EEG-BASED CHESS GAME MONITORING SYSTEM

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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

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Date : 24/1/2025

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DEDICATION

To my beloved mother, Masrinawati Binti Mohd Arifin, and father, my father Ahmad Nizam Bin Abdul Halim, all family members that are being my pillars of strength and to my supportive friends that inspires me every day.

ABSTRACT

This project successfully developed an EEG-based chess monitoring system, which analyzed players' cognitive and brain states after gameplay, in order to increase performance and provide deeper insight into mental processes. Using the MINDLINK EEG headset, the project complemented that with a webcam-based chessboard tracking system to capture the brain waves and synchronize them with the gameplay data. A GUI was developed in MATLAB for real-time monitoring and post-game analysis, while the data is safely stored in a local database for long-term tracking and performance evaluation. The system is also designed to deal with issues like capturing EEG data in a dynamic environment and processing brainwave patterns related to actual moves taken during a chess game. Results showed it works efficiently in giving feedback for action, helping players recognize emotions, reduce stress, and polish strategical thinking. It also gave better insight to coaches and researchers in the field of training techniques and cognitive research. This new development provides a simple yet secure tool with ample potential for the advancement of chess training, cognitive development, and the neuroscience of decision-making. While many challenges remain in the accurate recording of data from electroencephalogram (EEG) equipment and its integration into gaming metrics within a dynamic environment, the system has accommodated them quite well. The findings prove able to provide players with critical feedback about their mental performance, helping them identify their emotions, cope with stress, and improve their strategic thinking. The system enabled coaches and researchers to understand cognitive processes better so that they can train more effectively and contribute to the wider field of understanding how neuroscience works in chess. The achievement of project objectives resulted in a user-friendly tool for real-time monitoring of EEG data alongside chess game metrics, with the assurance of secure analysis. This innovation has tremendous improvements in chess coaching, progress in cognitive research, and investigation of principles across neurosciences and strategic gaming.

ABSTRAK

Tujuan projek ini adalah untuk mencipta dan melaksanakan sistem pemantauan permainan catur berasaskan EEG yang menyimpan data tentang proses kognitif yang terlibat dalam permainan catur. Teknologi ini akan merakam dan menyimpan isyarat EEG semasa permainan catur. Sistem ini juga akan menjana satu pangkalan data untuk menyimpan dan mengurus data EEG, pengukuran prestasi pemain yang merupakan data gelombang otak pemain, dan corak papan catur, serta analisis data dan alat visualisasi dalam terma GUI. Output yang dijangkakan ialah maklum balas masa nyata, penyimpanan dan pengurusan data, serta analisis dan visualisasi data. Pernyataan masalah ialah teknik semasa untuk pemantauan gagal menggabungkan data EEG masa nyata dan corak papan catur dengan lancar yang mempengaruhi perubahan gelombang otak pemain. Di samping itu, terdapat keperluan untuk sistem yang kukuh dan mesra pengguna yang mampu menangkap, memproses dan menganalisis data EEG sambil menjejaki pergerakan catur dalam masa nyata. Objektif utama projek ini adalah untuk membina sistem bersepadu yang mengambil data EEG masa nyata melalui set kepala MINDLINK EEG dan menyegerakkannya dengan gerakan catur yang dijejaki oleh kamera web dari papan catur di atas. Sistem Pemantauan Permainan Catur Berasaskan EEG dijangka berjaya menyepadukan pemerolehan data EEG masa nyata dengan penjejakan pergerakan catur, memproses isyarat EEG dengan tepat, mengekstrak ciri ke dalam GUI dan menyimpan data ke dalam fail tempatan yang boleh dianalisis pada masa hadapan. Sistem Pemantauan Permainan Catur Berasaskan EEG menyelesaikan keperluan penting untuk pemantauan kognitif masa nyata semasa permainan catur dengan menggabungkan teknologi EEG yang lebih tepat dengan pemprosesan data dan ciri visualisasi yang kukuh. Kejayaan pelaksanaan sistem ini akan menambah baik metodologi penyelidikan kognitif memberikan instrumen yang berharga untuk menyelidik interaksi keadaan mental dan proses membuat keputusan dalam aktiviti yang rumit.

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LIST OF ABBREVIATIONS

i.	EEG	= Electroencephalography
ii.	ERG	= Electroretinogram
iii.	BCI	= Brain Computer Interface
iv.	GUI	= Graphical User Interface
v.	VR	= Virtual Reality
vi.	ICA	= Independent Component Analysis
vii.	fNIRS	= Near-Infrared Spectroscopy
viii.	MEG	= Magnetoencephalography
ix.	ECoG	= Electrocorticography
x.	CSP	= Common Spatial Patterns
xi.	SVM	= Support Vector Machines
xii.	LDA	= Linear Discriminant Analysis

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CHAPTER 1

INTRODUCTION

1.1 Background

Chess demands extraordinary cognitive skills, such as sharp focus, strategic reasoning, and efficient stress management. Playing chess requires excellent brain functioning, focus, strategy thinking, and stress handling. Traditionally, the chess game was evaluated based on achievements in games as well as moves made by players. The newest instruments, such as neurology's electroencephalography, enable studying brain processes beneficial in chess playing in real time. The aim of the project is to improve players' performance in the game of chess by creating a monitoring system guided by the results of EEG studies. By means of providing real-time feedback, the system will collect data on players' brainwaves and mental activity. After the data is collected, the system show players how their mental performance influences the game. By using the convenient system, the players will be able to learn how to recognize their feelings and emotions during the chess gameplay. It is important that the progress of this project on reliable storage and acquisition method is successful. The sensitive cognitive data will be kept safe as the device will safely acquire and store EEG data along with the game performance measurements. Long term storage will mean that it is possible to track the development of a person's cognition across multiple training sessions and games. By analyzing this historical data, we may be able to gain some insight into the types of trends and correlations that exist between different cognitive states and chess performance.

1.2 Problem Statement

Gathering data of the brain process, also referred to as EEG data in real time, and tying it with moves in a chess game is considered to be one of the most difficult tasks. The issue is that it requires sophisticated techniques to record and analyze EEG signals correctly as the person would be moving the pieces across the board. The techniques utilized today are incapable of properly integrating the data in question, making it more complicated to identify individual processes of the brain with the moves in question. The next factor that makes it complicated is the need for accurate pattern selection. It implies that there is a need to develop an algorithm that would identify and analyze patterns of brain signals related to a particular move in the game. Overall, it is more challenging due to the fact that EEG signals are very different and can barely be analyzed without proper signal processing. Furthermore, the brainwave produced only print out waves in the GUI and does not specify which pattern that effects the changes of the players. The system's interface must be user-friendly for real-time monitoring and analysis.

1.3 Project Objective

The main objective of the EEG-Based Chess Game Monitoring System is to develop a tool that can capture and evaluate a player's brain activity in real-time while playing chess.

a) Develop a method that captures chess board changes and pattern which use the webcam as a data output and matches with the EEG data at the same time.

b) Use the MINDLINK EEG headset to capture the player's brainwaves during the game of chess

c) Create a MATLAB-based graphical user interface (GUI) that displays brain activity and chess pattern in real time, allowing for easy monitoring and analysis.

d) Save all collected data to a local database and organize it for simple access and analysis after the game.

1.4 Scope of Project

The scope of this project are as follows:

a) Hardware Integration:

- Using MINDLINK EEG headset to capture brainwave data from real-time brain activity.

- Implementing Arduino Uno as a microcontroller to receive signal and data from MINDLINK EEG headset.
- Application of Webcam use to capture chess board pattern changes.

b) Software Development:

- MATLAB
  - i) Developing MATLAB software as a program to communicate with MINDLINK EEG headset and capture real time data.
  - ii) Creates and integrating pattern that matches programs in MATLAB with EEG data and specific chess board patterns.
  - iii) Design a MATLAB-based GUI to display output of the data in real-time.
- Arduino IDE
  - i) Develop a program code to receive signal from MIND LINK EEG headset data and synchronization.

c) Data Storage and Management:

- Creating a structured local database to safely store all collected data.
- Organizing data files for easier access and analysis after the game.

d) Data Analysis and Reporting:

- Provides tool in the GUI to store data and display reports such as details of the data.
- Creates a visual representation of data.
- Use 3 different level of experience players in 10 minutes Blitz Gameplay.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The previous chapter described the project's background for developing an EEG-based chess monitoring system. The document defined the project's problem statement, objective, and scope. This chapter explains the literature study project. This study incorporates previously conducted research by students and institutions. This chapter includes the explanations of some project concepts. By understanding the relationship between theory and work which is necessary for project planning.

2.2 Electroencephalography (EEG)

The method used for capturing brain electrical activity is called electroencephalography, or EEG. The process is non-invasive and uses electrodes applied to the scalp to identify the electrical signals sent by neurons as they exchange information. The brain's activity which so called the brainwave shows during the time of the EEG scanned are produced, it is caused by the processing and amplifying all of the signals. During the examining the function of the brain and sensing neurological problems, EEG offer various advantages in both clinical terms and for research contexts. Through medical terms, EEG gives the benefits in scanning abnormalities in brain activity that may causing to a certain disease for instance the epilepsy, sleep problems, and brain traumas. EEG can be use as a tool in research context to study more areas of brain function, which includes the emotions and cognitive processes [1].

There are some major steps that involves in EEG applications. To ensure the accurate recording of brain activity, the electrodes are first crucial implanted that has to be on the scalp in order that recognized standards.[2] The signals that has been received by the electrodes are being amplified to allow their detection and analysis. In the next phase, noise and artifacts are been separated from the EEG data using the signal processing method, guarantees the captured signals are correctly represents the brain activity. Afterwards, some advance technique and methods including source localization, related potential events, and analysis spectrum that are works to decode the EEG data and derive important information into brain activity.[3] As for the conclusion, the EEG technology represents a a good insights that ensuring the improvements of the cognitive comprehension and performance across the area of domains due to its limitations to capture the brain activity in real time. [1]

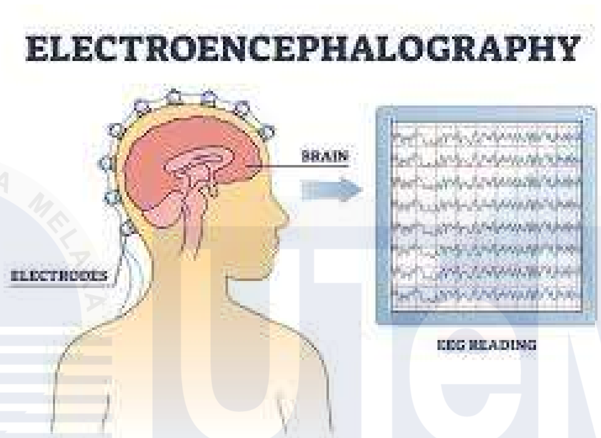

Figure 2. 1 EEG Process

2.3 Brain Waves

The brainwaves which are also known as the neural oscillations, defines the patterns of rhythmic or a repeating brain activity in the central nervous system. These oscillations act as the main role in various cognitive assessments and regularly examined by using electroencephalography (EEG), which detects the electrical activity in the brain. This literature review analyses the importance of brainwaves which in the cognitive and behavioral research are the methodology that being used to analyze the data, and the applications of brainwave monitoring in understanding of cognitive processes. The brainwaves are divided into several frequency bands and each of them related to specific cognitive functions and levels of consciousness: [2]

i) Delta Waves (0.5-4 Hz): Mostly in deep sleep and linked to healing and regeneration.

ii) Theta Waves (4-8 Hz): Related to creativity, intuition, and daydreaming; usually observed in light sleep and meditation.

iii) Alpha Waves (8-12 Hz): Related with peaceful, calm, and thoughtful states; frequently observed while a person is awake but at rest.

iv) Beta Waves (12-30 Hz): Active thinking, focus, and problem-solving are linked with conscious, alert states.

v) Gamma Waves (30-100 Hz): Observation and consciousness are examples of high-level cognitive processing.

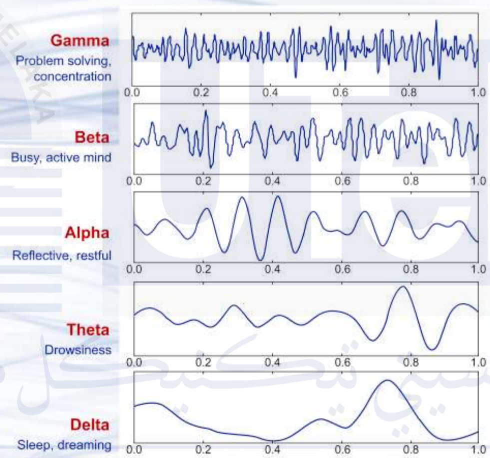

Figure 2. 2 Example type of Brainwave

2.3.1 Advantages of using Brain Wave in EEG

There are several advantages of using EEG brain waves which has been discovered in various research, that includes the neuroscience, psychology, and medicals purposes. The Non-Invasive and Cost-Effective is one of the advantages which a non-invasive method that does not need any surgical integration or expensive equipment. This observation concludes that it is a cost-effective technique for studying brain activity. Moreover, High Temporal Resolution is also an advantage because the EEG has a high temporal resolution which scientists can test how fast the brain activity changes during different cognitive and affective activities. Real-Time Feedback also consider as an advantage its is because the EEG provides the real-time feedback of the brain activity, that giving benefits for applications for instance, the brain-computer interfaces and neurofeedback training. Furthermore, the objective measurement which can be describe as the EEG can provides the objective measure of brain activity, that is not influenced or interfere by some factors for example the self-reporting or the behavioral observations. Lastly, other applications that related to a range of domains in which the EEG has applied with the range of domains, including the education, psychology, neuroscience, and medicine. Emotional processes like anxiety and sadness as well as cognitive processes like memory, attention, and decision-making has been used in this type of project for more purposes research.[3]

2.3.2 Disadvantages of using Brain Wave

Despite the EEG has contributed in advanced our knowledge of brain activities, there are a some of disadvantages to that may lower its performance from the perspectives of precision and efficacy. EEG has the low spatial resolution in which EEG captures the electrical signals from the forehead of the user, that makes it a little bit difficult to pinpoint the exact source of the neural activity in deeper brain structures.[4]This limitation occur because of the signals must go through the skull and other human parts such as tissues, muscles in which that it can mislead the data. [5]The EEG has the influence to differentiate all types of noise and the raw signals which is another disadvantage. An important data extraction can be collected by the amount of contamination EEG signals affected by the movements of artifacts, muscle activity, and external electrical interference. This includes the jaw clenching or an eye blinking. For instance, this act causing a large number of artifacts that surpass the electrical activity in the brain. These disturbances will never be completely separated or removed, but the advanced signal processing method are necessary to filter these problems out in which it could result in misinterpretations. The frequency range of the EEG is estimated can be constrained, which can normally, signals between 0.1 Hz and 100 Hz are recorded. Because of this type of limitation, it is impossible to identify the higher frequency brain oscillations that may be crucial for specific cognitive functions.[6]Furthermore, even the relation of low temporal resolution is suitable for some applications, it may not be enough to capture for instance the millisecond-level rapid dynamics of brain processes. This temporal obstacle makes it more difficult to explore in quick neuronal events and the method of synchronization between various brain area. Other than that, the importance degree of knowledge is required to the analyze EEG data. Advanced methods of analysis imply a lot of knowledge to be needed in order to decipher such complex and often non-intuitive patterns in brain waves. The complexity itself may confine an EEG technology in general to either healthcare or consumer-grade BCI devices, making them inaccessible to specialized research and therapeutic contexts.[7]

2.4 Brain Computer Interface (BCI)

Brain-computer interfaces (BCIs) decode the brain activities to commands for establishing a direct brain-to-device communication. EEG-based research in BCI is an important aspect in the sense that it exploits the non-intrusive condition and affordable nature of the EEG signal to improve human-computer interaction.[8].

In general, BCIs like these can be categorized into three types: partially invasive, non-invasive, and invasive. These invasive BCIs provide high-resolution signals that are perfect for therapeutic contexts—like, for example, the BrainGate system, which allows paralyzed people to control equipment via neural activity—thanks to the implantation of electrodes straight into brain tissue. Non-invasive brain-computer interfaces (BCIs) use external sensors for detecting brain signals. They include functional near-infrared spectroscopy (fNIRS), magnetoencephalography (MEG), and electroencephalography (EEG) y. All of these methods give less accuracy in comparison with intrusive systems but are much safer and easier to operate. Electrodes are placed inside the skull but outside the brain tissue in partially invasive brain-computer interfaces, including electrocorticography (ECoG), in an effort to balance surgical risks and signal quality.[9]

Precise identification, extraction, and interpretation of brain signals form the backbone of BCI technology. Machine learning algorithms, more so, are greatly involved in the translation to convey information into commands for external devices. Signal processing techniques filter noise, extract relevant features, and do signal classification. Wavelet transforms, common spatial patterns. (CSP), and power spectral density analysis and power spectral density are common techniques in feature extraction. BCIs` accuracy and responsiveness get enhanced by methods of classification, such as deep learning models and support vector machines (SVM), and linear discriminant analysis (LDA).[10]

Wearable sensor devices and real-time data streaming have increased the efficiency and reliability of EEG signal collection. Continuous collection and monitoring of data has become possible, which makes the BCI applications precise and dynamic. Moreover, sophisticated signal processing techniques like feature extraction and filtering have greatly enhanced the quality of EEG signals. These methods enhance the performance and power of BCIs by effectively filtering noise in the neural activity.[11]

Machine learning methodologies have so far been extensively applied to EEG data for several aspects, including clustering, regression, and classification. Such approaches use large datasets to train models that can interpret the complex patterns of impulses from the brain. Moreover, fuzzy models and transfer learning techniques have been introduced to improve the accuracy and robustness of EEG-based BCI systems. Whereas transfer learning enables the adaptation of previously trained models to new users or tasks, fuzzy models are helpful in dealing with the intrinsic uncertainty of brain input to enhance the generalizability of BCIs.[12][8]

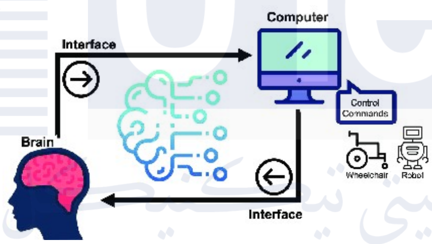

Figure 2. 3 BCI Block Diagram

2.5 Neuron Functions and Activities

The fundamental components of the nervous system and brain are neurons, which are in charge of processing information, receiving sensory input, and sending messages to various bodily regions. The structure, kinds, functions, and complex processes that underlie brain development and communication are all covered in the study of neurons.[13] One important characteristic of neurons is their capacity for activity-dependent modifications that alter the intensity and effectiveness of synaptic transmission; this is referred to as neuroplasticity.[14] Three main types of neurons which are Sensory neurons that detect physical and chemical stimuli from the environment and transmit signals to the central nervous system, Motor neurons are responsible for facilitating movement and function in muscles, organs, and glands by sending impulses from the brain and spinal cord and Interneurons that act as intermediaries in the brain and spinal cord, passing signals between sensory neurons, other interneurons and motor neurons to form complex circuits.[15]

Action potentials are electrical impulses that pass along axons and cause the release of neurotransmitters at synapses, which is how neurons communicate. If the electrical threshold is crossed, these neurotransmitters attach to receptors on the receiving neuron and may cause an action potential in the postsynaptic cell. Thorough investigation has shown that changes in mammalian behavior or brain state can be caused by the firing.[16]

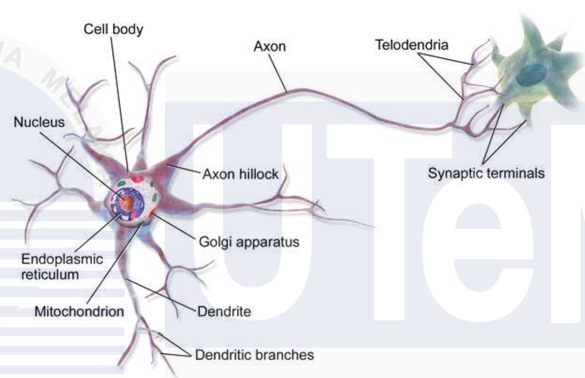

Figure 2. 4 Neuron Structure

2.6 Past Project using EEG Brain Wave

2.6.1 EEG-Based Emotion Recognition [10]

In the past years, various approaches based on electroencephalography (EEG) have been put forward for the identification and analysis of human emotions. All of them are related to the electrical activity of the brain to show the complexity of emotional states. The research in EEG-based emotion detection is currently a significant area because it represents a non-invasive technique with many potential applications in mental health monitoring, human-computer interaction, or adaptive learning environments.

A lot of research has been done on models of emotions, focusing on how best emotions can be identified and classified. Most of the models use large datasets and methods designed to evoke and quantify feelings in human beings. The datasets make a very rich source for developing and testing algorithms for emotion recognition, containing EEG recordings with different emotional states. The applied methodologies range from controlled experiments in a laboratory setup to real-world situations, thus making sure the models generalize well across contexts.

Emotion identification from EEG data depends strongly on the application of machine learning and deep learning techniques. These techniques play a huge role in processing and giving meaning to the complex patterns within the EEG signals themselves. Therefore, feature extraction and selection algorithms become of prime importance in this step, for they help isolate from the EEG features only those correlated with certain emotions. On this basis, researchers can then refine features to improve the accuracy and reliability of emotion recognition systems. Such advanced computational approaches have been incorporated to detect and classify human emotions, and these techniques enhance the capability a hundredfold in creating more sophisticated and responsive applications.

2.6.2 Human Brain's EEG Rhythms and Emotional States[17]

There is a good relationship between emotional moods and EEG rhythms, which piques the interest of many researchers to delve further into this relationship for emotion detection. EEG rhythms are reflections of the electrical activity of the brain and can give valuable information on how various, different emotional states neurologically manifest. Investigation might reveal patterns and indicators connected to specific emotions by analyzing these cycles, making it possible to build more accurate emotion identification systems.

Researchers have made quite a good amount of effort on most of the EEG-based methodologies for emotion recognition, focusing on their feasibility and effectiveness. Most of these studies report the performances of different machine learning and deep learning algorithms for processing and analyzing EEG data. Traditional techniques in machine learning applied for emotion state classification based on EEG features include support vector machines and random forest. These algorithms make use of manually extracted features and have shown quite reasonable effectiveness in emotion recognition tasks.

In contrast, these approaches have grown in popularity because they can automatically learn and extract features from raw EEG recordings. Probably the most popular deep learning models applied for this task are convolutional neural networks and recurrent neural networks. Such models can find complex temporal and spatial correlations in EEG signals and thus can realize more accurate and robust emotion recognition. These juxtapositions can realize the strengths and weaknesses of both machine learning and deep learning methodologies and therefore develop more effective EEG-based emotion identification systems.

2.6.3 EEG-Driven Virtual Reality (VR)[18]

The main point in merging EEG and virtual reality is the predominant enhancement of user experience by being able to change VR content in real-time according to the cognitive state of the user. With the EEG data showing the emotional and cognitive reactions of the user, VR systems would change dynamically to offer more engaging experiences that are personalized. In this regard, it would be possible to close the gap between the expectations of users and the VR world—thus developing a much more elaborate and satisfying engagement.

EEG-driven VR implementation involves constant monitoring of the user's EEG signals during his interaction with a VR system. These signals are captured to obtain changes in his cognitive and emotional states, attention, relaxation, stress, and excitement. From this real-time analysis, modifications can be made within the VR system at different levels. For instance, game dynamics, like levels of difficulty, speed, and even interactivity, can be adjusted to the current status of the user to ensure the presence of challenges and fun in the right amounts. At the same time, visual and auditory factors can be modulated in favor of immersion or reduction of hassle to have a more personalized experience with VR.

Significant advantages arise from the linking of EEG and VR, especially in providing both immersive and individual settings. Material from VR experiences will become more engaging and effective because it is tailored to the cognitive state of a user. Customization by itself retains users, consequently leading to higher total impact for a VR application. Such adaptable systems can be utilized in other therapeutic settings: Tailored VR experiences are able to relax, reduce stress, or even support the rehabilitation of cognitive functions. Real-time response is why EEG-driven VR systems are widely applied in education, gaming, and mental health spheres, as it enhances greater user engagement and experience.

2.6.4 EEG-based Brain-Computer Interface for Controlling a Robotic Arm[19]

A very excellent experiment in the arena of EEG brain wave research has developed a robust BCI system, which makes it possible to direct a robot arm. This method used EEG signals that mainly covered the occipital lobe and captured alpha waves in the 8-12 Hz frequency range. Alpha waves have a strong relation to visual attention and relaxation, and thus are considered an excellent choice for this application.

In developing this system, EEG inputs from the occipital lobe were first amplified and filtered to sort out alpha wave activity. After this, the device calculated the degree of concentration by using information related to the magnitude of these alpha waves. A drop in alpha wave power, indicative of increased concentration with respect to visual engagement, would trigger the robotic arm. This new interface provided an intuitive and direct way of controlling the robotic arm from a user's cognitive state.

Demonstrations of BCI system practical uses included game playing activities with a theme of "flappy bird." The user's focus and the level of visual attention, expressed through alpha wave activity, was immediately translated into game controls, resulting in fluent game playing and full immersion. The method was further used to estimate the level of children's attention, thus giving an important insight into their cognitive engagement that could be otherwise helpful in educationally or therapeutically oriented applications.

2.6.5 Cloud Infrastructure for Storing and Processing EEG and ERP Experimental Data[20]

One of the notable advances in the field of EEG and event-related potential research is the development of a cloud-based system for storing and processing experimental data. The creative project responds to the requirement posed by neuroscience research, which requires scalable and effective systems for data management. It will be capable of managing huge volumes of data accruing from EEG and ERP investigations by building on the cloud infrastructure as its base support in dealing with such data volumes.

This project will be based on a distributed data storage solution, ensuring that both EEG and ERP data are saved across not one, but several, servers. This increases the capacity and stability of storage. Besides the capacity and stability, distributed storage also enables better data redundancy and fault tolerance. It guarantees that crucial research data was saved and safe from hardware failures or other kinds of disturbances. Researchers will count on a stable and safe environment for data storage and big datasets.

Besides providing storage space for your data, it offers robust ways of signal processing that are tailored to work with EEG/ERP research. These embedded signal processing techniques allow for preprocessing, filtering, and effective analyses of the raw EEG data, thereby reducing the data and making inferences. By putting these signal processing features inside a cloud architecture, researchers can run complex studies without requiring significant local computational resources. This cloud-based processing enables faster and more powerful management of data, significantly enhancing the workflow of research work.

One key module included in this cloud solution is the secure storage of EEG data. The measures adopted protect the systems from infiltration and other breaches that may result in the loss of crucial experimental data. Ensured safeguards on the integrity and confidentiality of data include data encryption, access control measures, and regular security audits. Moreover, the cloud platform is designed to empower collaborative research through shared access to datasets for those authorized with reduced friction. This will foster greater cooperation across research teams for easy and efficient sharing of data and discoveries credible to a research study.

2.6.6 Cloud-based Data Platform for Efficient EEG Data Management, Collaboration and Analysis[21]

The project was to try and ease some of the complications and challenges that arose from handling this large volume of EEG data and provide a full and efficient solution for researchers. Developing this platform would thus be a major breakthrough in neuroscience research, improving the chances of managing data and providing collaborative efforts in their analysis.

This system can be used to store and share data with other researchers much more efficiently. It offers a scalable solution using cloud infrastructure to support the fast-growing volume of EEG data generated from several tests and investigations. It provided safe storage and access to its data from anywhere, hence promoting easy data sharing and collaboration. Due to the fact that the platform provided a single repository for all EEG data, the researchers did not worry about local storage restrictions or data transfer problems.

One of the key components of the platform was its set of various data management and analysis tools. The platform enabled the direct upload of EEG recordings, after which they could be further annotated and organized efficiently. It thus provided for detailed annotation in its functionalities, hence arranging datasets according to classes and searching for them became possible. Beyond that, too, the platform had advanced analysis capabilities that empowered academics to run a number of activities related to data processing, from simple signal processing to sophisticated statistical studies. All these tools were embedded into the platform and contributed to a clear workflow that made conducting complete data analysis without using external software possible.

Their use of this cloud technology has made a phenomenal difference in EEG research. It solved many logistical and most of the technical problems associated with conventional ways of handling EEG data, hence making it easier to use. This consolidated the safe and easily available platform of EEG data, allowing researchers to focus on their scientific questions rather than data management difficulties. Moreover, it provided new avenues for studying alone by opening powerful analysis tools and collaborative features of the platform for more complex and multidisciplinary studies.

2.6.7 Time Series Analysis for EEG Sensors [22]

The prior objectives successfully combined in this final-year project: the development of a novel interface system between the human brain and a computer using EEG sensors. This highly ambitious final-year project attempted to introduce communication solely through the electric activity of a brain within a computer, thus establishing the base for further refined brain–computer interfaces. The goals of the research were to capture and analyze EEG data for bridging neural activity with digital engagement.

The two major components of this research study were the collection and analysis of EEG data. It began with the help of some EEG sensors to capture the electricity activity of a working brain. The EEG sensors would get implanted at specified positions on the scalp and record data for different states of brain-related cognitive activities. The acquired EEG data is then analyzed properly using time series techniques of analysis. It allows the assessment of EEG signals across time, which details a temporal dynamics of brain activity.

The most important part of the activity was to investigate ways through which relevant information can be obtained in EEG time series data. The raw EEG signals were complicated and noisy, hence the need for advanced processing techniques for important patterns and features. The project investigated various signal processing methodologies to sort out meaningful brain processes from background noise, such as filtering, feature extraction, and pattern recognition. With techniques like Fast Fourier Transform and wavelet transforms, it was allowed to examine the components of EEG data at different frequencies, permitting the identification of distinct brain wave patterns associated with different mental states.

The successful completion of the research demonstrated that a functional interface between the human brain and a computer can be established using EEG sensors. This project has laid down, through example, a way of collection and interpretation of EEG data and inferring useful information from time series signals, thus laying the groundwork for future development in BCI technology. The findings put forward the potential for applying BCIs within several domains: assistive technologies for impaired people, neurofeedback, and improved interaction between humans and computers.

2.6.8 EEG Research Based on the Influence of Different Music Effects[23]

The current research project was conducted using EEG experiments to test the different musical stimuli on attention. The major aim of this experiment was to determine the analysis of EEG signals to look at a deeper level regarding the effects of different tempos and styles of music on the brain's processing of attentional resources. This study is very useful, relevant, particularly in an educational setting, therapeutic scenarios, and personal performance enhancement, where background music is always used to enhance concentration and other brain functions.

It focused on two kinds of auditory stimulants: one, the so-called "brainwave" music with a beat of 80 beats per minute, and two, heavy metal music, which receives beats of 140 BPM. Brainwave music is a kind of music that is used to entrain mental activity with its natural frequency, keeping the individual relaxed and, at the same time, cognitively alert. Envisaging the name itself, heavy metal music is fast with strong rhythmic beats and, thus, more likely to create high arousal and energetic levels. The study tried to show which of the two kinds of music had a greater effect on alertness.

Methodology The methodology applied Independent Component Analysis to EEG signals collected in the process of experiments. ICA is a computational approach to decomposing a multivariate signal into an additive set of independent components. It has been effectively used to sort out and consequently exclude artifacts, for example, eye blinks and muscle activity from EEG data, making sure that the remaining analysis is concerning neural signals of interest.

During preprocessing, the EEG data was investigated using a wavelet transform, which is one of the powerful tools while investigating non-stationary signals like EEG. The wavelet transform decomposes EEG signals into many components at different frequencies, providing extensive information about the characteristics of the different brain wave patterns. Three main brain wave frequencies were targeted: alpha (8-12 Hz), beta (13-30 Hz), and theta (4-7 Hz). Alpha waves are mostly associated with calm and relaxed awareness; beta waves appear more when people are thinking actively and focused on theta waves often relate to sleepiness, creativity, deep relaxation.

2.6.9 Electroencephalographic response of chess players in decision-making processes under time pressure[24]

In the present study, electroencephalographic responses of high-level chess players were assessed in order to undertake actions associated with decision-making under time pressure. The current study explored in greater depth the brain mechanisms underlying expert performance related to the performance of more demanding cognitive tasks by focusing on how chess experts make crucial decisions when time is limited.

The study aimed to compare experts playing high-level chess with non-expert players. In this regard, participants were asked to play chess games under time pressure, thus replicating the condition of critical decision-making with pressure. In both processes, EEG data was continuously recorded to monitor the electrical activity of the brain. Specifically, alpha waves were analyzed since this band tends to be involved in many cognitive processes: attention, relaxation, and mental effort.

The main findings of this study were that chess experts, compared to novices, had an overall higher level of alpha wave activities in time-constrained decision-making tasks. Ordinarily, alpha waves are associated with the calm alert state and efficient cognitive processing. Therefore, the greater alpha activity in the expert group could be interpreted as showing experts remaining calmer and more focused—maybe part of the reason for superior decision-making ability—even under such pressurized circumstances as during a match.

These findings thus support and confirm all the previous studies conducted on the role of alpha waves in chess ability. It has been shown in earlier research that increased activities in alpha waves are not only associated with enhanced cognitive abilities but also performance in many domains of knowledge. In chess, stronger alpha activity indicates that experts, by their huge amount of knowledge and experience, are able to access it fast and apply it appropriately in making quick and accurate decisions even when there is limited time.

2.6.10 Chess Players Increase the Theta Power Spectrum When the Difficulty of the Opponent Increases[25]

The purpose of the study was to find differences in the EEG power spectrum between chess players who win and who lose against opponents of various skills, considering only Theta, alpha, and beta waves. The objective of this research is to reveal the precise mental strategies and cerebral mechanisms of chess players in the face of rising difficulty of the opponent by analyzing neuron activity related to winning and losing.

The design of the study involves recording EEG data in chess players when playing against a computer at different levels of difficulty. The participants could be divided on the basis of match outcomes into the winning and losing group. The recorded EEG during all these matches was used to calculate the power spectrum of the theta waves, alpha waves, and beta waves at different locations on the brain, including the frontal, central, and posterior locations.

In hard opponents, it has been found that the winning group indicated comparatively more theta power at the frontal, central, and posterior sites. Theta waves are associated with memory encoding of cognitive functions, mental effort, and focused attention. The increase in theta power indicates a requirement for winning players to have deeper cognitive processing and remain at a higher degree of mental alertness as opponents become more difficult. The reason being that the chances of outsourcing them and winning are likely to increase due to this heightened cognitive activity.

On facing stronger opponents, there was a decrease in alpha and beta power for the losing group. On average, alpha waves are associated with relaxed wakefulness and effective brain processing while beta waves are associated with active thinking, problem solving, and cognitive activity. This relation can be seen through the lower alpha and beta power of the players who have lost a game, which would indicate that they were more fatigued and less cognitively efficient facing stronger opponents. It may be inferred that this drop-in brain activity means struggling to retain concentration and managing cognitive demand imposed through more intense competition.

2.7 Table of Comparison

Table 2.1 Table of Past Project Comparison

Title	Author	Advantage	Disadvantage
EEG-Based Emotion Recognition	Priyadarsini Samal Mohammad Hashmi	EEG feature extraction, selection, machine learning, and deep learning algorithms utilized. Nonlinear dynamic analysis techniques applied for studying	EEG-based BCI offers high temporal resolution for emotion recognition. BCI enables direct signal transmission from neurons to external devices. BCI can detect diseases accurately, including brain tumors and seizures.

		EEG data properties. BCI system components include signal acquisition, preprocessing, translation, and feedback	
Human Brain's EEG Rhythms and Emotional States	J. P. Fuentes-García, T. Pereira, M. A. Castro, A. C. Santos, and S. Villafaina	Participants played chess in real and simulated environments for comparison. HRV and EEG were continuously recorded during the chess games. EEG data was filtered using a high-pass and low-pass filter	Familiarization with simulated environments enhances focus and performance in chess players. EEG theta power spectrum differences indicate focus levels in chess players. HRV and EEG differences observed in unfamiliarized chess players in simulated scenarios
EEG-Driven Virtual Reality	E. Schiza, M. Matsangidou, K. Neokleous, and C. S. Pattichis	Systematic review based on Bargas-Avila and Cochrane methodologies. Searched six electronic libraries for relevant publications from 2014-2019. Identified 12 articles for data collection and analysis.	VR offers real-life environments for rehabilitation exercises. VR allows control of stimulus presentation and response measurements. VR enables safe assessment on unsafe tasks and standardizes protocols.
EEG-based Brain-Computer Interface for Controlling a Robotic Arm	Y.M., N.M., and K.V. are the authors of the research paper.	PRISMA model used for systematic literature review on EEG-based BCI applications. Cochrane Collaboration guidance followed for systematic literature review preparation.	EEG offers high temporal resolution and portability. Inexpensive equipment with easy setup and direct neural activity measurement
Cloud Infrastructure for Storing and Processing EEG and ERP Experimental Data	Petr Ježek Lukáš Vařeka	Signal processing tools for training and classifying ERP signals. Three packages for data reading, features extraction, and classification.	Cloud solutions enhance data processing and visualization for researchers. Secure data transfer from local notebooks to cloud solutions is ensured

A Cloud-based Data Platform for Efficient EEG Data Management, Collaboration, and Analysis	Qi Tian Wen Wu Qin Zhu Tao Cai	Enhanced cooperation: The cloud-based platform allows several researchers to interact continuously, speeding up the progress of neuroscience studies by streamlining data administration, research cooperation, and EEG data processing.	Data Quality Control: The platform is dependent on quality checks for uploaded data, which may not always be effective in discovering mistakes or anomalies.
Time Series Analysis for EEG Sensors	Nuhanovic and Kemal Dizdarevic in 2013	EEG signal analysis involves data acquisition, preprocessing, feature extraction, and classification. Various methods like Wavelet, Autoregressive, and Fast Fourier are compared	Fast Fourier Transform (FFT) method for feature extraction efficiency. Wavelet Transform (WT) method for performance in signal processing
EEG Research Based on the Influence of Different Music Effects	Y. Xu, X. Xu, and L. Deng,	Experiment divided into music stimulation, EEG data collection, processing, and analysis. Data preprocessed using pseudo-traction and ICA algorithm, then analyzed in Matlab.	Brainwave music enhances attention and relaxation. Brainwave music improves concentration and reading state. Brainwave music positively affects alpha and beta waves
Electroencephalographic response of chess players in decision-making processes under time pressure	Santos Villafaina 1, Daniel Collado-Mateo 2, Ricardo Cano-Plasencia 3, Narcís Gusi 1, Juan Pedro Fuentes	Flexibility: The platform supports multiple EEG data formats, including as EDF, BDF, and CNT, and users can upload data wirelessly or via a hard drive.	Data Transfer Time: Transferring big EEG datasets to the cloud might take significant time, which may be a disadvantage for researchers with limited time and resources.
Chess Players Increase the Theta Power Spectrum When the	Juan Fuentes-García Santos Villafaina Daniel Collado-	Participants played chess games at different difficulty	Winning group adapted to difficulty levels, increasing theta power.

Difficulty of the Opponent Increases	Mateo Ricardo Cano-Plasencia Narcis Gusi	levels. EEG was recorded during the chess games using Enobio device	Increased alpha power in posterior regions for creative ideation. Significant differences in alpha and beta power between winning and losing groups

Summary

The table involves multiple studies in EEG research, each addressing particular aspects of EEG use and analysis. "EEG-Based Emotion Recognition" investigates high-resolution emotion recognition using EEG feature extraction and machine learning methods. The study "Human Brain's EEG Rhythms and Emotional States" looks into EEG theta power spectrum differences in chess players, implying that virtual environments can help improve performance. "EEG-Driven Virtual Reality" stresses the use of VR in rehabilitation activities and task assessments. "EEG-based Brain-Computer Interface for Controlling a Robotic Arm" emphasizes EEG's portability and cost-effectiveness for measuring cerebral activity. "Cloud Infrastructure for Storing and Processing EEG and ERP Experimental Data" discusses signal processing tools and safe data transfer via cloud-based systems. "Time Series Analysis for EEG Sensors" surveys some of the approaches in EEG signal processing, showing that some of the techniques are quite effective, while "EEG Research Based on the Influence of Different Music Effects" discusses the positive effects of brainwave music on attention and relaxation. EEG research on chess players has shown that cognitive adaptability and power spectrum alteration are functions of game difficulty. These studies, therefore, take on the peculiar task of providing, on the whole, useful insights into EEG research across domains as broad as emotion recognition to cognitive responses to complicated tasks such as chess.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Tye primary objective of this project is to trace and support a detailed past record of chess players' brain activity while playing. Such a system would be able to trace complex cognitive processes and mechanisms of tactical decisions and strategic decision making that underlie the game of chess using electroencephalography technology. The tech tries to pair patterns of brain activity with strategic games using EEG data recorded simultaneously with chess moves and game events. It allows for insight into the cognitive underpinnings of performance and strategy selection among players. Information captured by a camera, in a local file snapping chess board pattern, is matched with the brain wave of the player. In addition, real-time monitoring that allows for rapid feedback and adaptive treatments depending on the observed cognitive states during gameplay can be realized. It can then make the system dynamic regarding modification of game parameters, provide individual feedback, and help in respect to cognitive states and performance indicators of players. An adaptive feedback strategy would increase the quality of the player's experience and skill development, cognitive training, or even performance optimization related to chess.

3.2 Project Overview

This is a future ARC EEG-based chess game monitoring system for tracking, monitoring, and analyzing the different cognitive states in chess players based on electroencephalography signals. Using the system, the brain waves of the player while playing chess will be recorded, and the brain wave patterns are then matched against certain chess moves or positions stored locally for analysis. The main aims are to capture EEG signals, relate such patterns correspondingly with chess movements, and store captured data into local files with the exact time of capture input.

3.3 Methodology

The EEG-based chess game monitoring system is a union of hardware and software modules collecting and storing EEG data for future analysis. This configuration includes an EEG MINDLINK headband that records the activities of the brain and another camera capturing chess patterns in relation to what the user sees. The acquired EEG signals are received and then processed through the data acquisition system, which is executed in MATLAB software. The signal processing module filters and preprocesses EEG data within the software framework, increasing its quality. It is also responsible for the features abstracted that would become indicators of these cognitive states. Real-time monitoring modules keep track of the players while playing games and continuously measure their level of attention and emotional state. Furthermore, the system has a Graphical User Interface (GUI) for user interaction and viewing monitoring outcomes. Crucially, the system incorporates a data storage component that stores both EEG data and images of chess patterns acquired by the camera. This saved data can be studied later to acquire insights into the cognitive processes that underpin chess skill and to find links between brain activity and strategic decisions. Overall, this integrated architecture enables smooth acquisition, processing, and storage of EEG data, allowing for thorough analysis and evaluation of chess gameplay.

3.3.1 Flowchart of the project

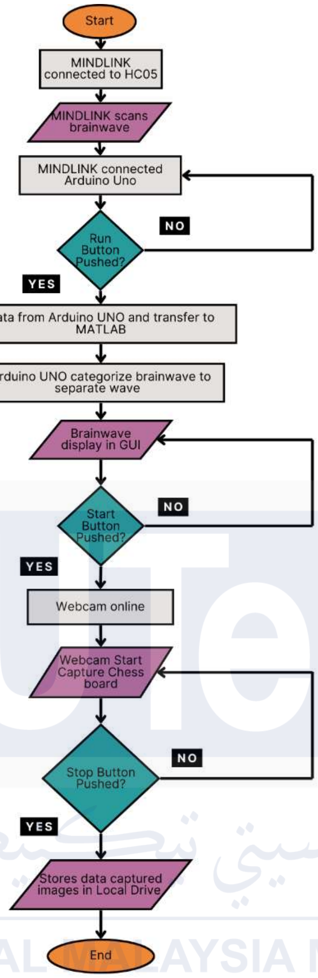

Figure 3. 1 Flowchart Process

The flow chart shows the flow of the project. This system starts with the MINDLINK connected to HC05 module. Then it scans the brainwave as an input. After that, if the run button is pushed, the MINDLINK senses the brainwave frequency, it sends the information to the Arduino Uno which is programed to read and filter the raw brainwave frequency into categorized frequency and displays it in the GUI MATLAB. If the run button does not push, the MINDLINK will stay scanned for brainwave. After that, if the start button in the GUI pushed, the webcam became online and started to capture the Chess Board. And if the stop button is pushed, the captured picture will be saved into local drive. But if it does not, it will stay capturing the Chess Board.

3.3.2 Block Diagram

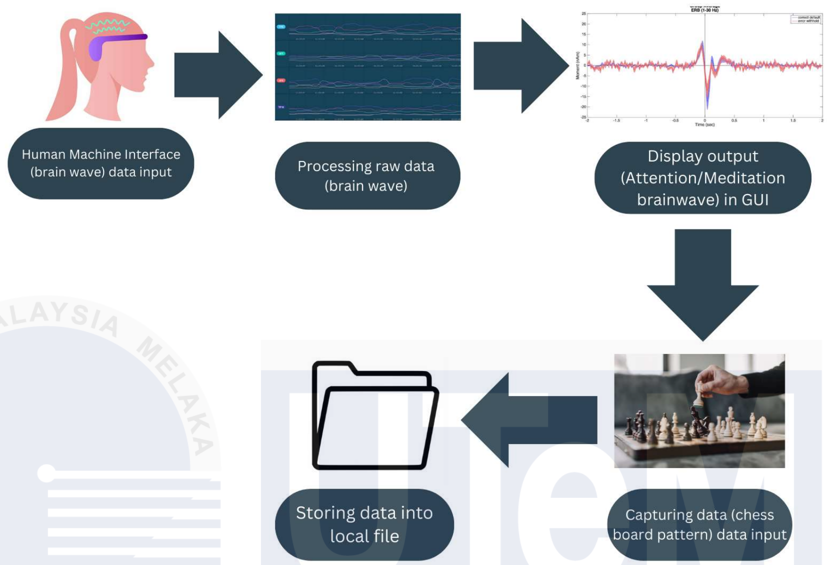

Figure 3. 2 Block Diagram

3.3.3 Project Concept

Figure 3. 3 Actual Structure Concept

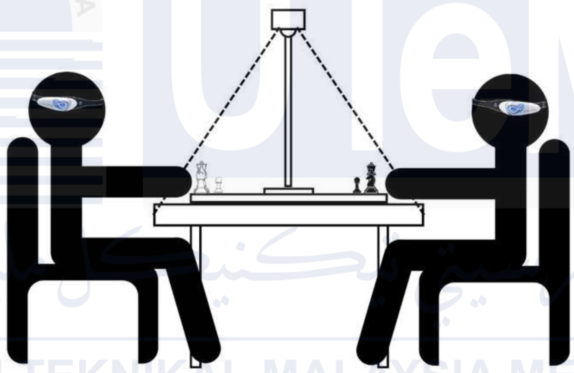

Figure 3. 4 Event Structure Concept

This figure above shows the project concept that use the component selection on top of the chess board and the brain sensor which is the MINDLINK headset are being wear by the players so that the brainwave can be read while they are playing chess. The webcam (camera) above is held around 60cm from the chess board so that it can capture the pattern of the chess board fully without disturbing the view of the players to move the chess pieces while they are playing the chess.

3.4 Experimental setup

The EEG-Based Chess Game Monitoring System is a system that combines multiple hardware and software components to process and analyze brain wave data during a chess game. These steps can help to stores data within live monitoring which involves personality of the subject such as brain wave data that can be define in many ways and can be used to analyze in the future.

3.4.1 Hardware Setup

This part is to define the hardware equipment that will be used in this project for the system to be accomplish the objective.

3.4.1.1 EEG-Based Device - MINDLINK EEG-Headband

The MINDLINK EEG headset is used to capture the brain wave activity of the chess player.

- Wireless connectivity via Bluetooth, multiple electrodes for comprehensive brain wave data capture, comfortable design for extended use.
- Ensure the headset is fully charged and properly fitted on the player's scalp according to the manufacturer's instructions. Connect the headset to the computer via Bluetooth.

Figure 3. 5 MINDLINK Headband

3.4.1.2 Arduino Uno Microcontroller

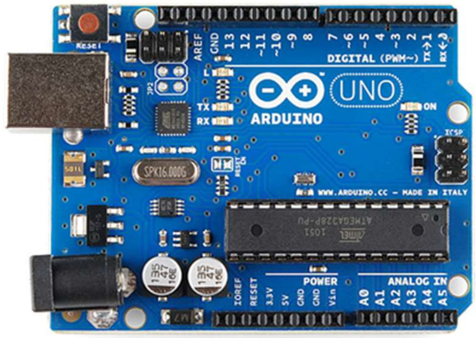

Figure 3. 6 Arduino Uno Board

The Arduino Uno is used to interface with MINDLINK EEG headset which captures data from brainwave that being detected and transmit the data to be display as an output. By choosing Arduino UNO, it is used as a microcontroller in this project as the Arduino UNO is more compatible and meets the requirement needed in this project perfectly.

3.4.1.3 Classical Chess Set

Figure 3. 7 Chess Set

The classical chess board is essential to this project because the main objective is to capture brain wave data with the pattern of the chess board. In this project, I am going to use the Blitz Game Chess type because the duration of the gameplay is maximized to 5 minutes only for each player. Hence, it is suitable for this project to capture a maximum 600 input (data) which includes the Brain wave data of players and the pattern of the chess board.

3.4.1.4 HC-05 Bluetooth Module

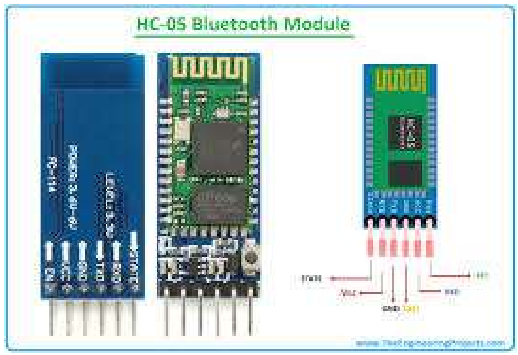

Figure 3. 8 HC-05 Bluetooth Module Layout

The HC-05 Bluetooth module is an economical microcontroller module for wireless communication between devices. Due to its consistent performance and straightforward integration, it is often to be used in a scope of Arduino projects. The HC-05 module allows for real-time monitoring the chess player brainwave activity system through wirelessly communicating data from the Arduino Uno to external devices or devices.

HC-05 Bluetooth module improves the efficiency of an Arduino-based Chess monitoring system by allowing wireless data transmission and real-time monitoring. This system is suitable for its consistent performance, adaptability and a simple connection. This module also offers precise monitoring data gain to be observed by researcher.

3.4.1.5 Camera (Poly 5 Webcam)

Figure 3. 9 Poly 5 Webcam

The Poly Studio P5 is a professional-grade webcam designed to enhance your video conferencing experience. It delivers high definition 1080p video with fine-tuned optics, ensuring clear and vibrant visuals. The webcam automatically means low-light compensation, allowing you to maintain proper exposure even in dim environments. Its built-in directional microphone focuses on your voice while minimizing background noise, providing clear audio during calls. This webcam is used to capture the chess board to be displayed in the GUI and also to capture the board pattern and saved in local drive.

3.5 Software Setup

This part is to define the software equipment that will be needed to execute this project for the system to be accomplish its objective.

3.5.1 MATLAB Software

Figure 3. 10 MATLAB Logo

MATLAB is used to access the APPDESIGNER to develop a GUI for data processing, analysis, and visualization. This software also has scripts and functions for filtering EEG data, extracting features, and matching patterns.

- Extensive library for data processing, real-time visualization, signal filtering, pattern matching, and data storage.
- Custom algorithms developed in MATLAB for signal filtering, feature extraction (such as frequency bands and amplitudes), and pattern matching.
- Implement the signal processing and pattern matching algorithms in MATLAB. Ensure real-time data processing capabilities.

3.5.2 User Interface (GUI)

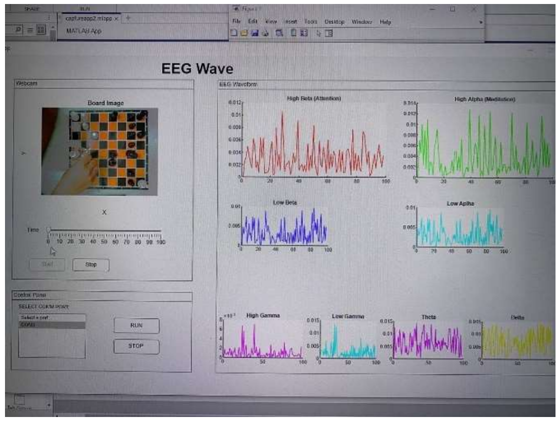

Figure 3. 11 GUI Brainwave Display

A MATLAB-based GUI for real-time data display and interaction. All of the output from this project will be displayed in GUI such as the details of the data, brain wave type and frequency. This data also will be saved in local files to be analyzed in the future.

- Real-time EEG data visualization, chess game display, data analysis tools, and reporting features.
- Develop the GUI in MATLAB, ensuring that it integrates seamlessly with the EEG headset and Arduino Uno. Include features for real-time display and comprehensive data analysis.

3.5.3 Arduino IDE

Figure 3. 12 Arduino IDE Logo

The Arduino IDE compiler is a C language programming software which is used to code and program the Arduino Uno. The codes written in this software are later compiled using the correct syntax to ensure that the proper outputs will execute correspondingly. It is used in this project to filter out the raw brainwave into separate categories.

3.6 Experimental Procedure

3.6.1 Preparation

- Set the Poly 5 Webcam above the chessboard and connect it to the computer. Ensure that the MINDLINK EEG headset is charged and synchronized. Set up the Arduino Uno as needed.
- Install and set up the MATLAB and Arduino IDE on your computer.

3.6.2 Data Collection

- The participants have to wear the MINDLINK EEG headset correctly.
- Launch the MATLAB GUI for EEG Webcam and brainwave. Start the Arduino program.
- Capture chess board pattern with webcam while the EEG headset capture the brainwave data during the game and monitor real-time data on the MATLAB GUI.

3.6.3 Data Processing and Analysis

- Signal processing involves filtering and extracting useful EEG features using MATLAB
- Pattern Matching and Correlation which use the predetermined patterns to detect correlations between EEG data and chess board patterns.

3.6.4 Analysis and Reporting

- Data Visualization which used the MATLAB to generate visual representations of EEG data and chess board pattern.
- Compile every result that describes the setup, details and result of each chess board pattern.

3.7 Summary

This chapter describes an innovative system for saving and displaying brainwave activity data, including details. The methodology aims to provide a simple, effective estimation without reducing accuracy. The methods were also intended to make advantage of the EEG's generally available but restricted data. The approach aims to achieve great accuracy while also being efficient, user-friendly, and practical for the chess board game analysis.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter covers the results and analysis on the development of an EEG-based chess monitoring system. The MINDLINK headset, connected to HS05 to the MATLAB GUI, is used to monitor players' brainwave activity and match it to the chess board. The suggested system's is to demonstrated through case studies using the EEG method. The case study is based on a player's brainwaves, which could indicate attention or emotion. The case study took place in a location where they could play chess peacefully, such as a library. It is important to put on a note that the brainwaves of chess players are measured using specified timing and chess board patterns. The results are validated using the time recorded in the MATLAB GUI.

4.2 Results and Analysis

The development of the results and analysis are based on the output of the project. There are several data that are collected from different people to show the differences of the brainwave generated in this project. The data analysis for this project is to monitor the attention and meditation value observed within 3 types of people that have beginner, moderate and professional level of experience in playing chess. The data is taken in the form of *Blitz Game* within 10 minutes for each player who received 5 minutes for their gameplay. From the data below which collected using the MATLAB APP, the professional, moderate and beginner level players have differences which can be determined by the average of the graph. It is found when the professional and moderate level use their attentive mode when in defending pattern have won their game. As for beginner level, it is more likely to lose because the player does not control their state, which is opposite than the other players.

4.2.1 Beginner Player

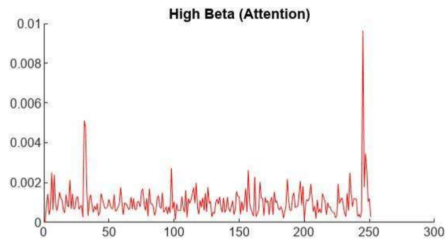

Figure 4. 2 Beginner Attention Graph

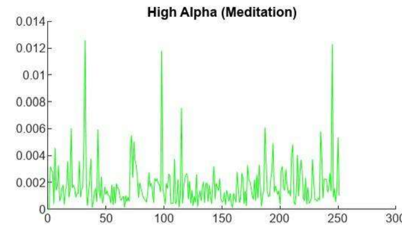

Figure 4. 1 Beginner Meditation

Figure 4. 3 Beginner Chess Pattern

The graph above shows the Attention and the Meditation values of a Professional chess player (black team) when it is in a defending pattern of the chess. The result of the black team lost. This shows that when the player was in a meditation state in a defending pattern, the player was more likely to lose.

The average of the beginner player in the graphs shows that their attention and meditation are low. The graphs also determine that beginner player does not control their attention and meditation while in the game.

4.2.2 Moderate Player

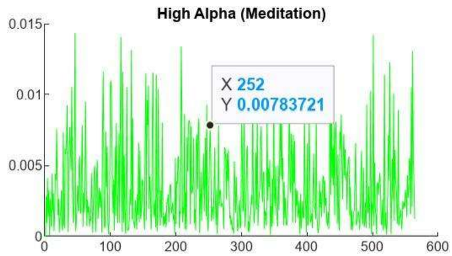

Figure 4. 5 Moderate Meditation Graph

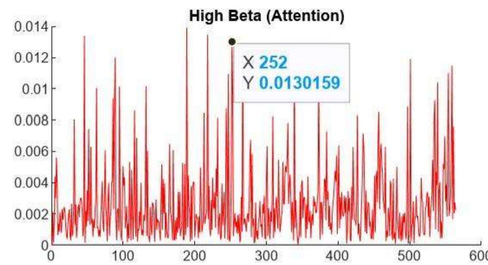

Figure 4. 6 Moderate Attention Graph

Figure 4. 4 Moderate Chess Pattern

The graph above shows the Attention and the Meditation values of a moderate chess player (white team) when it is in a defending pattern of the chess. The x-axis shows the time of the game which is 252 seconds. The result of the game is the white team wins. This shows that the player was in Attention mode while in the defending position and the player won.

The average of the moderate player in the graph shows that their attention and meditation are moderate. This determines that moderate player has the ability to control their attention and meditation state while in the game.

4.2.3 Professional Player

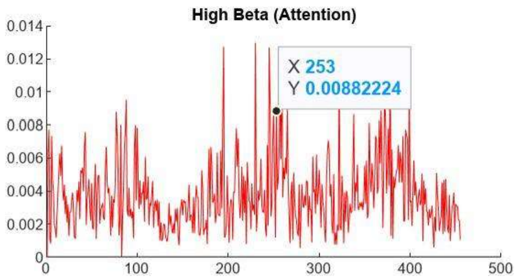

Figure 4. 9 Professional Attention Graph

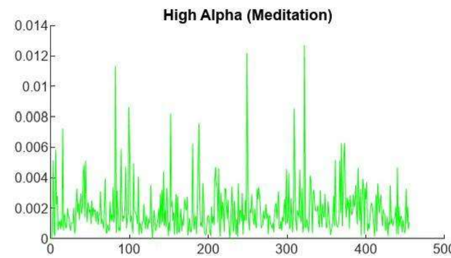

Figure 4. 8 Professional Meditation Graph

Figure 4. 7 Professional Chess Pattern

The graph above shows the Attention and the Meditation values of a Professional chess player (white team) when it is in a defending pattern of the chess. The x-axis shows the time of the game which is 253 seconds. The result of the game was the white team winning. This result shows that when the player is in Attention mode while in defending position, the player won the game.

The average of the professional player in the graph shows that their attention and meditation are high. This determines that professional player has the ability to control their attention and meditation state while in the game and knows how to use their state in the game.

4.3 Result and Analysis MATLAB GUI

The MATLAB program successfully demonstrated its ability to monitor and visualize attention and meditation levels in real time through an intuitive graphical interface. The displayed values were updated dynamically and formatted clearly, making them easy to read and understand. Also, the program handled live and efficiently, processing incoming information and updating the interfere smoothly and this made it a suitable tool for applications such as biofeedback training experiments, observation and the data saved can be diagnos or analyze after the observation.

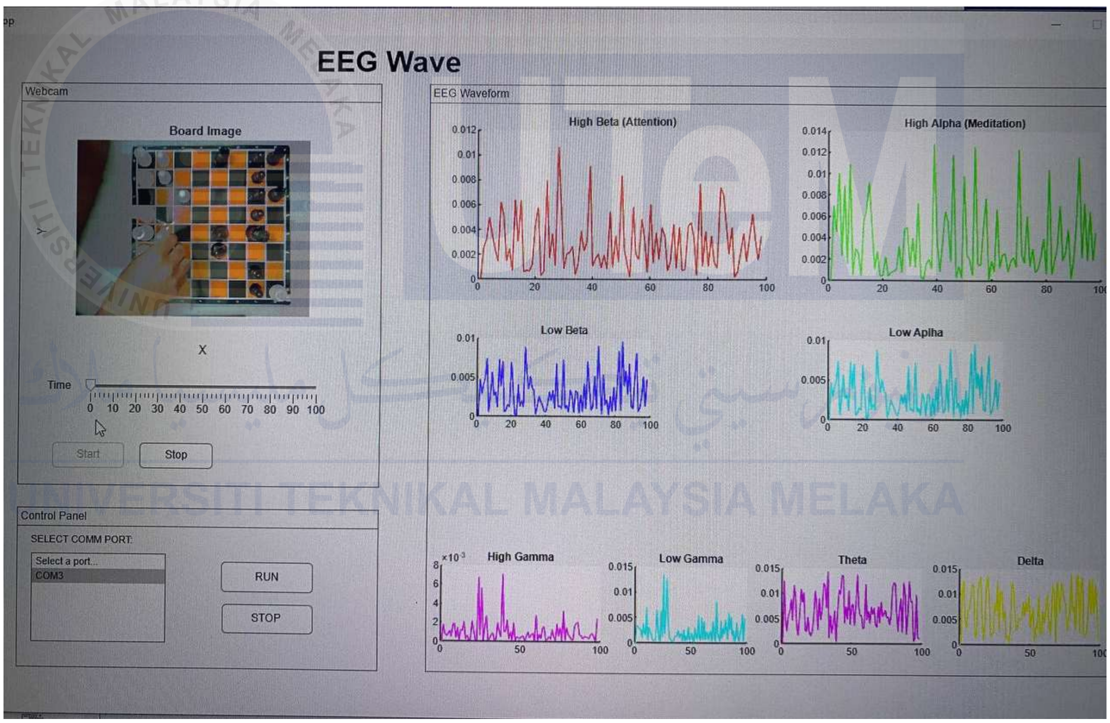

Figure 4. 10 GUI MATLAB Display

4.4 Summary

The MATLAB app successfully demonstrates the potential of the EEG-Based Chess Monitoring System to capture and analyze brain activity that integrates with cognitive process while playing chess. The observations that have been gained underscore the application of EEG between the different phase of chess board patterns. With interpreting EEG data in this project, we can observe the brain dynamics works during decision-making in play Chess. Furthermore, this study explores more refinements which is important for optimizing the system's accuracy and use in real-time configurations.

Through a APPDESIGNER, the MATLAB program effectively illustrated its capacity to track and visualize the levels of attention and meditation in real time. The displayed values were easy to read and comprehend because they were formatted clearly and updated constantly. The program processed incoming data, updated the interface smoothly, and managed real-time data effectively. This makes it a good instrument for uses that include cognitive evaluation, biofeedback training, or experiments that need real-time results. The levels of attention and meditation were reliably and consistently shown on a tally stop during the test.

By handling situations from the GUI, strong error handling also improved the program's consistency and showed how well the formatting functions that were used by the program functioned. Until the data could be missing or invalid, the continuous loop produced sure the interface was always flexible and functioning smoothly which is essential for real-world applications.

Although the program does a good job of displaying numerical values, it would be much easier to monitor trends and changes over time if it included graphical plots. A feature that allows data to be logged and saved for later analysis which would be another helpful addition.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this thesis shows a method that monitors and captures brainwave activity or EEG based on chess games in real-time with the objective of enhancing understanding and optimizing brain functions during gameplay. The recommended method which uses the EEG technology to gain real-time brainwave activity patterns, providing information into the cognitive states relates with strategic thinking and decision-making in chess. By integrating with EEG technology based and advanced data analysis, the system ensures to gain data is accurately with exact data details which are in real-time configuration. The output for this project also can be analyzed later on as the results are stored in local data with complete detailed and categorized.

Overall, a thorough analysis and synthesis of existing literature lays the groundwork for the feasibility and benefits of EEG-based chess monitoring. The project successfully not only fills existing gaps in our understanding of cognitive dynamics but also paves the way for future study and development in cognitive science and sports technology.

5.2 Future Works

This project has successfully achieved and meets the requirement of the objective and satisfied all the targets. However, there are some limitations that can be overcome, improved or upgraded in the future. For future improvements, the accuracy of EEG-Based Chess Monitor System could be enhanced as follows:

i) To do more research and applicants of the use of AI methods for instance learning method or deep learning to automate data processing, tailored training tactics to individual cognitive profiles, and improve real-time feedback capabilities.
ii) Other further research using the advantage of EEG data, during the gameplay, the real-time analysis can be used as improvement or strategical method to

overcome obstacles where the suggestion or advice can be made through third person such as coaches or an AI system (artificial intelligence).

iii) The GUI itself can display selected time as the user like when the captured webcam is finished. This can improve the efficiency of accessing the local storage without opening an external window which can save more time.

5.3 Project Potential

An EEG-based chess monitoring system that analyzes data post-game has significant potential in various domains. It can provide insights into cognitive and emotional states during gameplay, such as stress, focus, and mental fatigue, helping players understand their decision-making under pressure. By identifying moments of cognitive strain, it can offer tailored feedback and strategies for improving performance. Coaches can use this data to refine training programs, while researchers can explore the neuroscience of decision-making and strategic thinking. The system also has applications in competitive and casual chess, offering players new ways to enhance their skills and even engaging spectators with deeper game analysis. Furthermore, it could promote mindfulness, stress management, and cognitive health. However, challenges such as accurate data interpretation, ethical considerations, and hardware accessibility need to be addressed. Overall, the system has strong potential in chess training, neuroscience, AI development, and mental wellness, with broad appeal to players, researchers, and educators.

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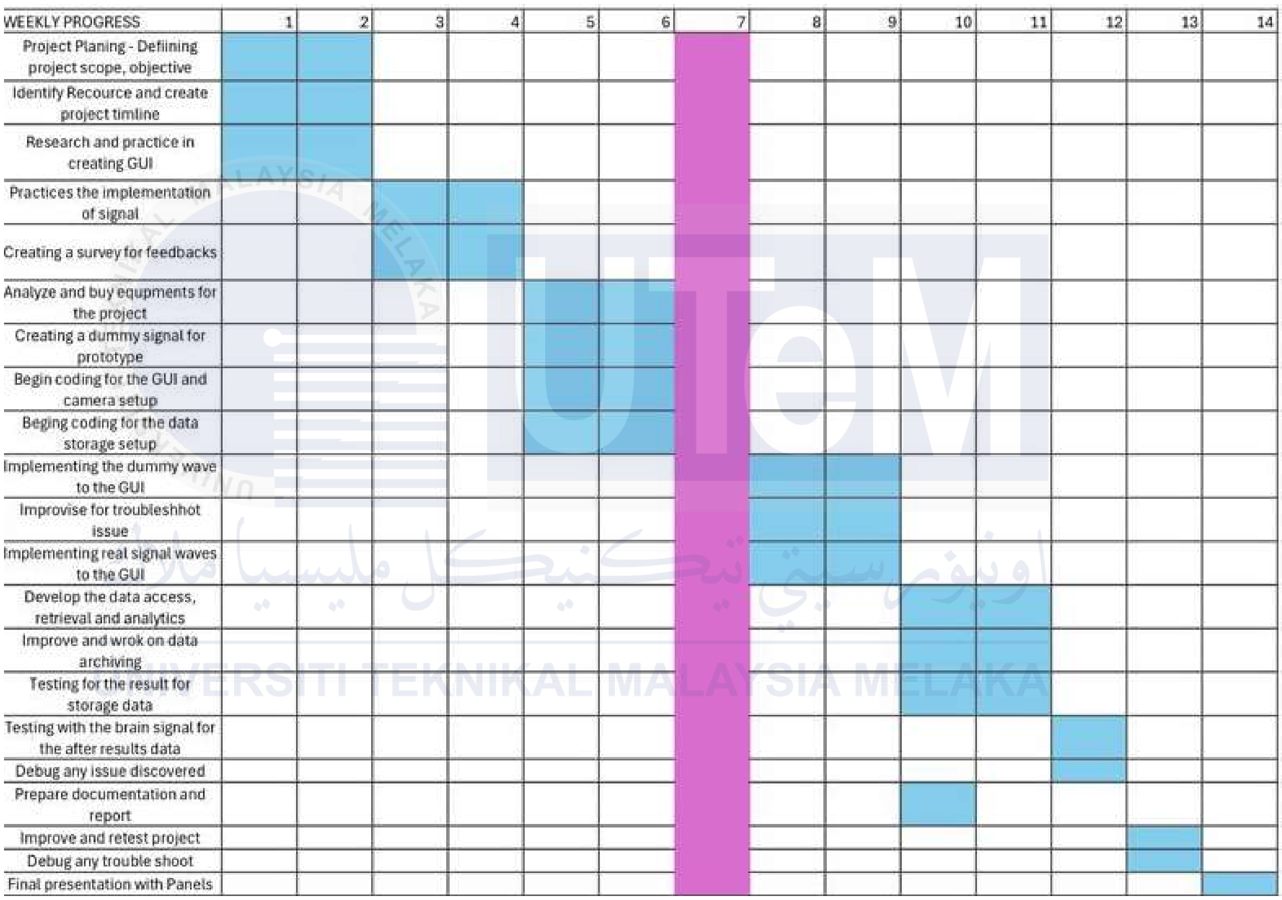
APPENDICES

Appendix A GANTT CHART PSM 2



PSM 1 GANTT CHART

Appendix B COSTING

Product	Quantity	Price (RM)
Arduino Uno	1	39.90
HC05 Bluetooth Sensor	1	9.90
MINDLINK EEG SENSOR	1	341.40
Wire	4	4.80
Chess Board (34cm x 34cm)	1	28.00
Webcam (A4Tech PK-910H)	1	66.00
Mounting camera	1	35.00
Total		**RM 525.00**

Appendix C Arduino IDE Code

```
int BAUDRATE = 57600;


// checksum variables
byte payloadChecksum = 0;
byte CalculatedChecksum;
byte checksum = 0;              //data type byte stores an 8-bit
int payloadLength = 0;
byte payloadData[64] = {0};
byte poorQuality = 0;
byte attention = 0;
byte meditation = 0;
byte quality_C = 0; //ni tambah Sept 2021
byte kira_attention = 0; //kira berapa kali attention
byte blinks = 0; //kira berapa kali blinks

// system variables
long lastReceivedPacket = 0;
boolean bigPacket = false;
boolean brainwave = false;
void setup() {


  Serial.begin(57600);       // Bluetooth
  delay(500);
```

```
}
byte ReadOneByte() {
  int ByteRead;
  // Wait until there is data
  while(!Serial.available());
  //Get the number of bytes (characters) available for reading
  //This is data that's already arrived and stored in the seria
  ByteRead = Serial.read();

  return ByteRead; // read incoming serial data
  }

unsigned int delta_wave = 0;
unsigned int theta_wave = 0;
unsigned int low_alpha_wave = 0;
unsigned int high_alpha_wave = 0;
unsigned int low_beta_wave = 0;
unsigned int high_beta_wave = 0;
unsigned int low_gamma_wave = 0;
unsigned int mid_gamma_wave = 0;

void read_waves(int i) {
  delta_wave = read_3byte_int(i);
  i+=3;
  theta_wave = read_3byte_int(i);
  i+=3;
  low_alpha_wave = read_3byte_int(i);
  i+=3;
```



```
  high_alpha_wave = read_3byte_int(i);
  i+=3;
  low_beta_wave = read_3byte_int(i);
  i+=3;
  high_beta_wave = read_3byte_int(i);
  i+=3;
  low_gamma_wave = read_3byte_int(i);
  i+=3;
  mid_gamma_wave = read_3byte_int(i);
}

int read_3byte_int(int i) {
  return ((payloadData[i] << 16) + (payloadData[i+1] << 8) + payloadData[i+2]);
}

void loop() {
  // Look for sync bytes
  // Byte order: 0xAA, 0xAA, payloadLength, payloadData,
  // Checksum (sum all the bytes of payload, take lowest 8 bits, then bit invers
if(ReadOneByte() == 0xAA) {
if(ReadOneByte() == 0xAA) {
payloadLength = ReadOneByte();
if(payloadLength > 169) //Payload length can not be greater than 169
return;
payloadChecksum = 0;
      for(int i = 0; i < payloadLength; i++) {      //loop until payload length
        payloadData[i] = ReadOneByte();             //Read payload
        payloadChecksum += payloadData[i];
```

```
        }
        checksum = ReadOneByte();
        payloadChecksum = 255 - payloadChecksum;
        if(checksum == payloadChecksum) {
          poorQuality = 200;
          attention = 0;
          meditation = 0;
  }
      brainwave = false;
      for(int i = 0; i < payloadLength; i++) { //
            switch (payloadData[i]) {
            case 02:
              i++;
              poorQuality = payloadData[i];
              bigPacket = true;
              break;
            case 04:
              i++;
              attention = payloadData[i];
              break;
            case 05:
              i++;
              meditation = payloadData[i];
              break;
            case 0x80:
              i = i + 3;
              break;
            case 0x83:                       //
              i++;
              brainwave = true;
              byte vlen = payloadData[i];
             // Serial.print(vlen, DEC);
            ///  Serial.println();
              read_waves(i+1);
              i += vlen; // i = i + vlen
              break;
            }                                   // switch
          }                                     // for loop

          if(bigPacket) {
            if(poorQuality == 0){
            }
            else{                               // do nothing
             }
           }

          quality_C = (100-(poorQuality/2)); //kalau kurang dari 100

              if(brainwave && attention > 0 && attention < 100) {

          Serial.print("R");
              Serial.print(attention, DEC);
          Serial.print(",");
              Serial.print(meditation, DEC);
          Serial.print(",");
              Serial.print(mid_gamma_wave, DEC);
```

```
Serial.print(",");
        Serial.print(low_gamma_wave, DEC);
Serial.print(",");
        Serial.print(high_beta_wave, DEC);
Serial.print(",");
        Serial.print(low_beta_wave, DEC);
Serial.print(",");
        Serial.print(high_alpha_wave, DEC);
Serial.print(",");
        Serial.print(low_beta_wave, DEC);
Serial.print(",");
        Serial.print(delta_wave, DEC);
Serial.print(",");
        Serial.print(theta_wave, DEC);
Serial.println(",");
delay(100);
```

Appendix D MATLAB APPDESIGNER CODE

MATLAB App

```
classdef captureapp2 < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure          matlab.ui.Figure
        WebcamPanel       matlab.ui.container.Panel
        StopButton        matlab.ui.control.Button
        StartButton       matlab.ui.control.Button
        TimeSlider        matlab.ui.control.Slider
        TimeSliderLabel   matlab.ui.control.Label
        UIAxes            matlab.ui.control.UIAxes
        uipanel2          matlab.ui.container.Panel
        axes8             matlab.ui.control.UIAxes
        axes7             matlab.ui.control.UIAxes
        axes6             matlab.ui.control.UIAxes
        axes5             matlab.ui.control.UIAxes
        axes4             matlab.ui.control.UIAxes
        axes3             matlab.ui.control.UIAxes
        axes2             matlab.ui.control.UIAxes
        axes1             matlab.ui.control.UIAxes
        uibuttongroup1    matlab.ui.container.ButtonGroup
        text3             matlab.ui.control.Label
        stop_button       matlab.ui.control.Button
        run_button        matlab.ui.control.Button
        portList          matlab.ui.control.ListBox
        text7             matlab.ui.control.Label
    end


    properties (Access = private)
        cam         % Webcam object
        snapTimer   % Timer for snapping images
        snapCount   % Number of snaps taken
        maxSnaps    % Maximum number of snaps (300 for 5 minutes)
    end


    % Callbacks that handle component events
    methods (Access = private)

        % Code that executes after component creation
        function startupFcn(app)

```

```
    [hObject, eventdata, handles] = convertToGUIDECallbackArguments(app);

    % Create a webcam object
    app.cam = webcam;

    % Initialize snap count and maximum snaps
    app.snapCount = 0;
    app.maxSnaps = 600; % 10 minutes * 60 seconds = 300 snaps extra 700 takut delay

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    serialPorts = instrhwinfo('serial');
    nPorts = length(serialPorts.SerialPorts);
    h = findobj(app.portList,'Type','uilistbox');
    app.portList.Items = [{'Select a port...'}, serialPorts.SerialPorts ]; % [{'aaa'},{'bbb'}];
    app.portList.Value = [{'Select a port...'}];
    %set(h, 'String', [{'Select a port'} ; serialPorts.SerialPorts ]);
    %set(h, 'Value', 2);
    % set(handles.history_box, 'String', cell(1));
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

    % Choose default command line output for GUI_EEG_show_wave
    handles.output = hObject;

    % Update handles structure
    guidata(hObject, handles);

end

% Function to snap a picture
function snapPicture(app)
    app.snapCount = app.snapCount + 1; % Increment snap count
    img = snapshot(app.cam);           % Capture image
    imshow(img, 'Parent', app.UIAxes); % Display in UIAxes

    % Save the image
    filename = sprintf('Snapshot_%03d.png', app.snapCount);
    destination = fullfile('Save Image', filename);
    imwrite(img, destination);

    % Stop timer if maximum snaps reached
    if app.snapCount >= app.maxSnaps
```

```
            % Stop timer if maximum snaps reached
            if app.snapCount >= app.maxSnaps
                stop(app.snapTimer);
                delete(app.snapTimer);
                app.snapTimer = [];
                uialert(app.UIFigure, 'Snapping complete!', 'Info');
            end
        end

        % Button pushed function: StartButton
        function StartButtonPushed(app, event)
            app.snapCount = 0; % Reset snap count
            app.snapTimer = timer('ExecutionMode', 'fixedRate', ...
                                  'Period', 1, ...
                                  'TasksToExecute', app.maxSnaps, ...
                                  'TimerFcn', @(~, ~) snapPicture(app));
            start(app.snapTimer); % Start timer
            h= findobj(app.StopButton,'Type','uibutton'); set(h,'Enable','on');
            h= findobj(app.StartButton,'Type','uibutton'); set(h,'Enable','off');
        end

        % Button pushed function: StopButton
        function StopButtonPushed(app, event)
            if ~isempty(app.snapTimer) && isvalid(app.snapTimer)
                stop(app.snapTimer);
                delete(app.snapTimer);
                app.snapTimer = [];
            end
            h= findobj(app.StopButton,'Type','uibutton'); set(h,'Enable','off');
            h= findobj(app.StartButton,'Type','uibutton'); set(h,'Enable','on');
            %uialert(app.UIFigure, 'Snapping process stopped!', 'Info');
        end

        % Close request function: UIFigure
        function UIFigureCloseRequest(app, event)
            if ~isempty(app.snapTimer) && isvalid(app.snapTimer)
                stop(app.snapTimer);
                delete(app.snapTimer);
            end
            clear app.cam; % Release webcam
            delete(app);    % Delete app
```

```
        end

        % Callback function
        function SaveButtonPushed(app, event)
            % img = snapshot(app.cam);
            %
            % filename = sprintf('Image_%s.png', datestr(now,'yyyy-mm-dd hh-MM-ss'));
            % disp(filename);
            % destination = fullfile('Save Image', filename);
            % imwrite(img, destination);
        end

        % Button pushed function: run_button
        function run_buttonButtonPushed(app, event)
            [hObject, eventdata, handles] = convertToGUIDECallbackArguments(app, event);
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            if ~isempty(instrfind)
                   fclose(instrfind);
                   delete(instrfind);
            end
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            % hObject    handle to simulate_button (see GCBO)
            % eventdata  reserved - to be defined in a future version of MATLAB
            % handles    structure with handles and user data (see GUIDATA)
            global k;
            k=0;%edit di sini
            global SS; %serial port number
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            %    VARIABLE UNTUK PLOT GRAF
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            w = 0;
            q=0;
            z1 = 0;
            z2 = 0;
            z3 = 0;
            z4 = 0;
            z5 = 0;
            z6 = 0;
            z7 = 0;
            z8 = 0;
            z9 = 0;
```

```
z7 = 0;
z8 = 0;
z9 = 0;
z10 = 0;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Baud_Rate = 57600;
Data_Bits = 16; %macam tak guna %asal 8
Stop_Bits = 1; %macam tak guna

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%    TAMBAH SERIAL LIST
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

app.portList.ItemsData = 1:length(app.portList.Items);
serPortn = app.portList.Value;
% disp(serPortn);
if serPortn == 1
    uialert(app.UIFigure, 'Select valid COM port!', 'Info');
    return;
else
    serList = app.portList.Items;
    serPort = serList{serPortn};
end

% set(handles.text3,'String',serPort);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

arduino = serial(serPort);
set(arduino,'BaudRate',57600);
fopen(arduino);

x=linspace(1,500); % double check untuk apa

array1 = zeros(100,1);
array2 = zeros(100,1);
array3 = zeros(100,1);
array4 = zeros(100,1);%edit di sini
array5 = zeros(100,1);
array6 = zeros(100,1);
array7 = zeros(100,1);
array8 = zeros(100,1);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%    SETTING STOP
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Get default command line output from handles structure
varargout{1} = handles.output;
handles.stop_now = 0; %Create stop_now in the handles structure
guidata(hObject,handles);  %Update the GUI data
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
global A;


while ~(handles.stop_now)
%     yourfunction()

k=k+1;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%    SETTING STOP DALAM LOOP
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
drawnow %Give the button callback a chance to interrupt the
handles = guidata(hObject);  %Get the newest GUI data
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


data = fscanf(arduino);

panjang = length(data);

            kirakoma = count(data, ',');
%             disp(kirakoma);

            if kirakoma == 10
            RR = strfind(data,'R');
            commas = strfind(data,',');
            save d.mat data
%             disp(data);
%              if ZZ == "R"

            ZZ = str2num(data(RR:commas(1)));
            ZZ = data(1);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%    IF DATA START DARI AWAL ATAU TIDAK
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%    IF DATA START DARI AWAL ATAU TIDAK
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            if ZZ == "R"
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            % NI TESTING JE ASALNYA BOLEH DELETE

            Z1 = str2num(data((RR+1):commas(1)));
            Z2 = str2num(data(commas(1):commas(2)));
            Z3 = str2num(data(commas(2):commas(3)));
            Z4 = str2num(data(commas(3):commas(4)));
            Z5 = str2num(data(commas(4):commas(5)));
            Z6 = str2num(data(commas(5):commas(6)));
            Z7 = str2num(data(commas(6):commas(7)));

            Z8 = str2num(data(commas(7):commas(8)));
            Z9 = str2num(data(commas(8):commas(9)));
%             Z10 = str2num(data(commas(9):end));
save zz.mat Z1 Z2 Z3 Z4 Z5 Z6 Z7 Z8 Z9 data
            Z10 = str2num(data(commas(9):commas(10)));

            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            array1(k) = str2num(data(RR+1:commas(1))); %DATA 1ST DARI ARDUINO.... BERTERUSAN
            array2(k) = str2num(data(commas(1):commas(2)));
            array3(k) = str2num(data(commas(2):commas(3)));
            array4(k) = str2num(data(commas(3):commas(4)));
            array5(k) = str2num(data(commas(4):commas(5)));
            array6(k) = str2num(data(commas(5):commas(6)));
            array7(k) = str2num(data(commas(6):commas(7)));

            array8(k) = str2num(data(commas(7):commas(8)));
            array9(k) = str2num(data(commas(8):commas(9)));
%             array10(k) = str2num(data(commas(9):end));
save aa.mat array1 array2 array3 array4 array5 array6 array7 array8 array9 data
            array10(k) = str2num(data(commas(9):commas(10)));


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Darab Equation untuk Plot Graf
    Z3=Z3*(1.8/4096)/2000;
    Z4=Z4*(1.8/4096)/2000;
    Z5=Z5*(1.8/4096)/2000;
    Z6=Z6*(1.8/4096)/2000;
```

```
        Z6=Z6*(1.8/4096)/2000;
        Z7=Z7*(1.8/4096)/2000;
        Z8=Z8*(1.8/4096)/2000;
        Z9=Z9*(1.8/4096)/2000;
        Z10=Z10*(1.8/4096)/2000;

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        z3=[z3,Z3];
        z4=[z4,Z4];
        z5=[z5,Z5];
        z6=[z6,Z6];
        z7=[z7,Z7];
        z8=[z8,Z8];
        z9=[z9,Z9];
        z10=[z10,Z10];

        %plot signal high gamma
        plot(app.axes1, z3,'color', 'm') ; %plot(z3, 'Parent',ax1)
        axes(app.axes1);
        xlabel('High Gamma', 'FontSize', 8);
        pause (0.01);

        plot(app.axes2, z4,'color', 'c') ; %plot(z4, 'Parent', handles.axes2, 'color', 'r')
        axes(app.axes2);
        xlabel('Low Gamma', 'FontSize', 8);
        pause (0.01);

        plot(app.axes3, z5, 'color', 'r') ; %plot(z5, 'Parent', handles.axes3,'color', 'b')
        axes(app.axes3);
        xlabel('High Beta', 'FontSize', 8);
        pause (0.01);

        plot(app.axes4, z6,'color', 'b') ; %plot(z6, 'Parent', handles.axes4,'color', 'm')
        axes(app.axes4);
        xlabel('Low Beta', 'FontSize', 8);
        pause (0.01);

        plot(app.axes5, z7, 'color', 'g') ; %plot(z7, 'Parent', handles.axes5,'color', 'b')
        axes(app.axes5);
        xlabel('High Alpha', 'FontSize', 8);
        pause (0.01);
```

```
    plot(app.axes8, z10,'color', 'm') ; %plot(z10, 'Parent', handles.axes8,'color', 'r')
    axes(app.axes8);
    xlabel('Theta', 'FontSize', 8);
    pause (0.01);


    assignin('base','bb',data); % masukkan variable ke dalam workspace


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   ARRAY TO SUB BAND EEG
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
global Overall_Real;

highgammaR(k) = array3(k)*(1.8/4096)/2000;
lowgammaR(k) = array4(k)*(1.8/4096)/2000;
highbetaR(k) = array5(k)*(1.8/4096)/2000;
lowbetaR(k) = array6(k)*(1.8/4096)/2000;
highalphaR(k) = array7(k)*(1.8/4096)/2000;
lowalphaR(k) = array8(k)*(1.8/4096)/2000;
deltaR(k) = array9(k)*(1.8/4096)/2000;
thetaR(k) = array10(k)*(1.8/4096)/2000;

save subband.mat highgammaR lowgammaR highbetaR lowbetaR highalphaR lowalphaR deltaR theta




%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            else
%                 fprintf('Data start tak betul');
                set(handles.text2,'String', "Irregular Input Signal");
            end
            end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%    END UNTUK DATA START DARI R
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
            end
        end

        % Button pushed function: stop_button
        function stop_buttonButtonPushed(app, event)
            [hObject, eventdata, handles] = convertToGUIDECallbackArguments(app, event);
            handles.stop_now = 1;
            guidata(hObject, handles);
        end
    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app) ...
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = captureapp2 ...

        % Code that executes before app deletion
        function delete(app) ...
    end
end
```