain ideal growing conditions, thereby enhancing the quality and yield of the crops.

"Monitoring pH in Hydroponics Using the Blynk Application" presents a valuable contribution to the field of smart agriculture. It showcases the benefits of using technology to address the challenges of modern farming, particularly in urban areas. The study's success in achieving high accuracy in pH monitoring highlights the potential for wider adoption of such systems to promote efficient, sustainable, and space-saving agricultural practices[17].

2.6.6 A Review of Fuzzy Logic Method Development in Hydraulic and Pneumatic Systems

This project has employed by Grzegorz Filo, fuzzy logic control systems to a wide range of applications such as the functioning of hydraulic turbines, pneumatic systems and also to robotic arms. It is thus proved that fuzzy logic can definitely be employed in a great number of control mechanisms. Designing parameters of both hydraulic and pneumatic fuzzy systems have been analyzed by Scientists where the input signals are mostly two; plurality of the units is single output and others are three outputs. The study emphasizes the advantages of fuzzy logic in enhancing control precision and improving user interaction in controlling robotic arms through human facial expressions, indicating potential advancements in intuitive control interfaces[18].Here the example of Fuzzy logic controller for a transport platform on pneumatic cushions in Figure 2.19.

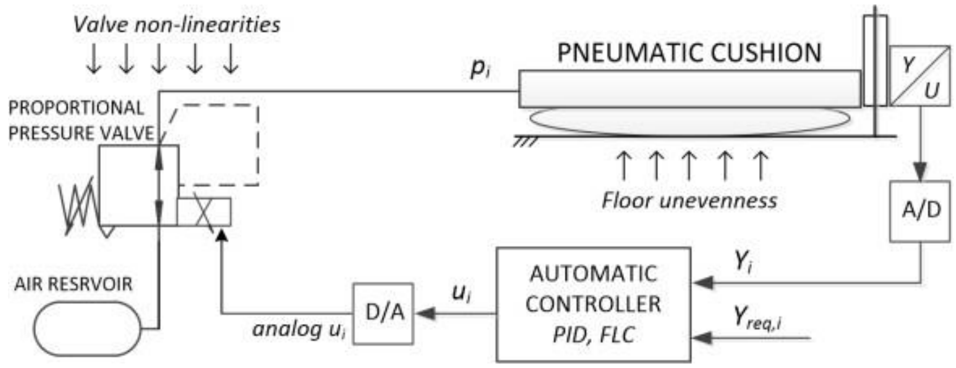

Figure 2. 19 Fuzzy logic controller for a transport platform on pneumatic cushions

Challenges identified in the project include limitations in movement options for the robotic arm, as it is designed for specific movements based on facial expressions, and the dependency on EEG signal quality for consistent and accurate control, posing potential obstacles in system performance[18].

2.6.7 Application of fuzzy logic: A literature review Renu Makkar

The project involves analyzing by Renu Makkar conversations between individuals using Excel's fuzzy lookup add-in to determine the percentage of truth and false in each conversation, aiding in determining admissibility as evidence.It explores the influence of the public lighting environment on local residents' subjective assessment, emphasizing sustainable development and energy savings in smart city-related research and projects[19].

The study presents the design and expected results of a digital twin monitoring and management system for a fully automatic robotic sensor assembly line, focusing on monitoring and stabilization Researchers have considered two types of datasets, weather, and forest fire information, for a comparative analysis using association rule mining approach, highlighting the need for fuzzifying datasets[19].

The project represents the use of fuzzy logic in various fields such as chemical science, medical science, agriculture, political science, and environmental science, showcasing its wide applicability beyond mathematical logic.

2.6.8 Working Principle of Arduino and Using it as a Tool for Study and Research

The conference paper "Working Principle of Arduino and Using it as a Tool for Study and Research" by Leo Louis, published in the International Journal of Control, Automation, Communication and Systems (IJCACS) in April 2016, discusses the foundational aspects and applications of Arduino boards[20].

Introduced in 2005, Arduino is an open-source microcontroller platform designed for ease of use and affordability, making it popular among hobbyists, students, and professionals for creating interactive devices using sensors and actuators. The paper highlights the active user community, the platform's growth, and its inexpensive hardware as key factors in its widespread adoption. Various Arduino boards, such as the Arduino Uno and Arduino Mega 2560, and shields for added functionality like Ethernet and wireless communication are discussed. The Arduino IDE, used for writing and uploading code, supports multiple operating systems and simplifies programming with functions like setup and loop. The paper also showcases notable projects, including ArduSat for space exploration, ArduPilot for drone autopilots, and Lilypad Arduino for wearable electronics, illustrating the platform's versatility and significance in both educational and professional settings[20].In this project will be include about Arduino in Figure 2.20 and Table 2.5.

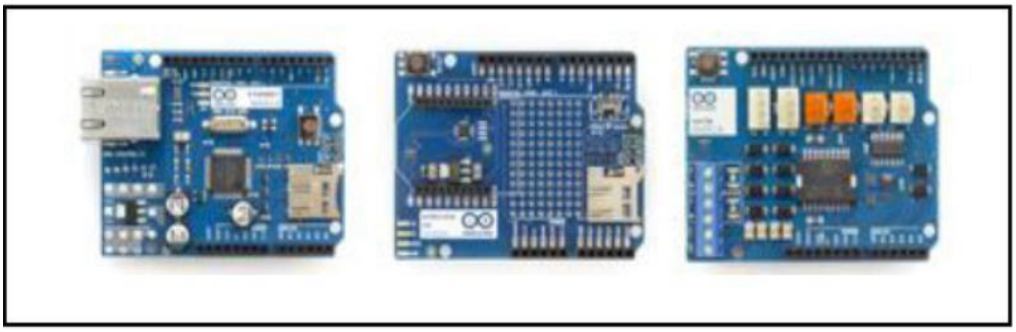

Figure 2. 20 Arduino shields

Table 2. 5 Arduino type

Arduino Type	Microcontroller	Clock Speed
Arduino Uno	ATmega328	16 MHz with auto-reset
Arduino Duemilanove / ATmega328	ATmega328	16 MHz with auto-reset
Arduino Nano	ATmega328	16 MHz with auto-reset
Arduino Mega 2560 or Mega ADK	ATmega2560	16 MHz with auto-reset
Arduino Leonardo	ATmega32u4	16 MHz with auto-reset
Arduino Mini w/ ATmega328	ATmega328	16 MHz with auto-reset
Arduino Ethernet	Equivalent to Arduino UNO with an Ethernet shield	
Arduino Fio.	ATmega328	8 MHz with auto-reset
Arduino BT w/ ATmega328	ATmega328	16 MHz with auto-reset
LilyPad Arduino w/ ATmega328	ATmega328	8 MHz (3.3V) with auto-reset
Arduino Pro or Pro Mini	ATmega328	16 MHz with auto-reset
Arduino NG	ATmega8	16 MHz with auto-reset

2.6.9 Smart house systems

One of the best examples is the thesis "Smart House Systems" by Roman Demianchuk, submitted to Centria University of Applied Sciences as part of his Bachelor's in Information Technology in September 2019. It takes an extensive look into smart home technologies-its development, implementation, and resultant benefits. The idea behind the concept started in the 1970s where smart homes involve using various intelligent building management systems that let one increase effectiveness and productivity in homes. These systems include different technologies that ensure the automation and control of various functions within a home, including but not limited to lighting, climatology, security, and multimedia. The sharp body and soul of such systems incorporate sensors, controllers, and highly developed software tailored to the efficient and safe maintenance of household appliances and systems. Actually, these systems are normally managed centrally through touch panels, internet interfaces, or mobile devices, thus enabling the perfect control of the home environment. Engineering communications of smart house systems involve the integration of heating, ventilation, air conditioning, and lighting. It brings huge energy savings that assess 10% to 40% of consumed electricity. Also, the economic efficiency of smart houses is high because they provide rational use of resources and reduce the operational expenditures. For example, intelligent controls of the systems allow getting a 30% reduction in heating, electricity, and water consumption. Gilani, however, claims that implementation of this system currently has quite a number of challenges. These systems also offer effective home expense management, which makes them very attractive to the mortgage lenders and insurance companies, especially in developed economies[21].

The market for smart home technologies is expanding rapidly, fueled by advancements in wireless technologies and the Internet of Things (IoT). Industry giants like Google, Apple, Amazon, and Alibaba are driving consolidation and growth in this market. In Finland, the adoption of smart home technologies is increasing, with significant market growth expected in the coming years. The thesis emphasizes that while smart home technology offers numerous benefits, including enhanced convenience, improved security, and cost savings, its success largely depends on effectively communicating these benefits to potential customers[21]. By understanding and addressing the practical, technological, and economic aspects of smart homes, stakeholders can better appreciate their potential to revolutionize modern living, making it more comfortable, secure, and efficient. The thesis ultimately portrays smart home technology as a promising field with a bright future, poised to become a standard in modern residential and commercial buildings[21].Figure 2.21 show example of smart house system.

Figure 2. 21 Smart house system

2.7 Table of comparison

Here is table comparison about past year project that related to Developement Of Smart Home Controller With EEG And IoT Integration

Table 2. 6 Table of comparison

TITLE	AUTHOR	ADVANTAGES	DISADVANTAGES
1)Survey on the Research Direction of EEG-Based Signal Processing	Sun, Congzhong Mou, Chaozhou	• Improved Distinction of Activation Function: The use of dropout before an activation function enhances the distinction of the activation function. • Transfer Learning (TL): TL supplements limited training data with data transferred from other domains to improve system portability and accuracy..	• Overfitting: Dropout is used to avoid overfitting, which is a common issue in deep learning models. • Limited Generalizability: The performance of EEG-based BCI systems can be limited by the subject-specificity of EEG signals, leading to lower cross-subject accuracy compared to within-subject accuracy.
2) Electroencephalography Signal Processing: A Comprehensive Review and Analysis of Methods and Techniques	Chaddad, Ahmad Wu, Yihang Kateb, Reem Bouridane, Ahmed	• Improved Classification Accuracy: Machine learning algorithms have achieved high accuracy in EEG classification, with some models achieving accuracy rates of up to 99%. • Enhanced Performance: Deep learning models have simplified the EEG signal processing pipeline, making it an end-to-end	• Data Complexity: EEG signals are complex patterns of electrical activity in the brain, and accurately classifying them often requires larger datasets than traditional methods to achieve similar performance. • Data Heterogeneity: Variations in the acquisition devices employed across different datasets can lead

		task and facilitating new research avenues such as generating images from EEG signals and transfer learning between different fields.	to data heterogeneity, which can be challenging to address.
3) Emotion Recognition with EEG-Based Brain-Computer Interfaces: A Systematic Literature Review	Erat, Kübra Şahin, Elif Bilge Doğan, Furkan Merdanoğlu, Nur Akcakaya, Ahmet Durdu, Pınar Onay	• Non-invasive Measurement: EEG is a non-invasive method, making it safer and more comfortable for users compared to invasive techniques. • Portable and Low Cost: EEG devices are often portable and relatively low-cost, making them accessible for various applications.	• Noisy Data: The data obtained from EEG can often be noisy, requiring extensive preprocessing to obtain clean signals. • Complex Setup: Proper electrode placement and setup can be complex and time-consuming.
4) Large-scale recording of neuronal activity in freely-moving mice at cellular resolution	Das, Aniruddha Holden, Sarah Borovicka, Julie Icardi, Jacob O'Niel, Abigail Chaklai, Ariel Patel, Davina Patel, Rushik Kaech Petrie, Stefanie Raber, Jacob Dana, Hod	• Freely-Moving Recording: The method allows recording neuronal activity in freely-moving mice without head fixation or attachment of a device, preserving natural behavior and more accurate activity patterns. • Large-Scale Recording: It enables cortex-wide activity recording, capturing data from multiple cortical regions simultaneously.	• Decay of Signal: The photoconverted red-to-green ratio (RGR) in CaMPARI decreases over days, with about 97% decay by one week, limiting the duration for which the recorded signal remains stable. • Light Dosage Sensitivity: Optimal light doses for photoconversion need to be carefully calibrated to avoid thermal damage and ensure accurate recording, which can be complex and time-consuming.
5) A beginner's guide on the use of brain organoids for	Mulder, Lance A. Depla, Josse A. Sridhar, Adithya Wolthers, Katja Pajkrt, Dasja Vieira de Sá, Renata	• Human Origin: Post-mortem material and mono- and co-culture cell models are derived from human tissue, ensuring relevance to human biology. • Clinical Representation: Post-mortem material accurately represents clinical conditions.	• Fixed Temporal Representation: Post-mortem material provides a snapshot of a single time point, limiting the ability to study dynamic processes. • Material Scarcity: Post-mortem material can be difficult to obtain.

neuroscientists: a systematic review			
6) Neuronal activity and remyelination: new insights into the molecular mechanisms and therapeutic advancements	Zhou, Yiting Zhang, Jing	• Improved Understanding of Molecular Mechanisms: The article provides detailed insights into the molecular mechanisms involved in neuronal activity and remyelination, which can help researchers and clinicians better understand the underlying processes. • Therapeutic Advancements: The article highlights potential therapeutic applications of understanding neuronal activity and remyelination, such as the development of new treatments for neurological disorders.	• Complexity of the Topic: The article discusses complex molecular mechanisms and therapeutic advancements, which may be challenging for non-experts to fully understand. • Limited Clinical Applications: While the article highlights potential therapeutic applications, the actual clinical translation of these findings may be limited by various factors, such as the complexity of the disorders and the need for further research.
7) Analysis of Relation between Brainwave Activity and Reaction Time of Short-Haul Pilots Based on EEG Data	Binias, Bartosz Myszor, Dariusz Binias, Sandra Cyran, Krzysztof A.	• Improved signal processing: The use of a Kaiser Window Finite Impulse Response (FIR) band-pass filter allowed for better signal processing and removal of noise. • Enhanced feature extraction: The logarithmic operation used to normalize the distribution of calculated features improved the extraction of meaningful information from the EEG signals.	• Limited scope: The study focused on short-haul pilots and may not be generalizable to other aviation professionals or contexts. • Methodological limitations: The use of a specific filter and feature extraction method may not be universally applicable or optimal for all EEG signal processing tasks.

8) Binaural beats to entrain the brain? A systematic review of the effects of binaural beat stimulation on brain oscillatory activity, and the implications for psychological research and intervention	Ingendoh, Ruth Maria Posny, Ella S. Heine, Angela	• Physiological measures like heart rate and skin conductance • EEG oscillatory activity and brainwave entrainment • Cognitive functions like attention and working memory	• Lack of control conditions in many studies, making it difficult to attribute effects solely to binaural beats • Inconsistent findings across studies regarding the specific effects of binaural beats on brain activity and behavior
9) Literature Review: Electroencephalogram (EEG) the Characteristics of Students' Learning Concentration Due the Audio Stimulus	Kurnia, Megasari Bakri, Ilham Ikasari, Nadzirah Wardani, Putri Indah Tanditasik, Priscillia Ingrid	• The use of adaptive backpropagation enhances the learning process with an accuracy of 75%. • Signal testing with wavelet extraction achieves 95% accuracy for training data.	• The accuracy for tested data is significantly lower at 45%. • The system's performance might vary depending on the EEG signal quality and the participants' conditions during the recordings

10) Design and Development of a Brain Computer Interface Controlled Robotic Arm	Hong Way, Khow	• Enhanced Control Precision: The project demonstrates that using only 7 electrodes is sufficient to control the robotic arm with an accuracy exceeding 90%, showcasing efficient control capabilities. • Improved User Interaction: By enabling control through human facial expressions, the system offers a more intuitive and user-friendly interaction method for operating the robotic arm, potentially enhancing user experience and engagement	• Limited Movement Options: The robotic arm in the project is designed to perform only four specific movements based on corresponding facial expressions, potentially restricting the range of actions that can be executed compared to more complex control systems. • Dependency on EEG Signal Quality: The system's performance is reliant on the quality of EEG signal acquisition and processing, which can be affected by factors like electrode placement and signal interference, posing challenges in maintaining consistent and accurate control
11) Use and Product Quality of Brain-Computer Interface (BCI) Systems: A Systematic Literature Review	Cobos, Juan Moreira, Christiann Cárdenas-Delgado, Paúl Cedillo, Priscila	• Comprehensive Analysis: Provides a thorough review of existing literature on BCI system quality. • Identification of Key Quality Characteristics: Highlights efficiency and usability as primary quality attributes.	• Scope Limitation: As a systematic review, it might be limited by the availability and quality of the existing literature. • Model Implementation: Identifies the need for a quality model but does not provide one.
12) Brain-computer interface: advancement and challenges	Mridha, M. F. Das, Sujoy Chandra Kabir, Muhammad Mohsin Lima, Aklima Akter Islam, Md Rashedul Watanobe, Yutaka	• Non-Invasiveness: Many BCI systems use non-invasive methods such as EEG, which are safer and more comfortable for users. • Improved Accessibility: BCIs offer potential communication means for individuals with severe disabilities, improving their quality of life.	• Signal Noise and Interference: Non-invasive methods are often subject to high levels of noise, making signal interpretation challenging. • User Training: Effective use of BCIs often requires significant user training, which can be time-consuming and demanding.

13) Brain computer interfaces, a review	Nicolas-Alonso, Luis Fernando Gomez-Gil, Jaime	• Assistance for Disabled Individuals: BCIs offer communication and control capabilities to individuals who are paralyzed or suffer from severe neuromuscular disorders. • Non-Muscular Communication: Provides a new channel for interaction that does not rely on muscle activity, which is crucial for those with motor disabilities.	• Complexity: BCI systems are complex, requiring sophisticated signal processing and pattern recognition techniques. • Signal Quality Issues: Non-invasive methods like EEG often suffer from poor signal quality due to noise and the need to pass through multiple layers (scalp, skull).
14) NeuroPhone: Brain-mobile phone interface using a wireless EEG headset	Campbell, Andrew Choudhury, Tanzeem Hu, Shaohan Lu, Hong Mukerjee, Matthew K. Rabbi, Mashfiqui Raizada, Rajeev D.S.	• Hands-Free Operation: Enables users to control mobile phones without physical interaction, improving convenience and accessibility. • Silent Communication: Allows for silent operation, making it ideal for situations where noise should be minimized.	• Signal Noise: EEG signals, especially from cheaper headsets, are prone to significant noise, complicating reliable signal detection. • Reliability Issues: The current prototype's reliability, especially in P300 detection, is less robust compared to other hands-off interfaces like voice recognition.
15) Brain Computer Interface Based Smart Home Control Using EEG Signal	Ahmad, Masood	• The system allows individuals with physical disabilities, such as those unable to move due to non-functioning nerve cells, to control household appliances using their brain signals. • Users can interact with the system through a graphical user interface (GUI), making it user-friendly and accessible	• EEG signals are very low power signals, which may lead to challenges in accurately extracting and identifying the actual signal from redundant signals, impacting system performance. • .Pre-processing and signal conditioning on EEG signals are required to improve signal quality, which adds complexity to the system setup and maintenance

16) Development of IoT Smart Home Controller Using Biosensor	Azraei, Muhammad Ab, B I N	• Improvement in Quality of Life: The system allows individuals, particularly those with disabilities, to control home appliances through brain signals, enhancing independence and ease of living. • Cost-effective: Utilizing low-cost EEG biosensors like the Neurosky Mindflex makes the technology accessible.	• Accuracy and Reliability: The accuracy of the EEG signals and their correct interpretation can vary, which may lead to inconsistent control of home appliances. • Complexity of Setup: Setting up the system involves multiple components and steps, including EEG device configuration, microcontroller programming, and IoT integration, which might be challenging for non-technical users.
17) Hydroponics Using the Blynk Application	Amin, Miftahul Ma'arif, Alfian Suwarno, Iswanto	• Efficiency in Monitoring: The use of the Blynk application allows for real-time monitoring of pH levels, reducing the need for manual checks and ensuring plants remain in optimal conditions. • High Accuracy: The study demonstrates high accuracy in pH measurement, crucial for maintaining plant health in hydroponic systems.	• Dependence on Technology: The system relies on internet connectivity and the functionality of the Blynk application, which may pose issues if there are connectivity problems or software malfunctions. • Initial Setup Cost: Setting up the system requires purchasing sensors, microcontrollers, and potentially other hardware, which may be costly.
18) A Review of Fuzzy Logic Method Development in Hydraulic and Pneumatic Systems	Filo, Grzegorz	• Innovative Control Methods: The research explores the utilization of fuzzy logic methods in hydraulic and pneumatic systems. • Increased Interest in Fuzzy Logic: The study highlights a significant rise in interest in fuzzy logic applications for hydraulic and pneumatic systems post-2005, indicating a growing trend towards adopting fuzzy logic for control and risk assessment in these systems.	• Underutilization of Advanced Methods: The research points out the underutilization of advanced techniques like the Takagi-Sugeno inference method and type-2 membership functions in publications, suggesting a gap in leveraging these methods for improved system modeling. • Dependency on Knowledge Base: Fuzzy logic systems rely on a knowledge base in the form of rules, which may require continuous updates and

			maintenance, posing a challenge in managing and optimizing the system's performance
19) Application of fuzzy logic: A literature review Renu Makkar	Makkar, Renu Renu Makkar, Correspondence	• Enhanced Precision: Fuzzy logic systems offer extreme precision in returning risk values, making them valuable in applications like operating room air quality monitoring systems. • Wide Applicability: Fuzzy logic is applicable in various fields such as chemical science, medical science, agriculture, and environmental science, showcasing its versatility and broad adaptability	• Dependency on Data Quality: Fuzzy logic systems may face challenges related to data quality, as seen in the reliance on EEG signal quality for consistent and accurate control of robotic arms based on facial expressions, potentially impacting system performance [3]. • Limited Movement Options: In projects involving robotic arms controlled by facial expressions, limitations in movement options may arise, restricting the arm to specific movements based on the input signals received, which could hinder its flexibility and adaptability.
20) Working Principle of Arduino and Using it as a Tool for Study and Research	Louis, Leo	• Affordability: Inexpensive hardware and free software. • Ease of Use: User-friendly IDE and simple programming. • Versatility: Suitable for a wide range of projects, from hobbyist to professional.	• Limited Processing Power: Less powerful compared to more advanced microcontrollers. • Memory Constraints: Limited memory for complex applications. • Not Industrial Grade: Less suitable for industrial applications requiring high reliability.
21) Smart house systems	Roman, D	• Convenience: Remote control of home functions such as lighting, climate, and security systems via mobile devices.	• Cost: High initial investment and potential high costs for installation and setup. • Complexity: Systems can be complicated to set up and may require professional assistance.

		• Energy Efficiency: Automated systems help in reducing energy consumption by optimizing the use of lighting, heating, and cooling.	• Maintenance: Ongoing maintenance and updates are needed to ensure systems function correctly.

2.8 Summary

Electroencephalography EEG-based control of home automation systems embedded in the context of Internet of Things IoT holds great promises for improving home automation and increasing user experience. In recent studies, the home devices that can be controlled from the Big Data brain signals are made possible using the IoT for processing and analyzing the EEG signals. EEG based smart home controllers have several applications especially in home automation, health care sector and entertainment but there are some challenges with these systems like signal noise, data transfer rate, user acceptability. To counter these hurdles, the research community is working on signal processing, user-friendly interfaces, and artificial intelligence/machine learning. More advanced EEG-IoT smart home controllers can be developed that will offer innovation and improved quality of life for users. From all this method that have been research, method that suitable to my project gonna be selected.

CHAPTER 3

METHODOLOGY

3.0 Introduction

This chapter included a clear and comprehensive explanation and rationale of the component, theoretical approaches, project idea, and methodology. Consequently, the flow chart's development showed that it was capable of offering clearer and more accurate explanations. The supplies used and the methods for setting up the system connections for the project were also supplied.Also this chapter will provide hardware and software that will be use from the beginning to end.

3.1 Methodology

This section will explain what should be done according to the method that was researched. A flowchart of the project flow system, a block diagram, and a survey about the process to be executed will also be included.Some of the component needed, input output project ,costing component that will be use.Also will be describe a little bit about hardware and software setup project that I want to do.This thesis actually explain about how to control and monitor smart home without need to get up and ON or OFF switches by using EEG headset. This really help to some people that old or disabled that unable to ON or OFF switches. We also can control and monitor from far.This project is combination of control method by using EEG headset and iot Blynk integration to control and monitor smart home.The signal from EEG headset will be integrate by microcontroller to translate into digital signal. Then, EEG headset will connect to Smart home system.This will allowing users to control various devices using brain signal. After that, utilize Blynk's IoT platform to integrate the EEG headset with the smart home system, enabling remote control and monitoring of the devices. Lastly, Design a user-friendly interface using Blynk's app to monitor and control the smart devices. Flowchart Figure 3.1 and Block Diagram Figure 3.2 will be included here.

3.2 Flowchart

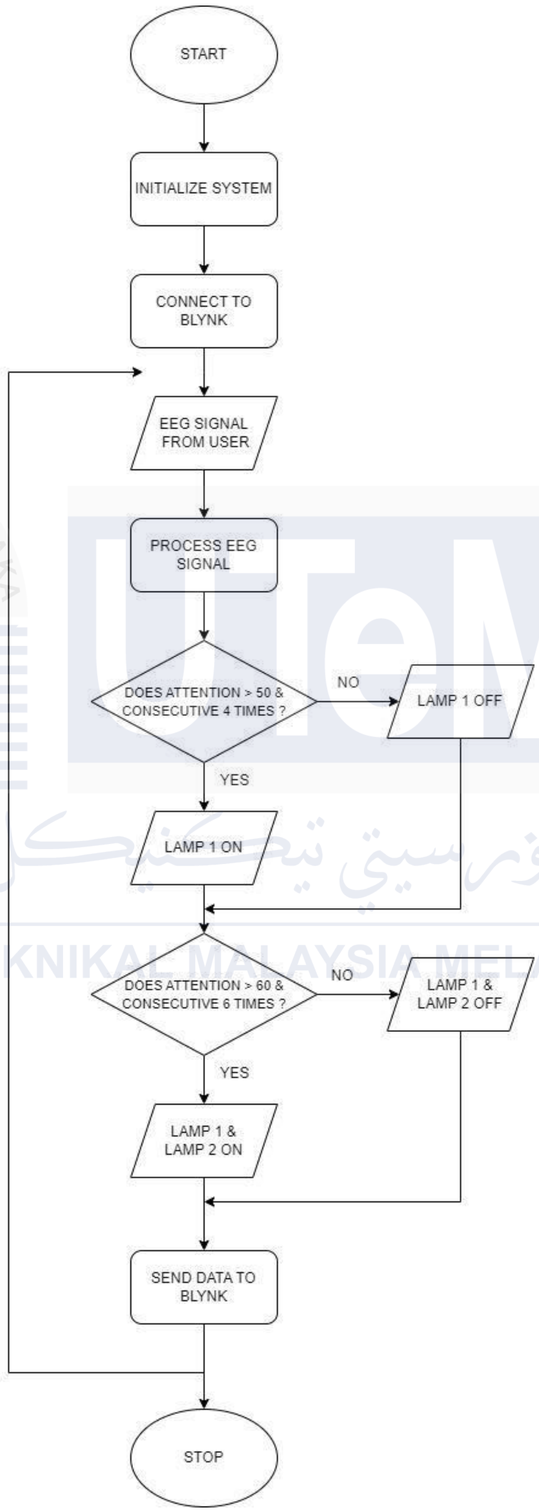

Figure 3. 1 Flowchart

Smart home controller system that uses EEG signals to automate lamp control based on the user's attention levels. The process begins with the initialization of the system and a connection to the Blynk IoT platform, enabling communication and data sharing. EEG signals are collected from the user, focusing on attention metrics. These signals are processed, and decisions are made based on specific thresholds. If the attention level of the user is greater than 50 for four consecutive readings, Lamp 1 is on; otherwise, it is off. If the attention level of the user is greater than 60 for six consecutive readings, both Lamp 1 and Lamp 2 are on; otherwise, they are off. Finally, the data is sent to the Blynk platform for monitoring and further actions. This system combines EEG and IoT into an automated intelligent solution for controlling smart homes.The flowchart shown at Figure 3.1

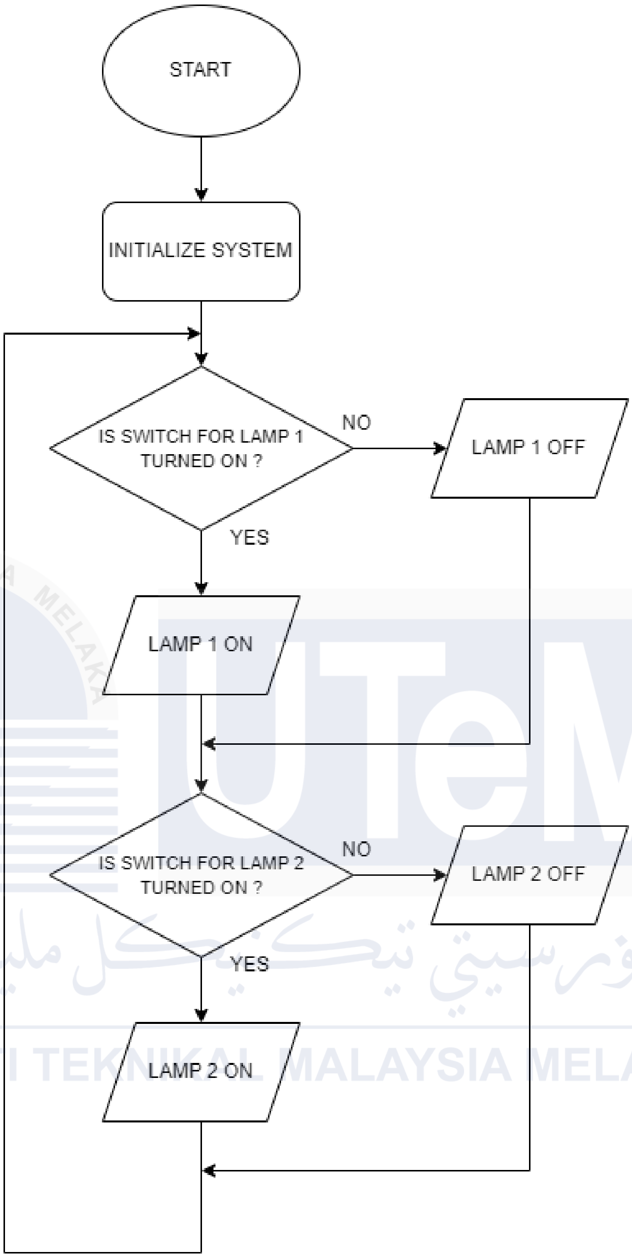

Figure 3. 2 Flowchart at blynk

The second flowchart shown at Figure 3.2 represents a simpler system where lamps are controlled manually using switches at IoT Blynk.After system initialization, the controller checks the status of the switches. If the switch for Lamp 1 is turned on, the lamp is activated; otherwise, it remains off. Similarly, the system checks the switch for Lamp 2 and turns it on or off accordingly. This system provides basic manual control of the lamps without any automation or integration with external platforms.

3.3 Block diagram

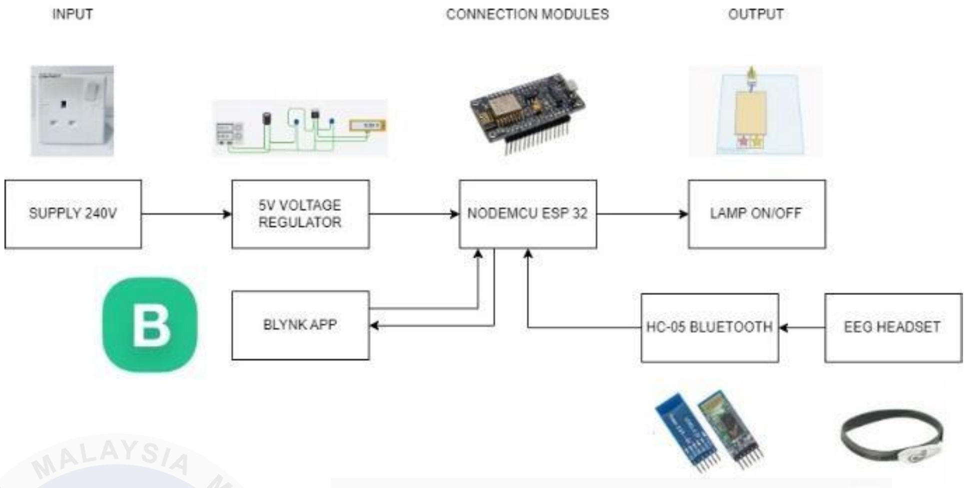

Figure 3. 3 Block diagram

3.4 Survey

A survey was carried out among a number of individuals to determine the level of knowledge and acceptance of the community in regard to smart homes using brain waves as controllers. The survey results indicated that 90.5% were Malay, while 9.5% were Indian. The majority of the respondents were between 21 and 30 years old, amounting to 76.2%, followed by 31 to 40 years old, with 19%. Only 4.8% of the respondents fall between 15-20 years, while there are no respondents above 40 years. In occupation, 61.9% are students, 38.1% are others, while educators are not represented.

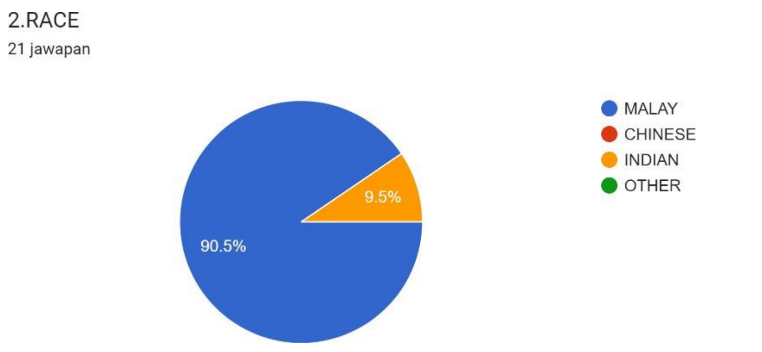

Figure 3. 4 Race

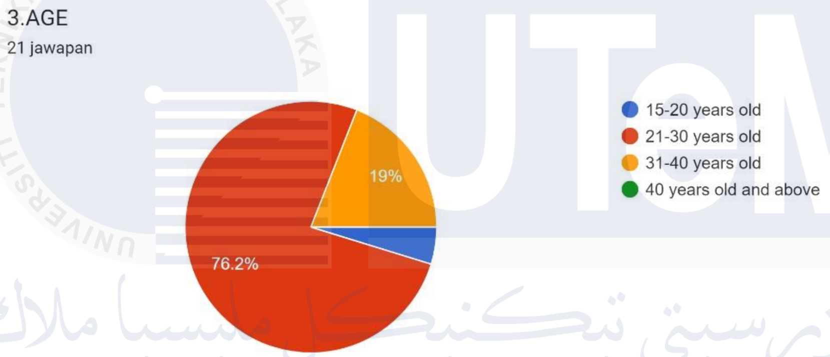

Figure 3. 5 Age

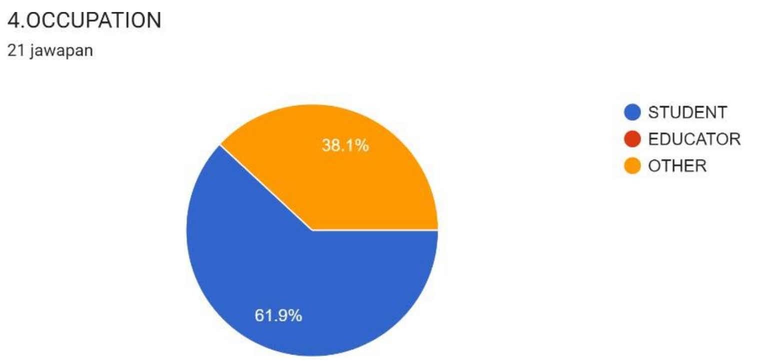

Figure 3. 6 Occupation

In addition, out of the total respondents, 71.4% had already used a smart device at home and 28.6% on the contrary.Fully understood EEG technology only 14.3%. Whereas 47.6% know somewhat, 38.1% is unfamiliar.Desired features in the smart home system: light control tops it all, 90.5%, next is home security 85.7%, then fan/motor control is at 76.2%, and 66.7% for energy efficiency.

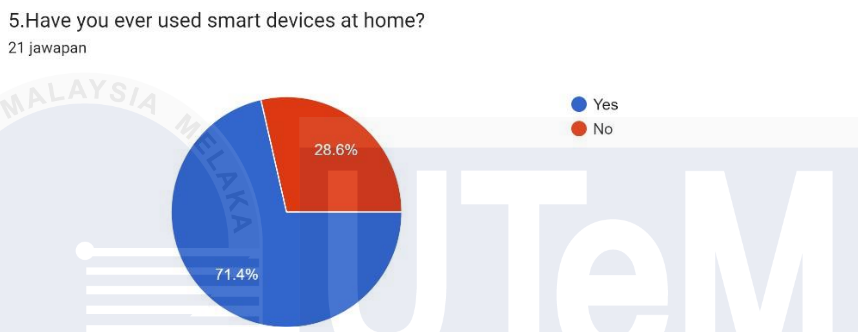

Figure 3. 7 Smart Home Device at Home

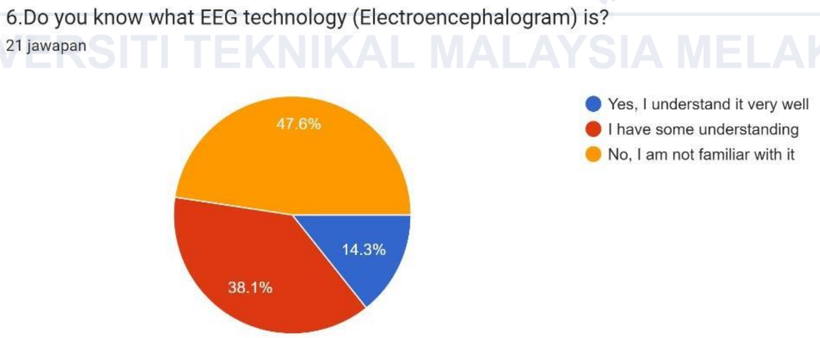

Figure 3. 8 EEG technology

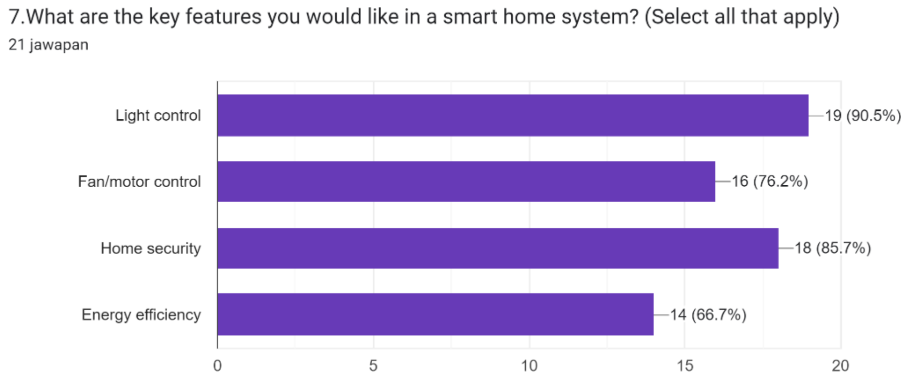

Figure 3. 9 Key features

Moreover, 85.7% showed interest in using the system controlled by brain signals, though there are issues of concern about cost (81%), data privacy (61.9%), and safety (66.7%). While 52.4% feel comfortable using EEG technology with a device such as a headset, 33.3% are not comfortable, and 14.3% are not sure.

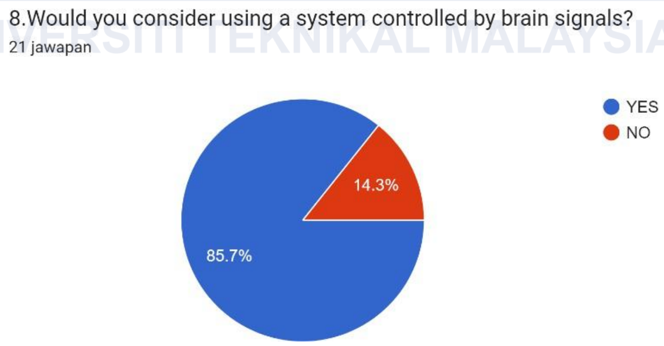

Figure 3. 10 Consider using brain signal

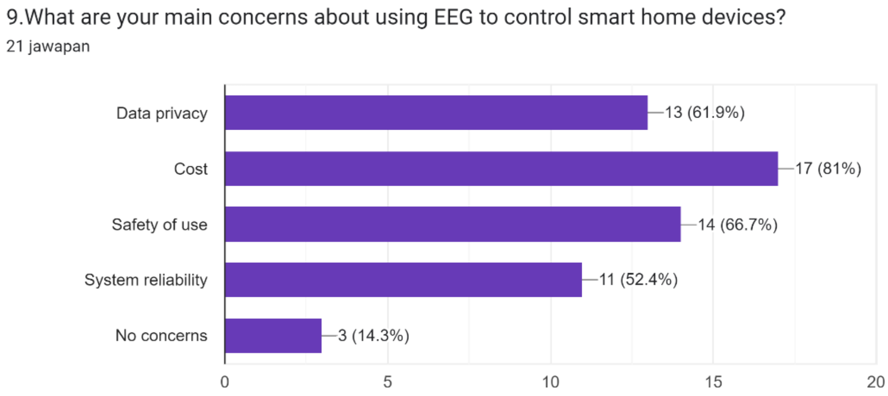

Figure 3. 11 Concern about EEG

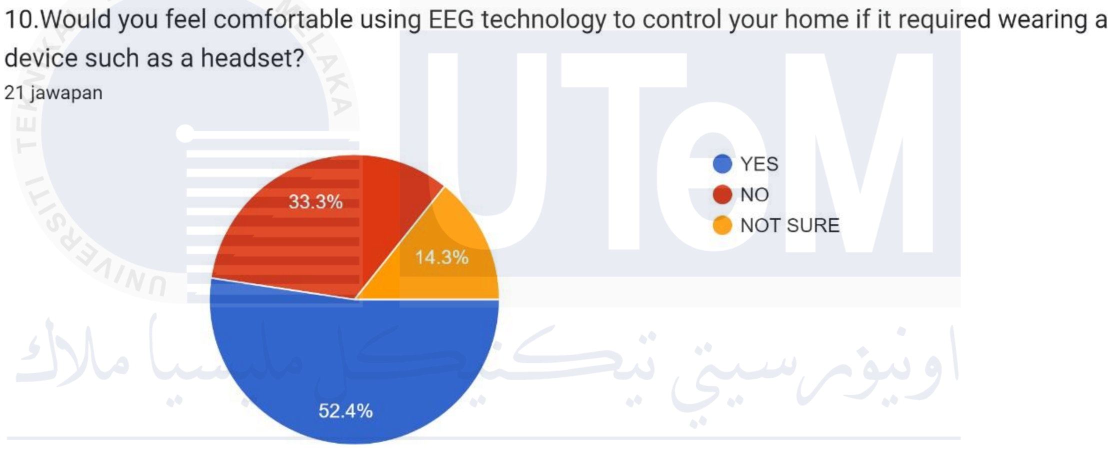

Figure 3. 12 If required wearing headset

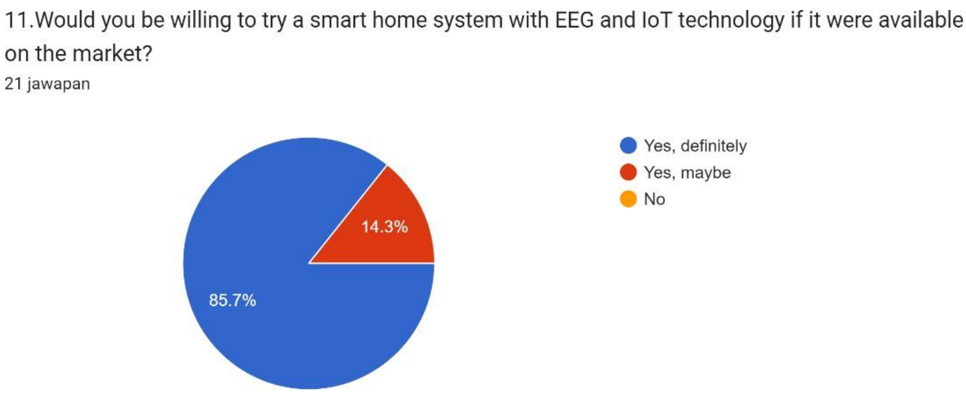

Figure 3. 13 Willing to try smart home

A very high potential was shown in adopting EEG and IoT technologies through the survey, but many concerns regarding cost, privacy, and system reliability need to be addressed along with improving awareness for this technology to reach broader acceptance.

3.5 Experimental setup

3.5.1 Hardware setup

This part will be list out some hardware that are being used and explain about how the component work.

Mindlink EEG headset

The MindLink EEG headset is a brain-computer interface device designed to capture electrical activity in the brain. It measures brainwaves such as alpha, beta, theta, and delta waves, converting these signals into digital data. This data can be used to interpret specific mental states like focus, relaxation, or excitement. In your project, the EEG headset likely serves as the primary input device, enabling users to control home appliances such as lamps via their brain activity, effectively providing a hands-free and intuitive control mechanism.

Figure 3. 14 EEG headset

NodeMCU ESP32

The NodeMCU ESP32 is a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities. It acts as the central processing unit of the system, receiving signals from the EEG headset via the HC-05 Bluetooth module or any other communication method. The ESP32 processes the EEG data, interprets commands, and controls connected devices such as lamps through the relay module. Its integration of IoT (Internet of Things) ensures connectivity with home networks or cloud platforms, enabling remote monitoring and control through a smartphone or web interface.

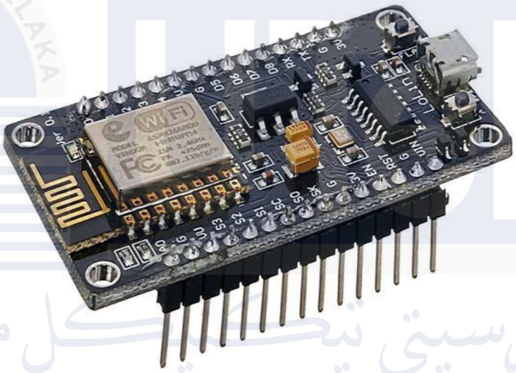

Figure 3. 15 NodeMCU ESP32

HC05 Bluetooth module

The HC-05 module is a serial Bluetooth transceiver module that facilitates wireless communication between the EEG headset and the ESP32. It ensures seamless transmission of brainwave data from the headset to the microcontroller. This module is essential for providing real-time communication in the system, enabling the ESP32 to respond to user commands based on EEG signals accurately and promptly.

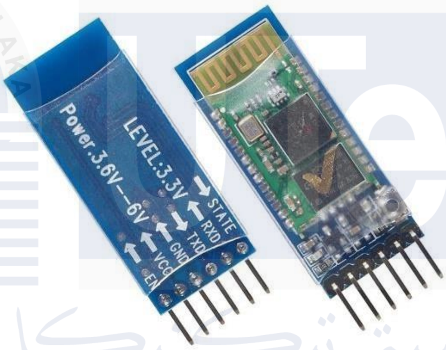

Figure 3. 16 HC05 Bluetooth module

Lamp

The lamp represents the output device in this smart home controller system. It is connected to the relay module, which allows it to be turned on or off as per the commands derived from EEG signals. This demonstrates how the system can be used to control home appliances, making it a practical application of brain-computer interface technology. The lamp serves as a proof-of-concept, but the system could control other devices like fans, heaters, or smart plugs.

Figure 3. 17 Lamp

5V Voltage Regulator

The 5V voltage regulator ensures a stable power supply to the components in the system, particularly the microcontroller, Bluetooth module, and relay. It regulates higher voltage input (e.g., from a 9V or 12V power source) down to the required 5V, preventing damage to sensitive components. Maintaining a consistent voltage is critical for the system's reliability and performance.

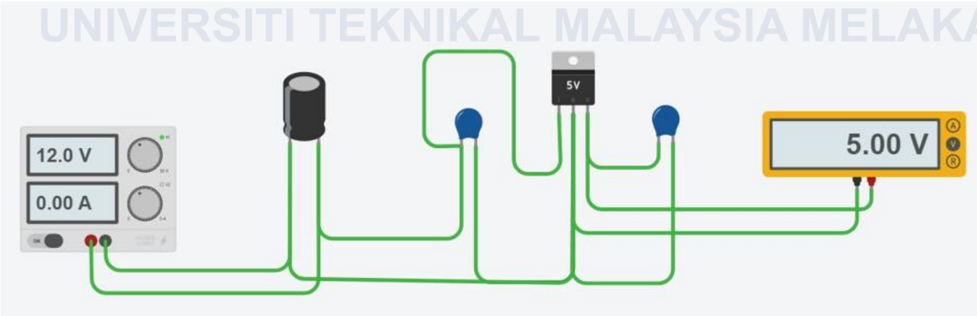

Figure 3. 18 5v DC voltage regulator

2 Channel Relay 5V

The 2-channel relay module acts as a switch to control high-power appliances like lamps. It receives control signals from the NodeMCU ESP32 and toggles the connected devices on or off. Since the relay operates at 5V, it safely isolates the low-voltage control system (ESP32) from the high-voltage appliances, ensuring user safety and system protection. The two channels allow control of up to two devices simultaneously, making the system scalable for additional outputs.

Figure 3. 19 2 Channel Relay 5V

Costing

The list of item equipment and component parts that be used to build up the control circuit and the external look for the innovative smart home controller with eeg and iot integration is shown in Table 3.1

Table 3. 1 Total cost for Component

BIL	NAMA ITEM PEMBELIAN	NO RESIT/INVOIS	NILAI (RM)	STATUS ITEM DALAM STOR (Diisi oleh PJ Stor Komponen)	
				Ada	Tiada
1	DC MOTOR	22411	8.00		
2	FAN PROPELLER	22411	4.00		
3	RELAY 4 CHANNEL	22411	15.00		
4	LED	22411	1.00		
5	JUMPER	22411	5.00		
6	USB CABLE 2.O	INV-2411-198	3.00		
7	JUMPER	INV-2411-198	5.00		
8	LuaNode ESP32	INV-2411-198	40.00		
9	SOCKET PLUG 13A	BILL115496	8.00		
10	BOX SOCKET PLUG 13A	BILL115496	1.60		
11	LED NIGHT LIGHT	330026	13.80		
12	HC 05 BLUETOOTH	22500	17.00		
13	8x10 ENCLOSEURE BOX	INV-2411-207	24.00		
14	TEMPERATURE & HUMIDITY SENSOR MODULE	INV-2411-207	10.00		
15	LuaNode ESP32	INV-2411-197	40.00		
16	USB CABLE 2.O	INV-2411-197	3.00		
		JUMLAH TUNTUTAN	198.40		

3.5.2 Software setup

Blynk IoT

Blynk IoT is a platform for building IoT applications with a user-friendly interface. It allows to create mobile or web dashboards to monitor and control connected devices remotely. In your project, Blynk might be used to create a smartphone app where users can monitor the status of appliances (like whether the lamp is on or off) or manually control them as a backup to the EEG-driven commands. By integrating Blynk, the project becomes more versatile, combining brainwave-based control with traditional IoT functionality for a seamless smart home experience.

Figure 3. 20 Blynk iot

Arduino IDE

The Arduino Integrated Development Environment (IDE) is a programming platform used to write, compile, and upload code to microcontrollers like the NodeMCU ESP32. In this project, the Arduino IDE would have been used to program the ESP32 with logic to process EEG signals, communicate with the HC-05 Bluetooth module, and control the relay to toggle the lamp. The IDE provides libraries and debugging tools to simplify development, making it a crucial component of the project workflow.

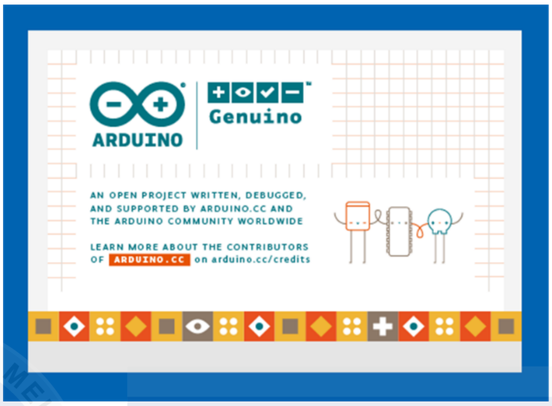

Figure 3. 21 Arduino IDE

Tinkercad

Tinkercad is an online 3D design and electronics simulation platform. It is commonly used for prototyping and testing circuits virtually before assembling them in the real world. In your project, Tinkercad might have been used to design and simulate the circuit, including the connections between components like the NodeMCU ESP32, HC-05 Bluetooth module, relay, and other peripherals. By using Tinkercad, Can identify and fix potential issues in design, ensuring the hardware works as expected when implemented physically.

Figure 3. 22 Tinkercad

Cirkit designer

A circuit designer tool, either standalone or integrated with platforms like Tinkercad or software like Fritzing, is used to create detailed circuit diagrams for your project. It helps visualize the connections between all components, such as the EEG headset, ESP32, HC-05 module, relay, and lamps. The circuit diagram ensures clarity during assembly and acts as a reference for troubleshooting. It also helps document the project for future improvements or sharing with others.

Figure 3. 23 Cirkit Designer

3.6 Experimental procedure

This project in details will focuses on determining the capability of a brain sensor to control a lamp by setting specific threshold values for turning it ON or OFF the lamp. It aims to integrate EEG signals with IoT technology like blynk app to demonstrate the practical application of brainwave-controlled systems in a smart home environment which is we can know the actual and real-time response of attention and also can on off lamp by using blynk app. This section provides an overview of the project’s development process and explains its operation in detail.

3.6.1 External design

In the beginning,start with conceptual planning using Tinkercad. This tool was used to create an initial design and framework to visualize the desired system layout. By designing the schematic in Tinkercad, able to refine the arrangement and ensure that the setup was practical and achievable. The finalized design, shown in Diagram Figure 3.24 and Figure 3.25 served as a blueprint for the subsequent stages of the project.

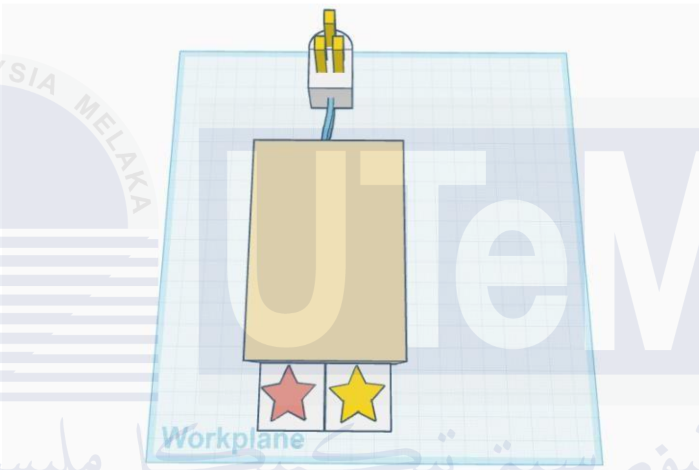

Figure 3. 24 External design front view

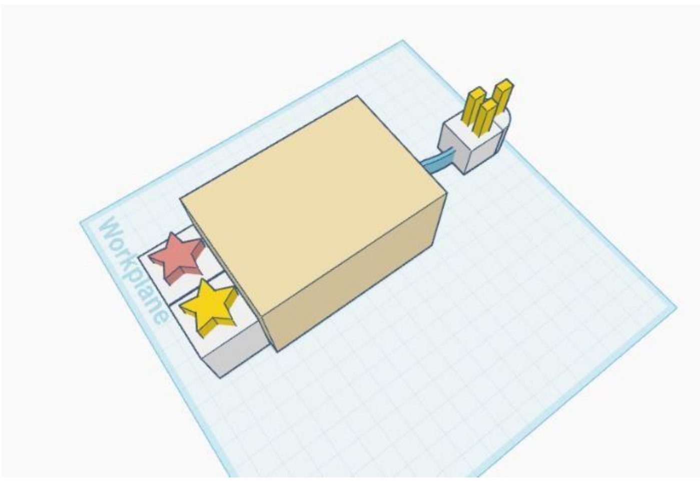

Figure 3. 25 External design front view

3.6.2 Internal design

Once the conceptual design was completed, attention shifted to the electronic circuit. By Using Circuit Designer, a detailed circuit layout was created to ensure proper connections among components. The circuit design was guided by insights from previous studies and research on similar projects, ensuring a solid technical foundation. This stage was crucial for identifying the best configuration to connect the brain sensor, bluetooth, ESP32, relay and other components.Circuit design shown at Figure3.26.

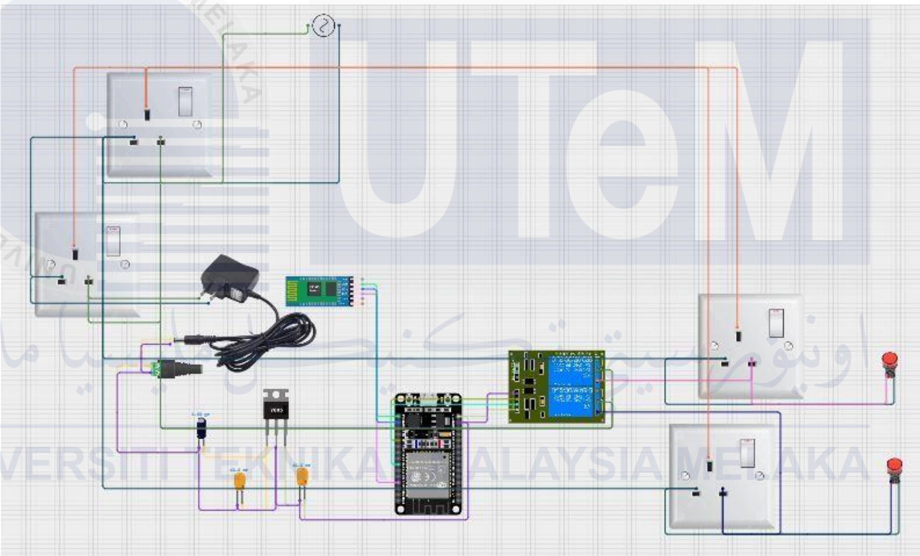

Figure 3. 26 Electronic design and connection

3.6.3 Circuit Programming

The Arduino IDE is the software used for programming. It provides a text editor for creating programs, compatible with C and C++, and unique code structuring. It also includes a wiring project software library that supports various input and output functions, enabling code uploading to Arduino hardware via USB for smooth hardware-programming communication. Figure 3.27 below shows the interface of the Arduino IDE software.

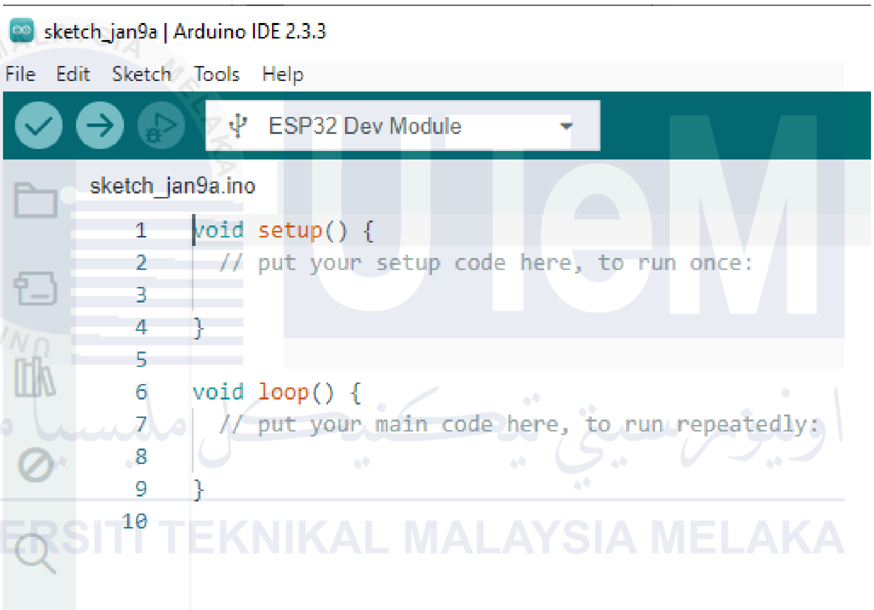

Figure 3. 27 Interface of the Arduino IDE software

The Arduino IDE has many benefits, such as a user-friendly interface, a wide range of libraries, plenty of examples for beginners, support for multiple languages, and a supportive community for any questions. The complete code will be included in the appendix. The Arduino IDE interface includes several key elements. Code editor : This is where we write, edit, and save our code. Toolbar : This contains buttons for common tasks, such as compiling and uploading code to the Arduino. Serial Monitor : This allows you to send and receive data to and from the Arduino. Message console : This displays messages generated by the Arduino IDE, such as error messages or status updates.

3.6.4 Blynk IoT app

In addition to brainwave-based control, the system was designed to incorporate IoT functionality through the Blynk app. This allows users to manage the lamp remotely via a smartphone, providing an alternative method of control. By integrating Blynk, the project not only showcases the innovative use of EEG signals but also emphasizes the flexibility and convenience of IoT solutions in modern smart homes.The blynk app must be download at play store.After that, need to setup place for control the lamp by using button and can monitor the value of attention.

Figure 3. 28 Blynk application setup

3.7 Project Overview

After the overall design of the project is completed, the next step is the assembly process. The assembly process needs to be very precise for the final product to be neat and organized, as shown in figure 3.29. Not only does proper assembly enhance the look of the project, but it also ensures that the project is functional and reliable.

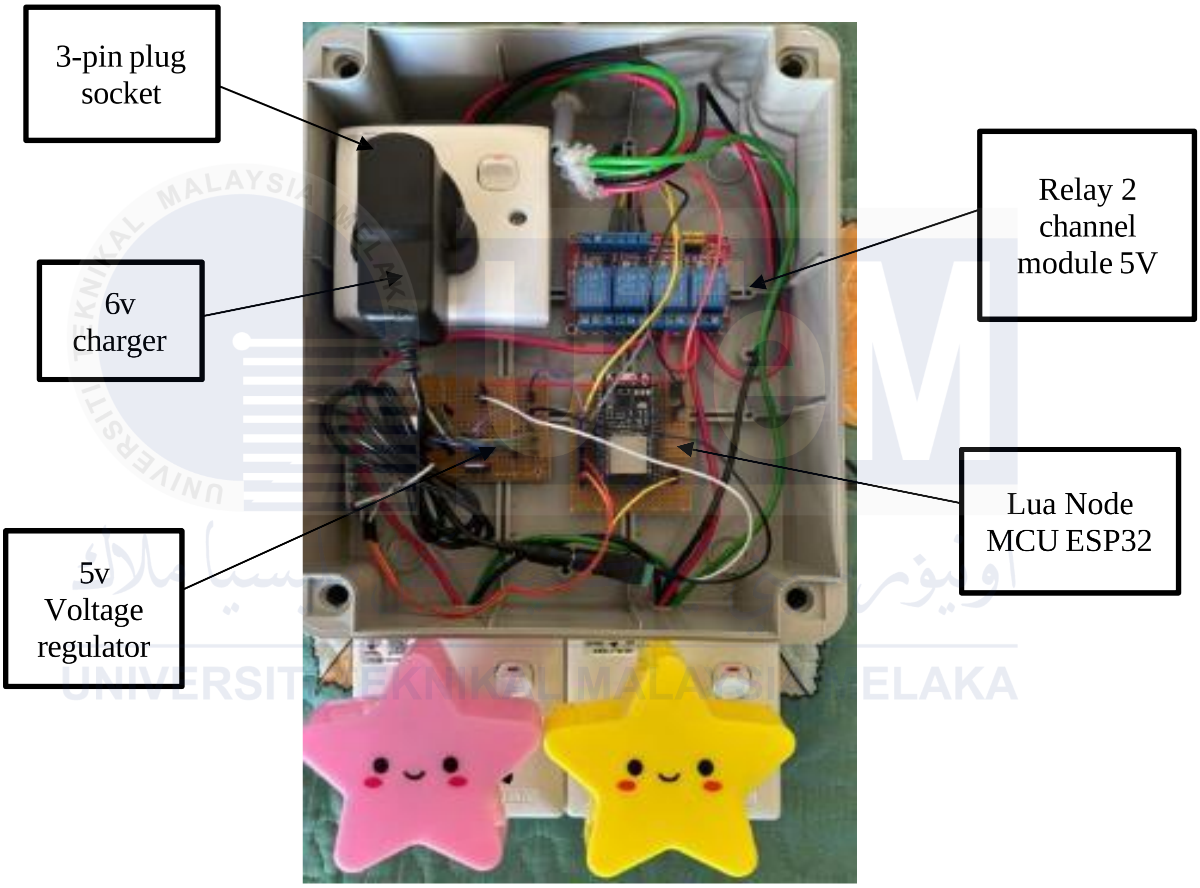

Figure 3. 29 Electronic assembly

For the internal components, a strip board will need to be prepared by soldering several component in. It requires very careful attention to secure that all attachments are well-seated and placed correctly. Of course, correct placing of the negative and positive terminals so as not to make any mistake in connection must be considered while being correctly connected. It is also paramount to ensure there is no accidental overlap on the stripboard or a short with other parts on the circuit board.Soldering is a very critical process in this project, as it allows the components to have a permanent and stable means of connection. It needs good quality solder and proper soldering techniques that will not allow loose connections that may lead to malfunctioning of the system. During this phase, one can check for continuity and correctness in the connections using a multimeter.

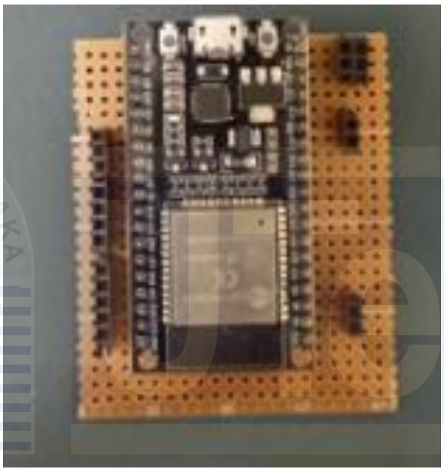

Figure 3. 30 Soldering component

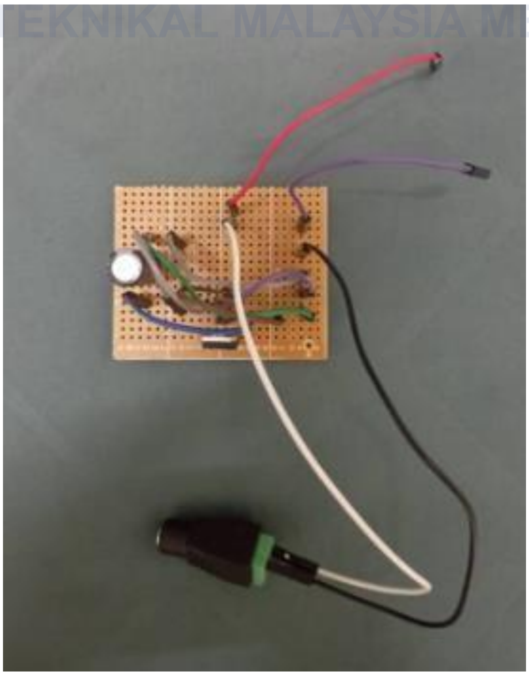

Figure 3. 31 Soldering component

Finally, the project must be tested to evaluate its ability to turn the lamp ON and OFF using brainwave signals and IoT control via the Blynk app. This testing phase is crucial to ensure that the system operates as intended and that both control methods function seamlessly.After done testing, close the box.Figure shown at figure 3.32 and figure 3.33.

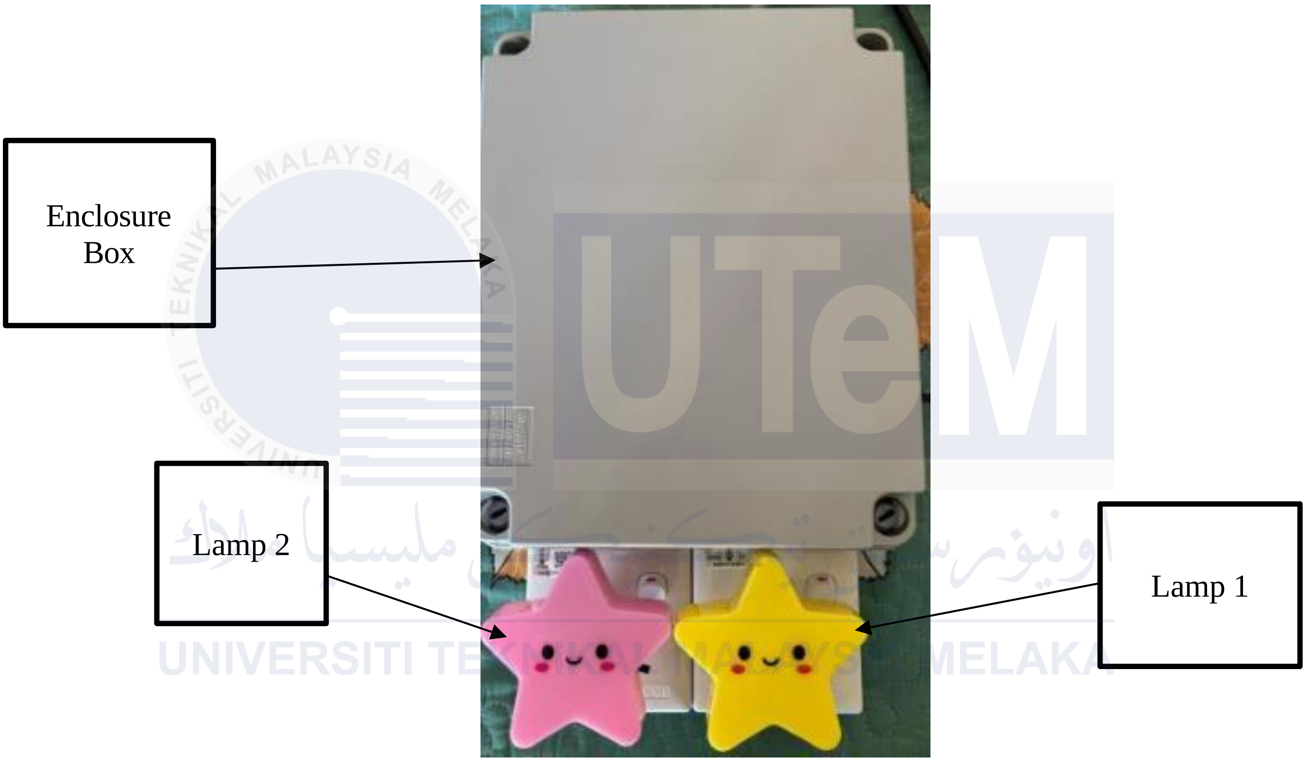

Figure 3. 32 Prototype Top View

Figure 3. 33 Prototype Side View

3.8 Summary

The integration of EEG technology with IoT platforms for smart home control will be demonstrated by this suggested technique, which shows a methodical approach from signal gathering to command execution.The bridge that transforms these brainwave impulses into control directives for smart home appliances is an ESP32 microcontroller.This integration is made possible via the Blynk IoT platform, which facilitates smooth communication between the microcontroller and smart home appliances. Real-time monitoring and control are made possible by the user-friendly Blynk app, which also guarantees an easy-to-use interface for controlling the smart home environment. This integration prioritises user experience and dependability, making it possible to effortlessly operate smart home equipment using brainwave signals—a feature that is especially helpful for people with restricted mobility.

CHAPTER 4

RESULT AND DISSCUSSION

4.1 Introduction

This chapter discusses the findings and evaluation regarding the creation of using brainwave to control Smarthome. During the field study, data analysis is undertaken to monitor the mindwave. Furthermore, research will be performed during this testing phase to determine ability and suitability of mindwave.

4.2 Result and analysis

4.2.1 Attention data analysis

Overall, 20 samples were taken every 0.8 second to test and identify the best turning On and Off values for the light. With such a sampling, data can be analyze the attention level to establish appropriate thresholds for reliable control of lighting. Accordingly, the analysis is divided into three parts: High Attention, Normal Attention, and Low Attention. Each category represents a different range of attention levels that could influence the decision on the light's control.A table was drawn out after the collection of data was over to systematically organize and summarize the information. This would form the graph showing the variation of attention levels light control states. After analyzing the graph for its trend and patterns, to establish where the exact thresholds should be in order for turning on and off the lights efficiently. These thresholds ensure the system responds accurately to changes in attention levels.Table 4.1 shown the attention level analysis.

Table 4. 1 Attention analysis

Time(s)	Attention value		
	High attention	Normal attention	Low attention
0.8	64	63	13
1.6	55	63	4
2.4	70	50	4
3.2	70	50	10
4.0	83	43	10
4.8	78	43	30
5.6	80	41	30
6.4	80	41	40
7.2	87	51	40
8.0	80	51	35
8.8	75	51	35
9.6	75	40	41
10.4	70	40	41
11.2	40	34	20
12.0	60	34	27
12.8	35	35	1
13.6	60	35	1
14.4	40	44	17
15.2	61	44	17
16.0	61	60	23
	1324	862	446

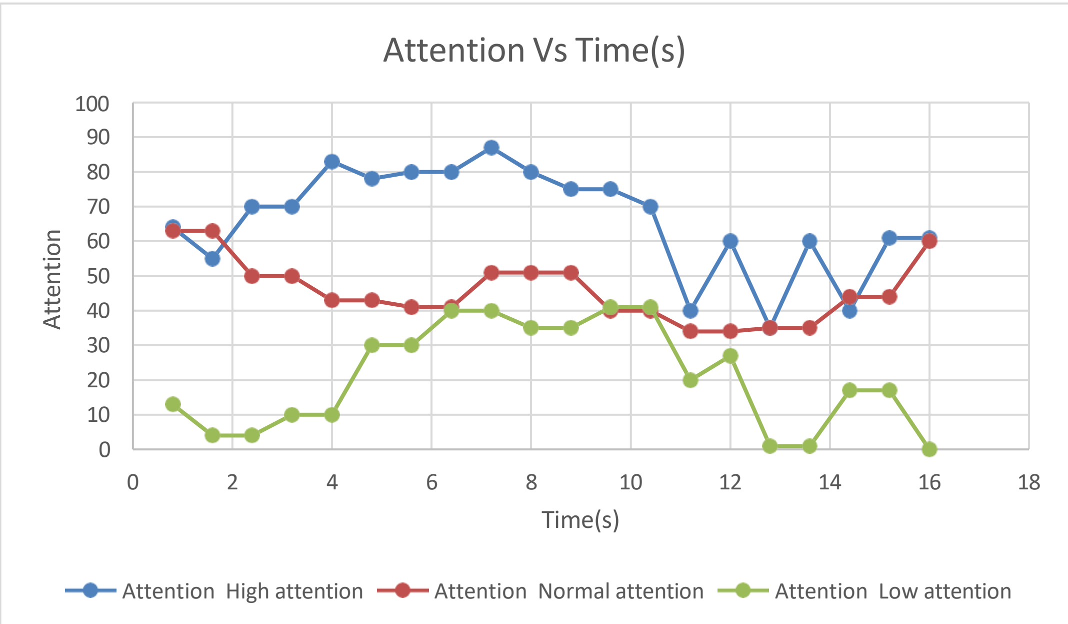

Figure 4. 1 Graph attention

A mathematical approach was made to fine the suitable value for the process of determining the right attention values. The mean value of the observations can be calculated using:

Average = Sum of all observations / Total number of observations

This formula will allow a straight forward and consistent method of finding the mean value that could serve as a benchmark for setting the thresholds. The use of the average in this regard makes the decision process much simpler and ensures that the values chosen will be representative of the overall data collected. Such a systematic approach enhances the reliability and functionality of the lighting control system, making it more efficient and user-friendly.

Average = Sum of all observation / Total number of observation

Average High Attention = 1324/20 = 66.3

Average Normal attention = 862/20 = 43.1

Average Low attention = 446/20 = 22.3

Thus, Based on the calculation of the average high attention value, can be conclude that the high attention level obtained is approximately 66.3. Therefore, can use this high attention value as a benchmark to activate the lamps. Since we are using two lamps, Can define the range for activation as approximately 50–70. Lamp 1 activated at value of 50 or higher, while Lamp 2 activated at 60 or higher.

For the "low attention" section, based on the average, the value obtained is 22.3.Can use this value as a benchmark for turning off the lights.Since have 2 lamps, Can predict that range for deactivate as approximately below 50-70.Lamp 1 deactivated at value below 50 or lower,while Lamp 2 will be deactivated at 60 or lower. This action can create a smooth cycle and make it easier for users to use it

These values were determined not only from graphical observations but also by a calculated average of the data collected. The use of an average is to ensure that the thresholds determined remain the same with minor variations in the reading of individuals. This ensures a steady and consistent response of the lighting control system to small fluctuations in attention data.These values are also important in making a proper balance of sensitivity and efficiency within the lighting control system.In addition, it ensures that the measurement of attention of a user is done and utilized effectively and efficiently for the operation of the system. The functionality and reliability of the lighting control mechanism are thereby enhanced to make it practically feasible for real-world applications.

4.2.2 Attention count

The instability of brainwave signals sometimes makes it challenging for users to achieve their desired condition, such as turning the lights on or off. Therefore, an experiment was conducted to determine an appropriate count value, ensuring that the lights can be turned on or off as intended by the user.

Table 4. 2 Attention value

Time	Attention value when focus	Attention value when relax
0.8	58	63
1.6	67	78
2.4	58	54
3.2	46	25
4	57	37
4.8	89	25
5.6	90	16
6.4	94	10
7.2	67	17
8	91	11
8.8	65	15
9.6	78	30
10.4	70	35
11.2	50	46
12	46	35
12.8	43	30
13.6	68	56
14.4	78	68
15.2	67	78
16	70	70

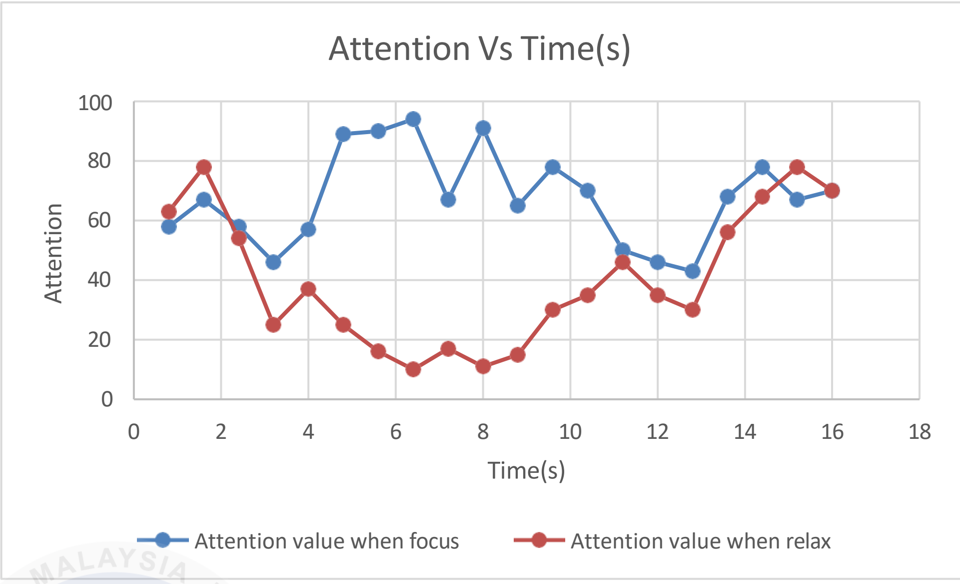

Figure 4. 2 Attention graph

To test the suitability of the count value, 20 samples were taken every 0.8 seconds. For turning on Lamp 1 and Lamp 2, the attention value needed to exceed 60. Based on the graph, it was observed that the attention value during focus exceeded 60 in 16 out of 20 instances. Conversely, during relaxation, the attention value fell below 60 in 15 out of 20 instances, which is required to turn off Lamp 1 and Lamp 2. After repeatedly testing the suitability of the count value, it was found that the optimal and convenient count value for turning on and off the lights is 4 counts for Lamp 1 to On or Off and 6 counts for Lamp 2 to On or Off.

4.2.3 Enviroment factor

Sometimes, environmental factors like excessive noise can make it harder for users to focus and reach the attention level needed to turn the lights on or off. To understand this better, an experiment was carried out to see how much these factors actually affect attention level.

Table 4. 3 Attention level

Time	Attention value when quite	Attention value when noisy
0.8	76	53
1.6	67	68
2.4	79	34
3.2	58	45
4	78	27
4.8	62	15
5.6	90	16
6.4	58	80
7.2	46	77
8	64	81
8.8	65	55
9.6	45	30
10.4	58	85
11.2	80	46
12	69	55
12.8	43	80
13.6	68	56
14.4	70	18
15.2	67	48
16	70	70

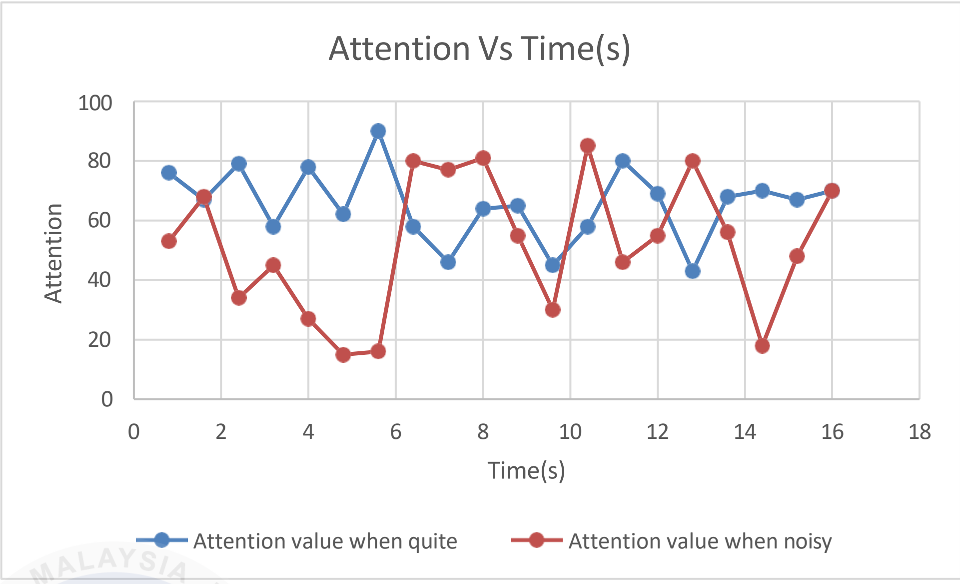

Figure 4. 3 Attention level

Based on observations of the table and graph shown at Table 4.3 and Figure 4.3, it is clear that attention levels in a quiet environment tend to be more stable and reach the desired levels more easily compared to focusing in a noisy environment. For the quiet condition, the experiment was conducted in a closed room without any external noise interference. Meanwhile, for the noisy condition, the experiment was carried out with loud background noise, specifically music played at a high volume.

4.2.4 Testing EEG at different people

The next experiment focused on testing the smart home whether different individuals would produce varying outputs to turn the lights On or Off. This experiment was conducted with five participants. Each participant was given only two minutes to turn on the light. The participants varied in age and levels of intelligence.

Table 4. 4 People with different age and education

People	Age	On/Off lamp
Person A	22	3
Person B	24	2
Person C	25	5
Person D	26	4
Person E	21	3

The table shows at Table 4.4 that different individuals produce varying values, indicating that the results are not consistent under a single condition. However, the ability to reach the desired attention level can be trained, making it easier for users to turn the lights on and off.

Figure 4. 4 User On lamp 1

Figure 4. 5 User On lamp 1 & lamp 2

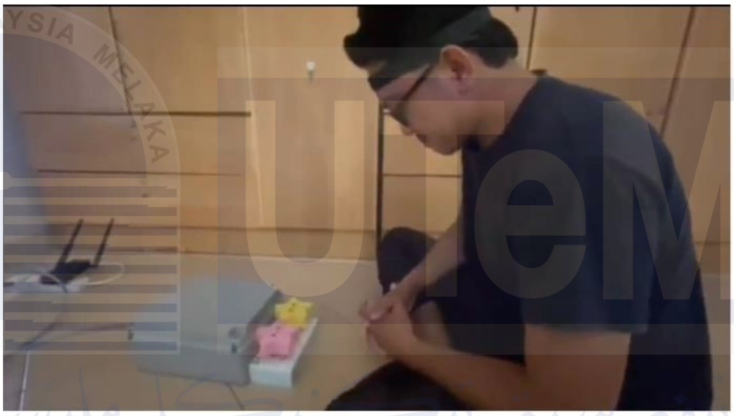

Figure 4. 6 User Off both lamp

Figure 4. 7 Blynk interface

4.2.5 Summary

Chapter 4 presents the findings and evaluation of using brainwaves to control smart home lighting. Data analysis identified attention thresholds for activating and deactivating lights, with results showing reliable system functionality under defined conditions. Environmental factors like noise and individual differences among users were found to influence performance, but these challenges can be mitigated through controlled environments and user training. Overall, the system demonstrates potential for practical application, offering efficient and user-friendly lighting control based on brainwave activity.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A significant advancement in home automation is the development of a smart home controller that combines EEG technology with IoT, designed to make smart home control accessible and user-friendly, especially for people with impairments. The system allows users to operate home appliances using brainwave signals and includes a smartphone interface via the Blynk app for real-time monitoring and control. This technology enhances independence for individuals with physical challenges and simplifies smart home management for all users. The study demonstrates that integrating IoT and EEG can create an inclusive, efficient, and practical smart home system.

The development of a smart home controller integrating EEG technology and IoT not fully successfull enables users to control devices using brainwave signals. The inclusion of a user-friendly interface within the Blynk app ensures seamless real-time monitoring and control through a smartphone, making the system both accessible and practical for enhanced convenience and independence.Have some problem that need to improve next time.

The first issue is that when Lamp 2 is turned on, Lamp 1 also lights up. The lights cannot be controlled individually, making it impossible to activate Lamp 2 without also turning on Lamp 1.The second issue is a slight delay in the Blynk IoT gauge displaying the readings. This delay causes users to be uncertain about the actual values.

5.2 Potential for Commercialization

Considering its novel design, as well as the extent of applicability, huge commercialization potential may be involved in the union of EEG technology with IoT for such a smart home controller.It supports various vital market needs of the elderly and those with some form of disablement, where freedom and quality of life are made possible by allowing brainwave signals to operate smart home appliances. Other than that, modern technology and intuitive interface - thanks to the Blynk application - make this system easily accessible and friendly in use, and therefore appealing to absolutely different users. Adoption is facilitated by the quick growth of the global smart home market and the rising need for integrated IoT solutions.Sales of hardware, software, and app services, as well as joint ventures with makers of smart home appliances and healthcare providers, can all bring in money. The system is positioned for success in the cutthroat smart home industry because to its customisable, expandable, and potentially global capabilities.

5.3 Future Works

This project not fully successfully meets all stated objectives and satisfies all target requirements. However, some limitations can be overcome, improved, or upgraded in the future, including the following:

i. Add more output like fan, more lamp, or buzzer
ii. Ensure that all EEG data and IoT communications are encrypted to prevent unauthorized access.
iii. Use energy-efficient components to reduce power consumption
iv. Provide user-friendly guides, setup instructions, and troubleshooting resources to make the system more accessible to non-technical users.
v. Combine EEG control with other modalities like voice recognition or gesture controls to offer hybrid usage.
vi. Integrate machine learning or AI models to enhance the accuracy of interpreting EEG signals, distinguishing between intentional commands and background noise.

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APPENDICES

APPENDIX A GANT CHART PSM 1

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Registration														
Gant Chart														
Literiture Review														
Introduction														
Objective														
Scope														
Project Background														
Methodology														
Preliminary Result														
Ready for Slide														
Presentation														

PSM 1 GANTT CHART

APPENDIX B GANTT CHART PSM 2

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Start to create coding suitable to my project according to research that study before														
Buy the item of project and start to create the project														
Integrate the brain sensor to Smarthome														
Test the project to show that the brain sensor can apply at smarthome														
Fix and improve at coding so can get real-time response and easy to use														
Update report project especially at chapter 3 & chapter 4														
Final touch up and finish the project														
Present														
Submit report														

PSM2 GANTT CHART