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REPORT 2 (FYP 2)

ANALYSIS AND DEVELOPMENT OF A CONTROL STRATEGY FOR ROBOTIC WHEELCHAIR CONTROLLED USING SINGLE CHANNEL EEG HEADSET

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(Control, Instrumentation & Automation)

June 2015

"I hereby declare that I have read through this report entitle "*Analysis And Development Of A Control Strategy For Robotic Wheelchair Controlled Using Single Channel EEG Headset*" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Electrical Engineering (Control, Instrumentation & Automation)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle "*Analysis And Development Of A Control Strategy For Robotic Wheelchair Controlled Using Single Channel Eeg Headset*" is the outcome of my own study except as cited in references. The report has not been accepted for any degree is not concurrently submitted in application of ano ther degree.

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Date : 24/6/2015 ……………………………………

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ABSTRACT

Nowadays, with modern days of new generation many improvement and new innovative of machine, system and devices have been made. These developments also take account of in refining in quality life of people especially in medical. Biomedical signal lately have been a hot topic for researchers, as many journals and books related to it have been publish. In this paper, the control strategy to help damaged motor patient using BCI on basis of EEG signal was used. BCI is a technology that obtain user thought to control a machine or device. This technology has regained ability for quadriplegic or in other words a person that lost capability of his four limbs to move by himself again. Within the past years, many researchers have come out with a new method and investigation to develop a machine that can fulfill the objective for quadriplegic patient to move again. Besides that, due to the development of bio-medical and healthcare application, there are several ways that can be used to extract signal from brain. One of them is by using Electroencephalography (EEG). This research is carried out in order to detect the brain signal to controlling the movement of the wheelchair. A group of 5 healthy people will be chosen in order to determine performances of the machine during dynamic focusing activity are to focus on a stimulus. From the result that been collected during experiment, neural network configurations will be implemented to classify the signal. Data collected will be extracted and will be used to set a threshold for the machine to active. As a conclusion, a good neural network configuration and a decent method of extracting EEG signal will lead to give a command to control robotic wheelchair.

ABSTRAK

Generasi moden hari ini telah melakukan pelbagai inovasi dan penambahbaikan terhadap mesin, sistem dan peralatan. Transformasi ini termasuklah penambahbaikan kepada kualiti dalam pelbagai bidang terutamanya bidang perubatan. Isyarat bio-perubatan muktahir ini telah menjadi topik hangat dalam kalangan penyelidik. Ini kerana terdapat banyak jurnal dan buku yang berkaitan dengannya telah diterbitkan. Projek yang dihasilkan ini, strategi kawalan akan membantu pesakit yang lumpuh dengan menggunakan Otak-Komputer Penghubung (BCI) berpandukan isyarat EEG yang akan dikumpul. BCI adalah teknologi yang digunapakai untuk mendapatkan signal (isyarat) daripada otak untuk mengendalikan mesin atau peranti. Teknologi ini akan mengembalikan kemampuan pesakit untuk bergerak sendiri. Dalam tahun kebelakangan ini, ramai penyelidik telah menghasilkan kaedah baru untuk membangunkan mesin yang dapat memenuhi objektif untuk pesakit lumpuh bergerak semula. Melalui pembangunan aplikasi bio-perubatan dan penjagaan kesihatan, terdapat beberapa kaedah boleh digunakan untuk mengambil isyarat dari otak. Salah satunya melalui penggunaan Electroencephalography. Kajian ini dilakukan untuk mengesan isyarat otak yang akan digunapakai bagi mengawal pergerakan kerusi roda. Sekumpulan 5 orang yang sihat dipilih untuk menentukan keupayaan mesin. Aktiviti fokus adalah aktiviti untuk memberi tumpuan kepada bahan rangsangan yang akan diberikan bertujuan untuk menghasilkan isyarat 'tumpuan' yang tinggi. Data yang dikumpul akan dikeluarkan dan digunapakai untuk menetapkan had keaktifan mesin. Sebagai kesimpulan, konfigurasi rangkaian neural yang baik dan kaedah yang cekap untuk mendapatkan isyarat EEG akan menghasilkan kawalan yang baik untuk menggerakkan kerusi roda robot.

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LIST OF ABBREVIATION

BCI	- Brain Computer Interface
ECG	- Electrocardiogram
EEG	- Electroencephalography
EMG	- Electromyography
FP	- False Positive
FFBPNN	- Feed Forward Back Propagation Neural Network
FFT	- Fast-Fourier Transform
Hz	- Hertz
LED	- Light Emitting Diode
MATLAB	- Matrix Laboratory
ms	- Millisecond
MSE	- Mean Square Error
REAT	- Rehabilitation Engineering and Assistive Technology
ROC	- Receiver Operating Characteristics
SSVEP	- Steady- State Visual Evokes Potentials
TP	- True Positive
UTeM	- Universiti Teknikal Malaysia Melaka
uV	- microvolt

LIST OF SYMBOL

α	-	Alpha
β	-	Beta
δ	-	Delta
γ	-	Gamma
θ	-	Theta

CHAPTER 1

INTRODUCTION

This section gives data in regards to basis of the study, issue explanations, and goals of the study. This part additionally clarifies the extent of the study. The arrangement of how the study will be led likewise introduced in this section.

1.1 Research Background

Currently, the use of bio-signals such as EMG , EEG and ECG to help the life of elderly people and disable are rising. People who are severely immobilized, quadriplegics in particular, may not be capable to easily control an electric wheelchair and are thus confined to a push-chair, depend on external support [1]. However, researcher has developed tools to use EEG as human command to control machines. At the same time, many ways have been develop to help this kind of patient to recover their ability to move. One of the ways to regain the ability is by using robotic wheelchair. This project introduces a robotic wheelchair controlled by using single channel EEG headset to control the movement of stop and forward and gaze tracking algorithm to control the direction of the wheelchair. It means the purpose of this project is to develop an effective robotic wheelchair using single channel EEG headset which can be used without being implanted in the user body. The significance of this research had been supported by many academic publications. One of the academic papers [2] written by Khalil Ullah and co.

1.2 Motivation

Nowadays, people suffer from quadriplegic are assumed to be ended their life alone on bed without an ability to move by theirselves again. Recently, several companies have invented equipment's that can be used to obtained brain activity that can convert desired in thought into actions in real life. EEG, ECG and EMG are some of the well-known technique to collect data from patients. All of these equipment's functions are wave and resonance based. Simple, user-friendly, effective, and accurate are the reason these equipment's is having a broad intensively used in determining and analyzing of human illness. The numbers of people with the quadriplegic difficulties are growing not only in Malaysia but all over the world. Based on that fact, the mounting demand and awareness of people suffer of quadriplegic from a health care provider are also increasing. Basically quadriplegic problem may due to several factors such as accidents, ageing and other influences. This problem believes due to injury of neck that cost all motor sensory to be impaired. In order to identify the brain signal, Neurosky Mindwave headset was used to detect the electrical signal produced by the brain and from the collected data [3]. After that, we can apply a neural network control technique to classify the person intention that has a quadriplegic to move. This research carried out in order to gain the knowledge about EEG and experience on how EEG data can be used in applications. Besides that, this research also will identify the significant activities that will help quadriplegic patient to regain moving ability by their own self and how to apply EEG signal for other purpose. Although lack of knowledge and information, by doing research, it can motivate students and other researchers to study and explore more problems related to any EEG signals.

1.3 Problem Statement

Quadriplegic are the patient that loss the control to move the human motor functions. They suffer this disorder regularly due to neck injury that leads to limb paralysis. Paraplegic is an illness that quite similar with quadriplegic but paraplegic only cost the patient to lost the movement the organs on waist and below. While, quadriplegic lost the ability to control organs starting from neck to below.

However, this patient have still have the ability of their upper organ such as hearing ears, seeing with eyes and moving their mouth. This is includes brain that can control the whole body activity. Brain activity also preserved for quadriplegic patients. Thus, detection of EEG signal is possible. By applying BCI concept this signal can be obtained by placing a correct spot of electrode on subject head. By using EEG signal that can be turned into command a quadriplegic person can make their desired action into real life just by imagine in their heads.

By taking advantages of robotic wheelchair facility, quadriplegic patient can regain their movement by their own selves with assistance of single channel EEG headset as a medium between robotic wheelchair and controller on the wheelchair. Robotic wheelchair basically consists of motor and controller, in certain cases includes sensor for safety of the user.

1.4 Objectives

The main objectives for this project are:

i) To implement neural network control technique in order to move and stop robotic wheelchair.

ii) To analyze and evaluate which is the best EEG signal pattern for moving and stopping the wheelchair.

1.5 Scope Of Work

In order to achieve the objectives of this research, there are several scopes as listed. To determine the EEG signal, there are several criteria need to be considered. Firstly, the hardware that will be used as intermediate between quadriplegic intention and robotic wheelchair is Neurosky Mindwave headset. This headset type use non-invasive BCI method to obtain EEG signal. Apart from that, this headset also a single channel EEG headset. The EEG signal will classify, validate and tested by random subject that will be selected. This project's subject selections are 5 healthy people. Selections of participant are chosen by random among student in UTeM. This is because demanding and complex procedures are needed to get participants that are quadriplegic person. Next, to identify the electrical signal yield by the brain, subject will going to complete the experiments in a controlled surroundings. This is to ensure no mental distractions, wandering thoughts, lack of focus, or anxiety that may lower the performance of the machine.

1.6 Expected Results

Based, from the objectives some of the funding listed below are supposed to be obtained at the end of the project.

1. Brain signal from Neurosky Mindwave Headset to be used for robotic wheelchair command.
2. Neural network configuration that consist of brain signal as input and moving and stopping the robotic wheelchair as output of the system.
3. A suitable method for subjects to focus in order to avoid subjects from suffering fatigue.

1.7 Report Structure

This report comprises of five sections which are Chapter 1: Introduction, Chapter 2: Literature Review, Chapter 3: Methodology, Chapter 4: Result and Chapter 5: Conclusion.

Chapter 1 is Introduction, which review about the undertaking study framework, objectives, problem statement and extent of the study. Part 2 is Literature review which is assessment the past undertaking and all material concept use in this study. Chapter 3 is about Methodology where procedure of equipment and programming utilized in this project procedure. Chapter 4 will consists of the discussion of findings of the experiment. Lastly Chapter 5, the conclusion section which is the part that concludes all the results obtained in Chapter 4 and recommendation for future research.

CHAPTER 2

LITERATURE REVIEW

This part displays the literature review of the analysis and improvement of a control strategy for robotic wheelchair controlled using single channel EEG headset.

2.1 Theory And Basic Principles

2.1.1 Introduction

This chapter concentrated on the factual and also theoretical aspects of the project. It is relating to the fundamental of controlling robotic wheelchair using Neurosky Mindwave headset. In order to obtain complete and accurate information, in-depth research should be done especially through reading articles and journals.

2.1.2 Robotic Wheelchair

Wheelchair is a four wheeled transportation used by people that unable to walk due to accidents of illness. An external support often needed for those people that severely immobilized, quadriplegics in particular, rely on help of others to move but researchers have developed tools that translate the patient desired into command to control machine. Robotic wheelchair is a wheelchair that moved by motor instead of an assist by someone or by the patient own hands. A robotic wheelchair is usually are motorized that stimulated by the patient intention. EEG signal was used to deliver the patient intended location to move. In other words, this is an effort to utilize brain signal to control motorized devices. A personal computer is attached to the back of the seat to plays the part as the intelligent controller for this system [4]. Figure 2.1 shows the previous design of wheelchair setup [5].

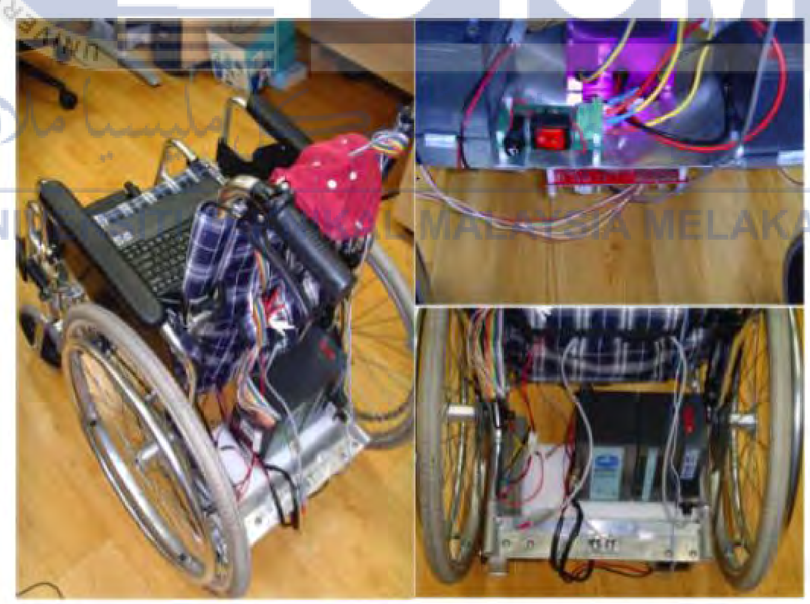

Figure 2.1: Wheelchair system setup [5].

2.1.3 Electroencephalography

Electroencephalography is an electrical signal that produces by brain activity. Affective computing studies and develops systems that can recognize, interpret, process, and even simulate human emotions [6]. From the concept of the cortical homunculus, different areas of the cerebral cortex control movements of different body parts [7]. A raw data is then extracted into few band of frequency. After that, the data filtered, processed and generates them into command to control software or hardware devices [1]. Basically, EEG signal are always produced but only a specific pattern of EEG signal will be used. These signals can be obtained by several methods. Most used method is non-invasive BCI due to its convenient and low cost of production. Appropriate positions over the scalp are selected to achieve the preferred EEG signal [2]. For this project the best spot on head to receive the preferred signal is on left forehead. Based on Laguna [8] the sensory cortex are located on left of cerebral cortex which means the best spot is on left forehead. Before signal being obtained by electrode on scalp, the surface of forehead must be clean enough to reduce noise. Forehead surface and sensors will be cleaned by using alcohol wipes. Apart from that, any make-up and sweat must be removed before experiment [9].

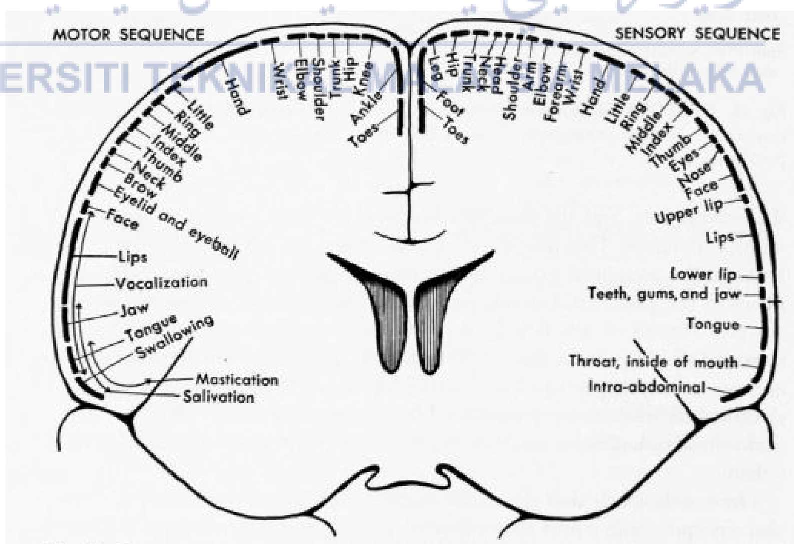

Figure 2.2: Cross section of the cerebrum through the sensory motor region with the motor and sensory sequence indicated [8].

2.1.4 Brain-Computer Interfaces

Brain-Computer Interfaces (BCI) is a system that acquires and analyzes neural (brain) signals with the goal of creating a direct high-bandwidth communication channel between the brain and the computer [10]. This system only activates if the right signals from brain are acquired in other words certain level of threshold are reached. It just likes a human-machine interface such as joystick, a mouse or keyboards. That functions by the movement of the muscle. BCI whereas used an electrical signal from brain wave activity. BCI consist of two type's i.e. multi-channel and single channel. Multi-channel is very expensive and not practical with domestic use. While, single channel EEG headset is simple, low-price and durable [2]. The pathway of a BCI , as shown in Figure 2.3, affords a direct linking in the middle of the user's brain signals and computer because the BCI produces an different channel of communication that does not include the traditional way as muscles and nerves [6]. A shared control system is important due to safety precautions as well as to reduce user tiredness, frustration and stress. An algorithm and sensor also used apart from signal extracted from brain. This shared control system will ensure the safety and reduce fatigue of user.

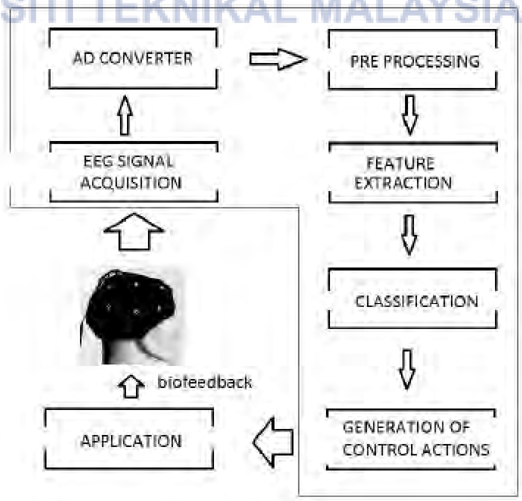

Figure 2.3: Basic structure of BCI [6]

2.2 Review of Related Study

Based from previous related works, this project has many similarities with robotic wheelchair that already been built. There are many combinations to develop a robotic wheelchair, some of the project are using head gestures as directional movement of wheelchair, instead of using iris or pupil to control the direction. All of the combinations have their own purpose, disadvantages and advantages.

Figure 2.4: A person wearing an EEG-cap and navigating the Bremen Autonomous Wheelchair Rolland [1]

Figure 2.4 shows the Bremen Autonomous Wheelchair Rolland that comprises of sensorial equipment, an LED-panel, an EEG cap and a processing laptop [1]. This project has good classification result but the usage of EEG-cap is not very practical because it will create such an uncomfortable issue for the user but on the bright side this project have comes up with two laser range finder to detect any obstacles nearby and also use SSVEP method that can support many commands [1]. Relating to this project it also uses LED panel as stimulus for user to focus their attention.

For a reliable but slow speed of BCI based wheelchair was accomplished by Rebsamen and .co [11]. In his project the machine was set in a familiar environment where the user selects the destination from television displayed and the wheelchair will move towards the intended location (see appendix A). Similar with Mandel [1] this project also use EEG cap to collect data from user brain. A few promising about this project is that it has a short response time and low cost due to usage of simple proximity sensors and bar code scanner, devices that can be obtained earn in market.

Francesco Carrino [12] project is slight differ compared to others because he have develop his own application called GERBIL. GERBIL is an application that review endlessly the sorting of output and it also in charge to make a decision based on the classification result and converting them into commands for robotic wheelchair. Unfortunately, this project electrode needs to be humidified with saline solution before can be use and this hardware project are quite pricey.

Low-cost yet dependable project by Khalil [2] have made up with self-made electrode reduce the overall project cost. This project use single channel EEG as well to command robotic wheelchair. Compared to others this project have comes up with cheap, simple plus reduced time in signal processing but the only problem is that the self-made electrode issue have made his project not very convincing.

Lastly, Fatma Ben Taher and Co. [13] project are quite incredible because this project have offered a four types of control wheelchair modes. The modes are expressive mode, cognitive mode, expressive/cognitive and head movement modes. All modes have its own benefits such as head gestures modes that movement of head control the direction of robotic wheelchair. The only problem is that EMOTIC EPOC neuroheadset price is expensive.

2.3 Summary and Discussion of the Review

Table 2.1: Review of related works

No.	Title	Author	Advantages	Disadvantages
1.	A Brain Controlled Wheelchair to Navigate in Familiar Environments [11]	Brice Rebsamen and Co.	• Short time response. • Low cost due to usage of simple proximity sensors and bar code scanner. • Use P300 method (multi-channel)	• Only can be applied on familiar surroundings. • Requirement to use television for location display might affect the power to move the wheelchair. • Usage of EEG-cap that not very comfortable for user.
2.	A self-paced BCI system to control an electric wheelchair : evaluation of a commercial, low-cost EEG device [12]	Francesco Carrino and Co.	• Combine EEG signal and several types of sensors. • Used developed own application to process the signals • Wireless .	• Need to humidify using saline solution. • High cost due to expensive tools and complex system.

3.	Navigating a Smart Wheelchair with a Brain-Computer Interface Interpreting SSVEP [1]	Christian Mandel and Co.	• Equipped with two laser range finders. • Use LED panel as stimulus. • Use potential changes in brain as input.(SSVEP method)	• Usage of EEG-cap that not very comfortable for user. • Use wheelchair platform Rolland a wheelchair that highly cost due to its system that comprise completed robotic wheelchair.
4.	Low-Cost Single-Channel EEG Based Communication System for People with Lock-in Syndrome[2]	Khalil Ullah and Co.	• Cheap • Simple • Reduced time in signal processing to prevent mental fatigued of user.	• Use single channel, hence data collected are quite insignificant • Self-made electrode and EEG amplifier that the performance might not reliable
5.	EEG control of an electric wheelchair for disabled Persons [13]	Fatma Ben Taher and Co.	• Use head-gesture and eye tracking to control wheelchair movement. • Control wheelchair with 4 different	• High cost due to EMOTIV EPOC neuroheadset price.

			modes.	
6.	Head movements based control of an intelligent wheelchair in an indoor environment. [14]	Ericka Janet Rechy-Ramirez and Co.	• Consist of two modes for control i.e. one head movements and four head movements. • Do not require any illumination of lightning to operate.	• There are no obstacles avoidance sensors. • High cost due to EMOTIV EPOC neuroheadset price.
7.	Evaluating the Performance of a Face Movement based Wheelchair Control Interface in an Indoor Environment. [15]	Lai Weit and Co.	• Jaw and face movement combined to move wheelchair. • Wheelchair has a complete system including obstacles sensor, visual sensor and motor control unit.	• Controlled indoor environments. • Ample light intensity is needed on order for the eye movement tracking to function.

Based from Table 2.1 it shows that numerous of way to develop robotic wheelchair to help people with limb disabilities have been done. There are multi-channel and single channel methods to extract data from brain. Each method has its own positive side either in terms of cost, efficiency or reliability. For this project, it will be focus on single channel method and non-invasive BCI technique to create a solution for a low cost product.

CHAPTER 3

RESEARCH METHODOLOGY

This part determines the amount of work that needs to be done to fulfill the study goals. The global illustration of data processing progression for this study activity is indicated in Figure 3.1, which partitioned into a few stages and discloses the methodology to accomplish the targets of the study.

3.1 Summary of the Methods Used In Previous Works

Table 3.1: Review of the methodology of related works

No.	Title	Author	Methodology
1.	A Brain Controlled Wheelchair to Navigate in Familiar Environments [11]	Brice Rebsamen and Co.	• User select destination from a list in a menu that have predefined location. • Require no training • Using stimuli 3x3 matrix

			panel • Focus on intended button. • Use five healthy subjects
2.	A self-paced BCI system to control an electric wheelchair : evaluation of a commercial, low-cost EEG device [12]	Francesco Carrino and Co.	• Motor imagery task to imagine a left or hand movement.
3.	Navigating a Smart Wheelchair with a Brain-Computer Interface Interpreting SSVEP [11]	Christian Mandel and Co.	• 10 minutes preparation • During training, decision threshold was set for individually according to subject. • Focus randomly on stimulus given. • Navigate through a course of obstacles with clockwise and anti-clockwise movement to reach starting point again.
4.	Low-Cost Single-Channel EEG Based Communication System for People with Lock-in Syndrome[2]	Khalil Ullah and Co.	• Subject choose a character I array of a selection • Each subject has different location and different sessions of mental tasks.
5.	EEG control of an electric wheelchair for	Fatma Ben Taher and Co.	• Training needed • Before user can use the

	disabled Persons [13]		machine, they concentration rate must be more than 50%. • During learning phase, subject must imagine moving the chair to left or right for 20 seconds.
6.	Head movements based control of an intelligent wheelchair in an Indoor environment. [14]	Ericka Janet Rechy-Ramirez and Co.	• Two healthy subjects tested the wheelchair using three different control modes. • Subjects must follow the route that already designed. • Apart from the two control modes, subject must operate the wheelchair with joystick to compare the time taken to accomplish the task.
7.	Evaluating the Performance of a Face Movement based Wheelchair Control Interface in an Indoor Environment. [15]	Lai Weit and Co.	• Controlled surroundings with ample lightning condition. • 5 subjects are selected and asked to follow a designed route.

3.2 Methodology of Collecting Data

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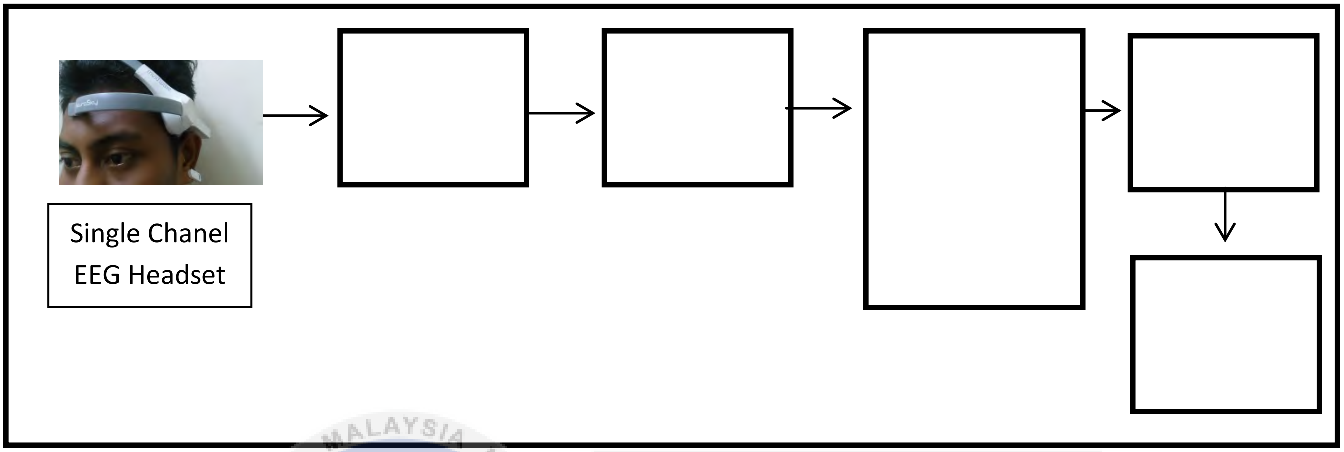


Figure 3.1: Flow of the project

This research will focus mainly on recording electrical signal produced by brain activity. EEG signal of human brain activity will be recorded and there are a few criteria amid the procedure of selection the example. The subjects are required to be great in mental and physical shape. The amounts of human subject selection are 5 individuals that selected randomly in order to examine the various outcomes of the result to ensure the best pattern to command the wheelchair.

For this study, dynamic exercises have been picked to get the electrical signal created by the brain. Subject will experience a test with a given assignment to get the electrical signal pattern. The pattern is then will be collected by using Neurosky Mindwave headset as interference between computer and robotic wheelchair.

3.2.1 Control Strategy

Control strategy is defined as how a system will be controlled. In this project how to control the motor of the wheelchair as the motor are controlled by the EEG signal, gaze tracking and sensor. An efficient and reliable control strategy advance control techniques of robotic wheelchair will be attained with the combination neural network control technique and mathematical modeling that will be made. For this project, input signal from single channel EEG headset such as delta, theta alpha, beta and gamma from Neurosky Mindwave will be input for a neural network control technique that will produce command to motor for stop and forward movement of the wheelchair. For data preprocessing description from the recording until the data are fed into neural network analysis for data classifying purpose are explained in the Figure 3.2 - Figure 3.6.

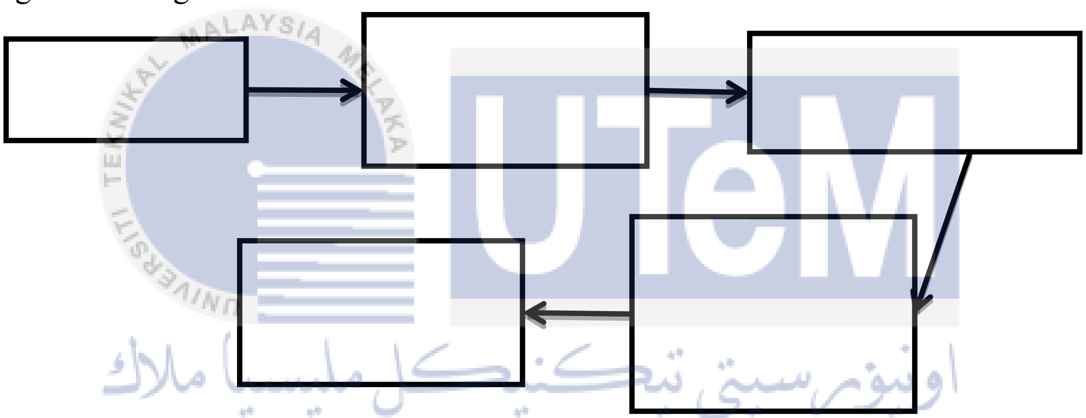


Figure 3.2: Overall data process

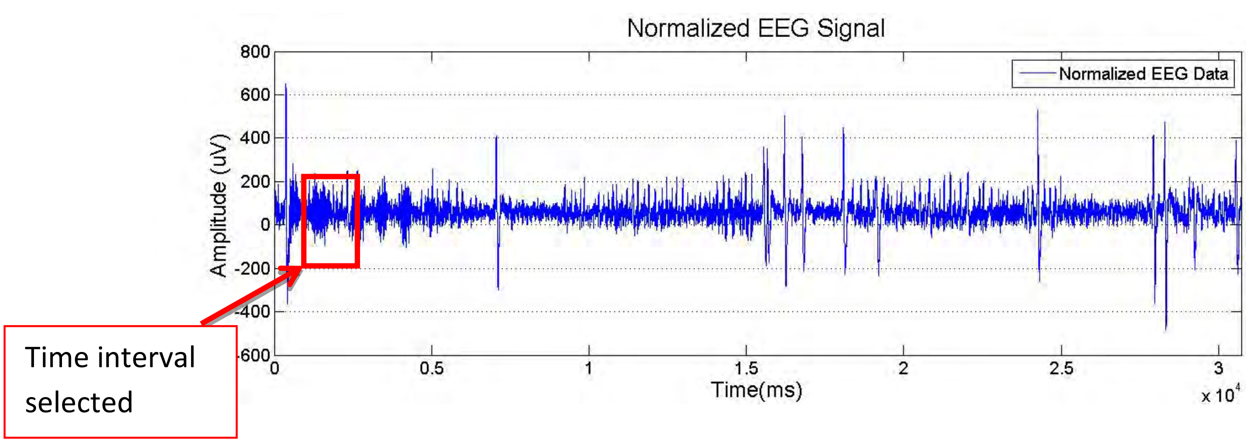


Figure 3.3: An interval at certain time is taken on Normalized EEG signal

From Figure 3.3 an interval will be selected according to the time for subject's stop and forward movement table. Neurosky Mindwave Headset sampling rate is 512 Hz [18], hence to determine when exactly subject will move forward and stop a video recording have been set up at each trial.

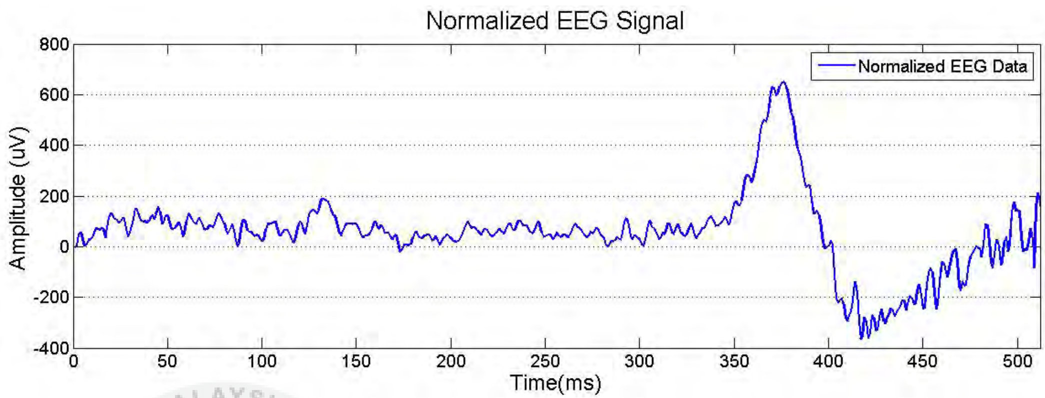


Figure 3.4: Scaled view of normalized data of 1 second

Based from Figure 3.4 an interval was selected to process the data for further analysis. From the MATLAB software Fast-Fourier Transform can be implemented.

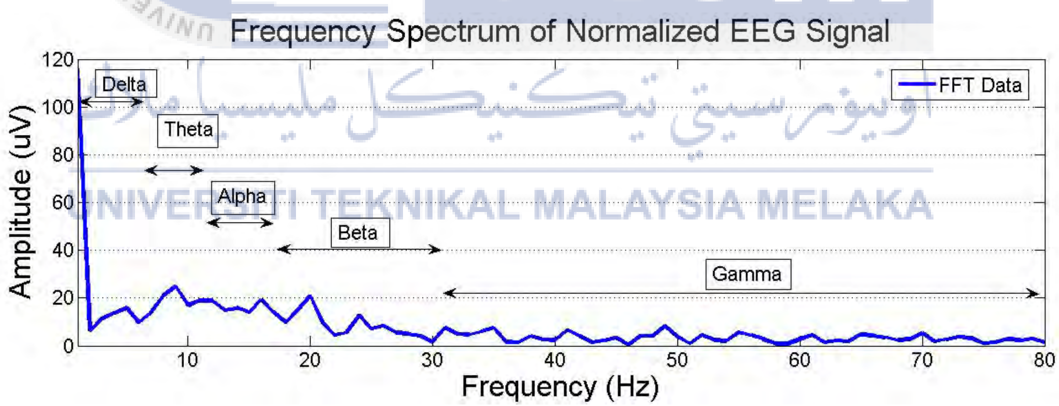


Figure 3.5: Fast-Fourier Transform was carried out at the selected time interval

EEG signal waves can be determine respectively after Fast-Fourier Transform analysis was carried out to the selected interval time.

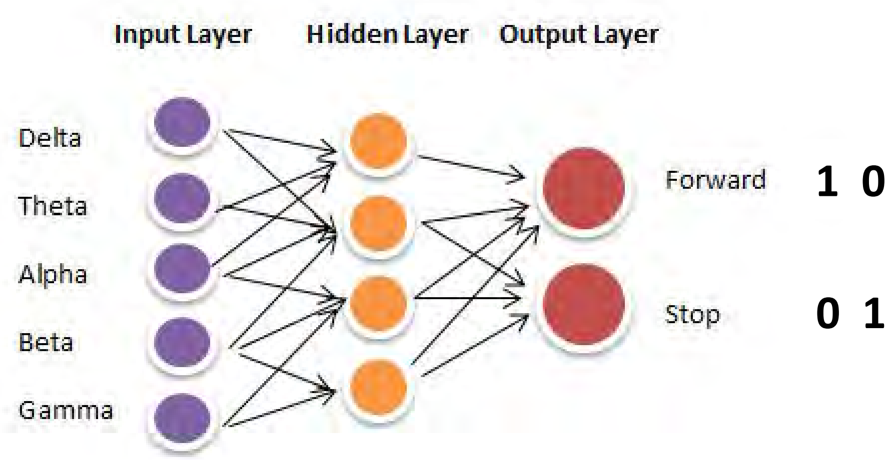


Figure 3.6: Diagram of neural network configuration

After all data preprocessing are completed, Neural Network configuration can be built to analyze the result of the experiment. Data arrangement also plays an important role to archive best performance results.

3.2.2 Neurosky Mindwave Headset

This project will use Neurosky Mindwave headset as medium to collect EEG signal from brain to computer. This hardware consist electrode that will placed on left forehead to attain the signal. Neurosky Mindwave headset also have comes up with a chip that already extract the EEG signal from raw data into normalized, with this means some of the noise already been filtered. Although, the normalized data are mostly noise-free the data still needs to be categorized into its own wave ranges types such as alpha, beta, delta, theta and gamma. In order to classify EEG wave, Fast-Fourier Transform will be used to accomplish the wave classification. Next, average of each range EEG waves will be used for Neural Network input.

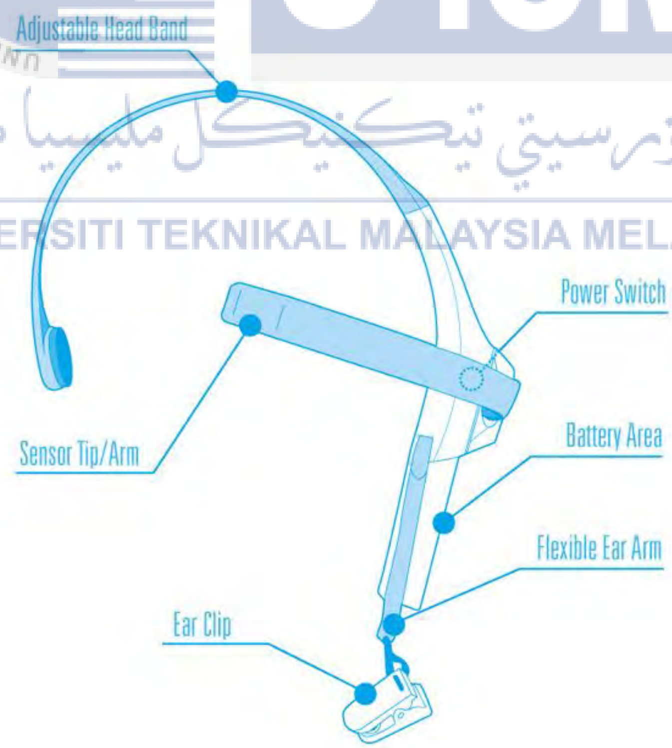


Figure 3.7: Neurosky Mindwave Headset [16]

Table 3.2: Neurosky Mindwave Headset Specifications and Hardware Overview [16]

Hardware Overview	**Specifications**
• Portable EEG brainwave headset • TGAM1 module, with TGAT1 ASIC • Automatic wireless computer pairing • Static headset ID • Single AAA battery • 6-8 hours battery run time	• Weighs 90g • Sensor arm up: Height: 225mm x Width:155mm x Depth: 92mm • Sensor Arm down: height: 225mm x width:155mm x depth:165mm • 30mW rate power; 50mW max power • 2.420 - 2.471GHz RF frequency • 6dBm RF max power • 250kbit/s RF data rate • 10m RF range • 5% packet loss of bytes via wireless • UART Baudrate: 57,600 Baud • 1mV pk-pk EEG maximum signal input range • 3Hz – 100Hz hardware filter range • 12 bits ADC resultion • 512Hz sampling rate • 1Hz eSense calculation rate

3.2.3 Scalp Preparation

It is important that a surface of scalp must be clean enough to reduce noise that will interrupt the chance to obtain a good EEG signal. Skin impedance is non-avoidable but can be minimize to get a better contact between scalp and electrode. Based on previous research that related with the action of extraction data from skin, there are three techniques for cleaning the skin, which is by utilizing a unique conductive cleaning glue, unsullied alcohol and fine sandpaper [9]. In favor to verify the skin is prepared and in great condition for the test, the skin will be in red light shading after skin prearrangement done. This study will utilize just unsullied alcohol cushion as a skin readiness before putting the contact.

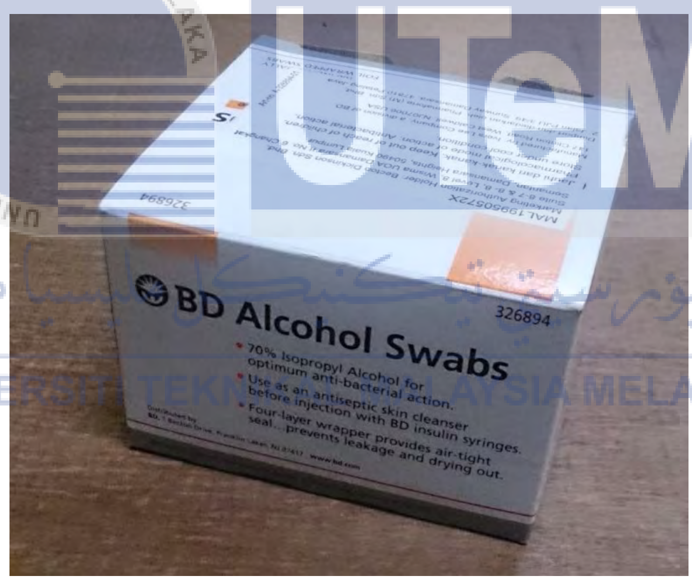


Figure 3.8: Alcohol swabs

3.2.4 Placement of Electrodes

After skin arrangement preparation is complete, the following step is to place the electrode on the frontal lobe. At this stage, arrangement of terminals will focus the securing of these EEG signals to reduce artifacts. EEG signal signifies the brain activity in all condition neither during meditation and easing mode. In order to get the uniformity of EEG signal data, the placement of electrodes will be placed on the same location of frontal lobe and it is better to place the electrodes on the same point and circumstance of scalp while repeating collecting data. By referring to former research, cerebrum which the largest part of brain consists of the right and left of cerebral hemispheres that control the motor of muscle. Sensory cortex and motor cortex are located in the cerebrum [8]. There is specific position where the motor and sensory cortex relates to the certain parts of the body. Frontal lobe is vital for controlling thoughts, reasoning and behavior [17] and [18]. This part also called Broca area, apart from that this part also controls motor functions of human [19]. (See Appendix B)

Before engaging the headset, the subjects are advised to sit on a wheelchair and in relaxing mode in order to familiarize with the condition to avoid subject's attention from distract during the test. Figure 3.9 shows the placement of headset before the experiment.

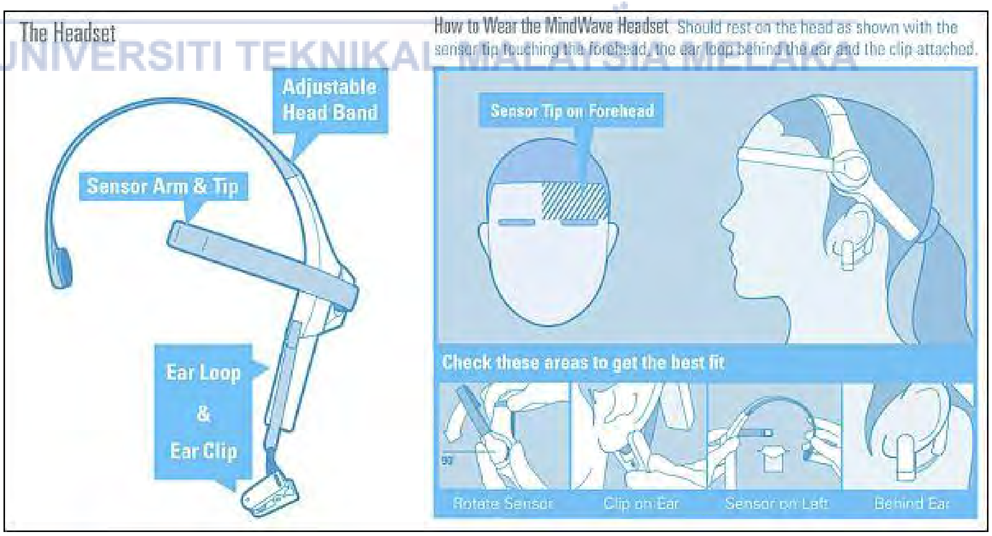


Figure 3.9: Neurosky Mindwave headset placement on head [19].

There are three stages of the process in this study which are before the test, during the test and after the test. These three stages are regularly done by most expertise to improve signal and to evade undesirable EEG data. The primary stage is before the test. Amid this stage, a few tasks needs to be finished by subjects, for example, equipment examination, skin preparation, subject selection and trial instructions. Next, the second stage of the process will be directed for this experimental. Second stage of this examination is amid the investigation will be run. In this stage, the procedure of gathering EEG signal information will be held.

Researchers must follow the experimental process as a recommendation to avoid from any misbehavior and to evade undesirable EEG signal. Spot of headset engagement on head is vital while gathering the EEG signal. An intensive activity was designated to provide the best focusing method for this research.

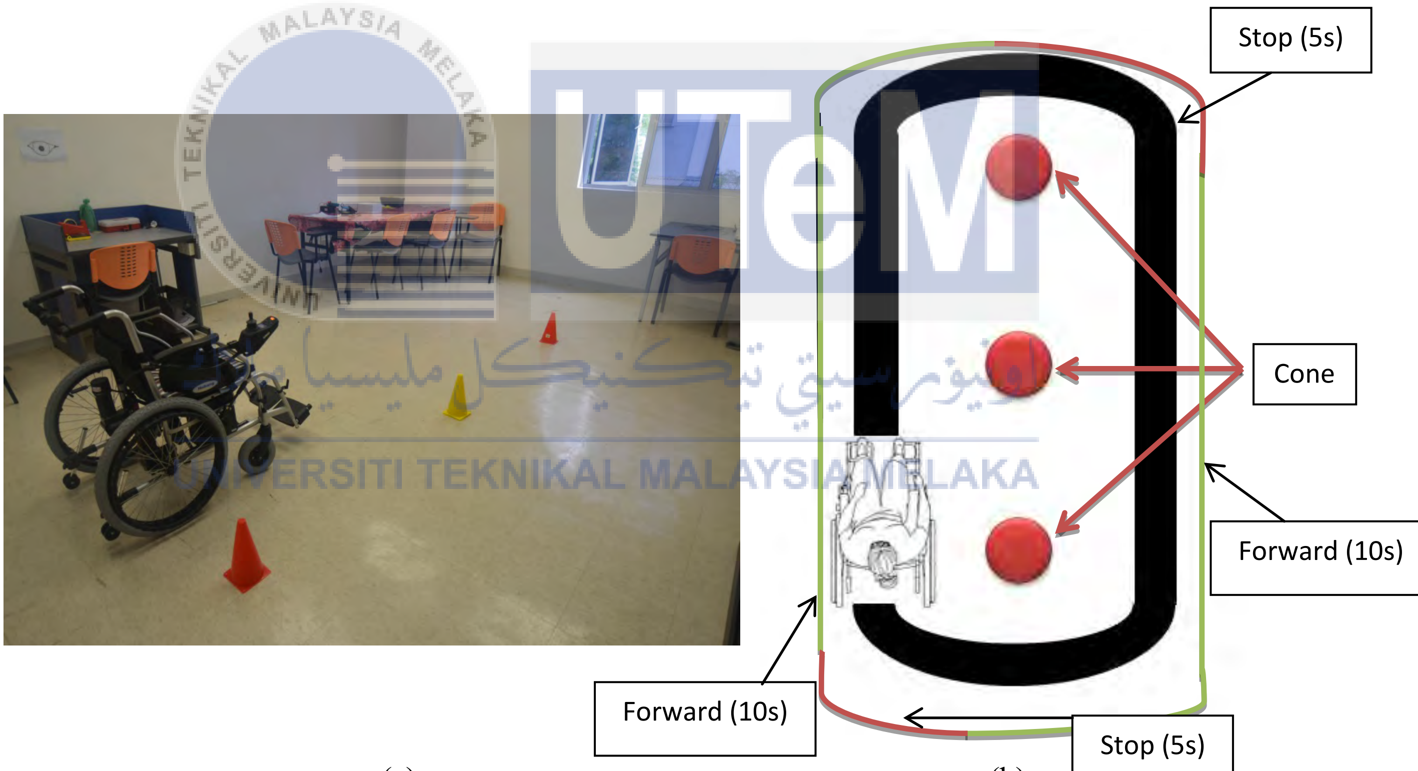
The final stage of this study is thing need to be done after accomplished the trial. This stage will come out with the extracted structures from signal gathering, which the extracted features will be matched to get accurate pattern of signal band for validation purpose.

3.2.5 Before Experiment

At this stage, all the criteria identified with subject determination and EEG utilized for this examination will be resolved. After finishing the subject preparation such as experimental briefing and equipment setup, the procedure will keep on cleaning the skin. A appropriate skin preparation was a critical part to improve of EEG signal quality. For this trial, alcohol swabs were utilized to evacuate the dirt. Firstly, all the subjects that chosen must be clarified about the trial procedure designed. For this examination, alcohol swab will be utilized as an option approach to evacuate the dead skin cells. This part is required and vital to enhance the grip of the headset, particularly for sweat-soaked skin sorts and element development conditions. Next, after the scalp was cleaned with alcohol swabs, sweep surface with wet tissue to guarantee the scalp surface clean. Scalp surface ought to be in light red hues which demonstrate great skin impedance.

3.2.6 Experimental Procedure

A study of previous experimental technique is carried to be performed by subjects. All the scope stated must be considered before any procedure is confirmed. Rehabilitation Engineering and Assistive Technology (REAT) lab situated on second floor of G block, Faculty of Electrical Engineering, Universtiti Teknikal Malaysia Melaka (UTeM) was selected due to few factors such as controlled surroundings away from public noise, public sight and ease to get a subject for data recording. Subject intent must not be distracted to reduce a noise from the raw data collected. Apart noise from public, operating machines also might disturb the performance of Neurosky Mindwave headset as the headset use a wireless application and a small magnetic field might interrupt the performance. After preliminary procedure executed a track for subject was set up in the controlled room.



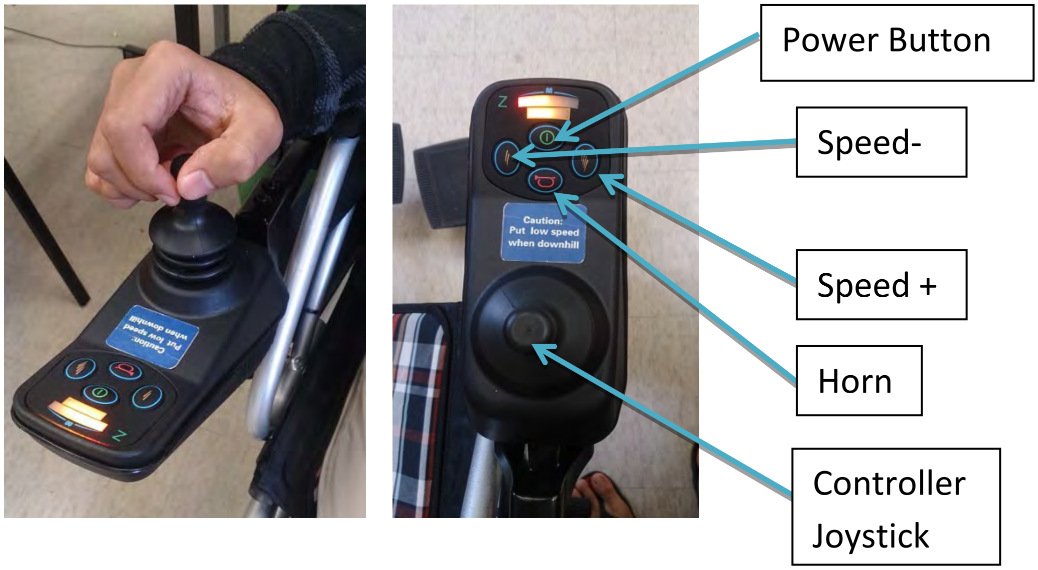
(a) (b)

Figure 3.10: Track was setup for the experiment (a) and top-view of the track (b).

Subject was given a period to familiarize with the automatic wheelchair that controlled using joystick on the right-side arm rest pad. On the interface of the controller there are few features such as speed controller and horn function for safety reason. For experiment procedure the speed was set up with 3 for all subjects to make sure there is no difference between the subjects for data recordings. A brief explanation about the experimental methods later to all the subjects before the data recording session takes place. The experiment will be proceeding as the table below:

Table 3.3: Time for subject to move and stop the wheelchair

No.	Remarks	Time(s)
1.	Forward	0
2.	Stop	10
3.	Forward	15
4.	Stop	25
5.	Forward	30
6.	Stop	40
7.	Forward	45
8.	Stop	55

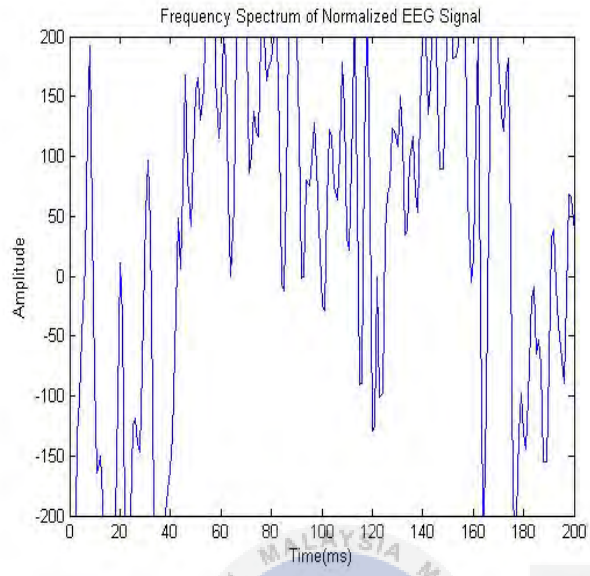


(a) (b)

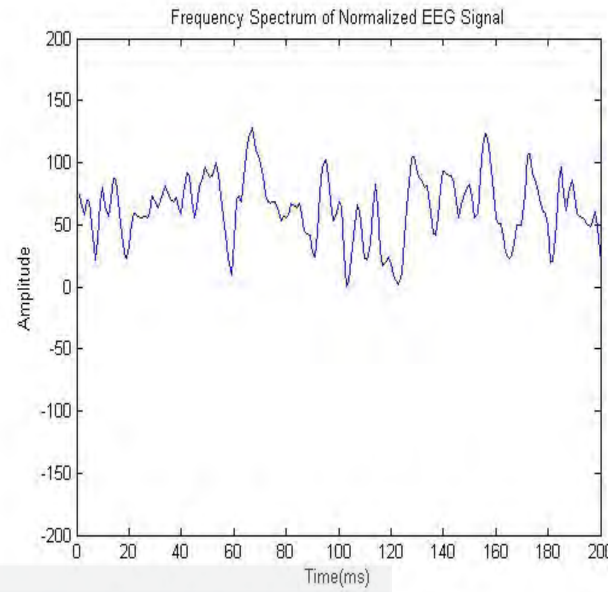
Figure 3.11: Wheelchair joystick to control the movement (a) and speed set to level 3 (b)

Before the experiment, subject was demonstrated on how the experiment will occur and to ease the operation this table was formed to give them idea on how the procedure. There will be stop and forward movement during the one-minute operation. This action will repeated 3 times for each subject to have more data for neural network pattern recognition as the performance will be more accurate if the sample data are many.

A testing for the Neurosky Mindwave was carried out to obtain a reduced-noise data. If the data recorded was not very satisfying a few step must be done such as cleaning again the forehead, earlobe, electrode and change the battery in the Neurosky Mindwave headset. After the recorded data collected is satisfying, the experiment can be implemented. An unwanted signal often occurs due to subject's skin are not clean enough and improper placement of electrode.



(a)



(b)

Figure 3.12: A comparison between an unwanted (a) and good (b) data recording.

In order to get consistency for the data collected, all the setting to all equipment used in the experiment was set up to be same for all subject including speed of wheelchair, distance between cones and the time for stop and forward movement while repeating the data recording process. For best result each of the subjects was given 10 minutes to test the wheelchair without the track to familiarize with the turning and the speed of the wheelchair. This action also will reduce a noise from EEG signal because they might nervous to operate the wheelchair. Any uneasy or nervous thought will bother the performance of the EEG signal, which means that a subject must focused on to moving the wheelchair only while operating it.

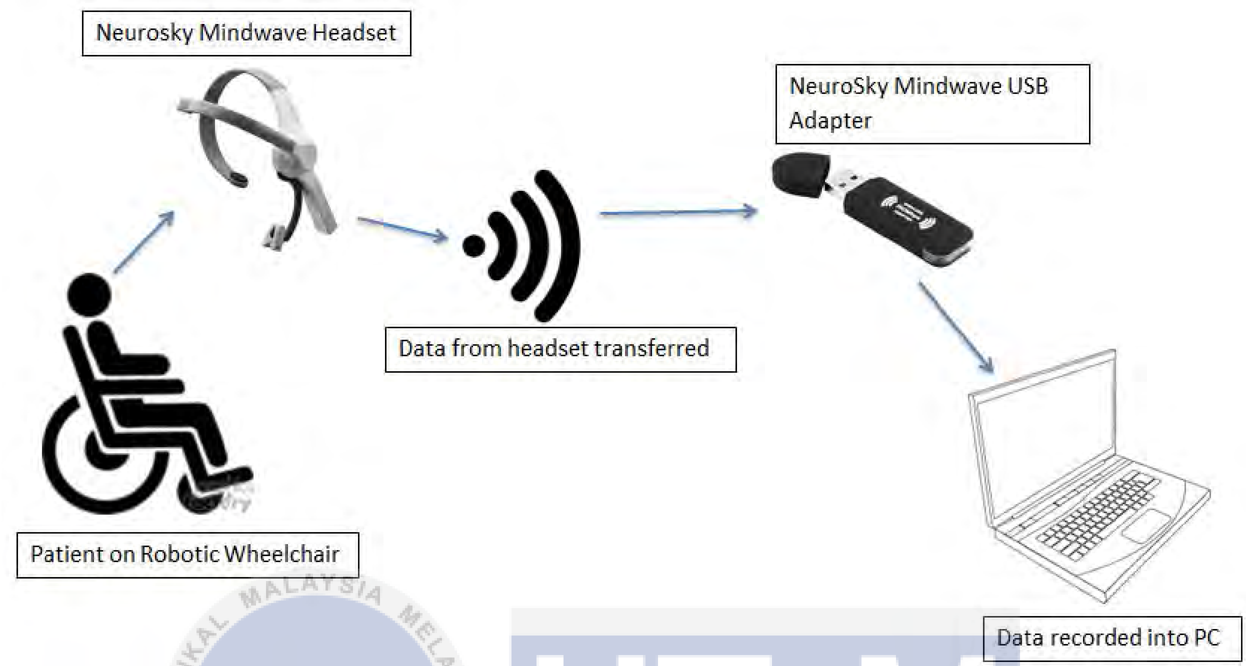


Figure 3.13: Overall experiment setup

Figure 3.13 display an entire idea on how the experiment will be carried out. Firstly, the subject will control the robotic wheelchair while using NeuroSky Mindwave headset. Data from NeuroSky Mindwave headset are transmitted wirelessly by using USB adapter that comes with the NeuroSky Mindwave headset package. At the same time, NeuroSky Mindwave headset will transmit the data from subject to the NeuroSky Mindwave USB adapter that attached to personal computer. Personal computer will run MATLAB software for further data processing to obtain the result of the experiment.

3.2.7 After Experiment

After completing the process of collecting the EEG signal, the next step is analyzing the data to extract the features from EEG signal collected. In this step, Pattern Recognizing tools in MATLAB software will be used to extract the features of the signal. The signal collected will be analyzed. Confusion Matrix, Mean Square Error (MSE) and Receiver Operating Character (ROC) result will be used to show the comparison between stop and forward mode.

3.2.8 Type of Analysis

In every single trial, subject will operated the wheelchair provided to move around the track setup. Each subject will complete trials 3 times which will provide 24 sample data for each subject. Random subjects are selected to run the experiment. A total of 5 subjects will provide 120 of required normalized data. Then signal extraction was done based on data collection. There are several methods can be used to extract the features of the normalize data. From signal obtained, EEG signal will be divided into few bands of frequency such as theta, beta and gamma and will be tabulated. The data arranged then will be used in Pattern Recognition Tool features in MATLAB. A detailed discussion about the result of the data will be explained in the next chapter.

3.3 Project Gantt Chart and Key Milestones

Table 3.4: Gantt chart table

	2014 [FYP 1]				2015 [FYP 2]					
Activity / month	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAC**	**APRIL**	**MEI**	**JUNE**
Understanding project										
Literature review										
Seminar journal preparation										
Experimental Setup										
Design a methodology										
Progress report writing & FYP 1 presentation										
Selecting a samples										
Collecting Data for EEG Signal										
Evaluation the efficiency and reliability of project										
Final report writing										
Prepare for Presentation project FYP 2										

Chapter 4

RESULTS

This part will bring up and give information about the findings of the study, which are examined the outcome and the examination of the outcome. This part will interpret more on the method of analyze the outcome from the phase of information gathering until the procedure of extraction features and result support.

4.1 EEG Analysis

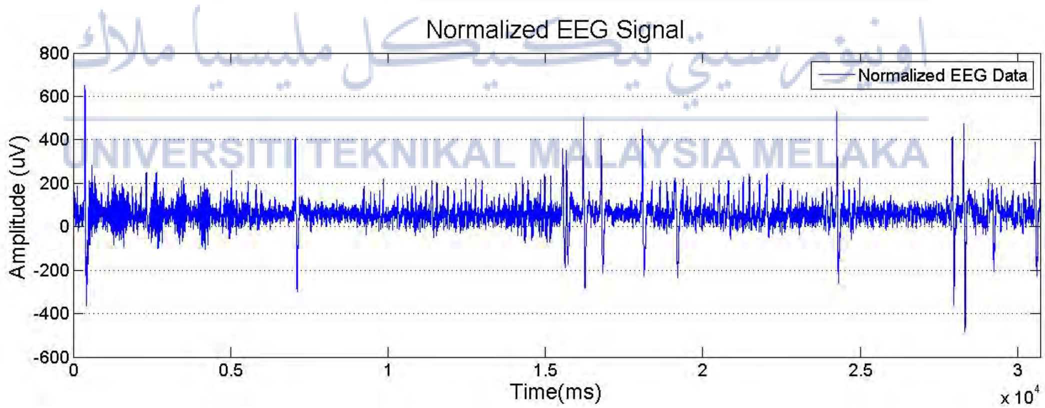


Figure 4.1: Normalized EEG signal

From the Neurosky headset a data in the Figure 4.1 was obtained. The x-axis of the data represent the time (ms) for the data to be record versus y-axis which represent the amplitude of the data (uV) for each second in the trial experiment period. From the headset specification, it states that every 1 second it will generate 512 of normalized data [16]. From total of 1 minute recorded time for experiment operation there will be 30720 of tabulated data. It means that there are no raw or un-normalized recorded during this experiment.

$$Sampling\ rate = 512\ Hz$$
$$Each\ second\ NeuroSky\ Mindwave\ Headset\ will\ generate\ 512\ data.$$
$$Hence, for\ 1\ minute\ total\ data\ obtained$$
$$= 512\ Hz\ x\ 60\ seconds$$
$$= 30720\ data$$

Next, this data divided into each part for further process. In the previous chapter the experimental procedure was explained which there was stop and forward movement of the wheelchair. Those stop and forward movement time were recorded and the time interval between these two actions is identified. For the next process a data from each interval was organized. At 5,17,27,32,37,47,52 and 59 second, a data have been selected for Fast-Fourier Transform that will produce a frequency versus amplitude graph. Basically, Fast-Fourier Transform will converts time domain to frequency domain or vice versa.

Example of how to determine the data recorded at desired interval is explained in the mathematical equation below. For instance from the recorded video the subject stop at 11th second. In order to obtain the normalized data for Fast-Fourier Transform analysis simple mathematical task need to be done.

- For 11th second
- Sampling time is 512 Hz

$$11\ seconds\ x\ 512\ Hz = 5632$$
$$5632 + 512 = 6144$$

Hence, from the tabulated Normalized EEG signal table data ranging from row numbered 5632 until 6144 can be selected for Fast-Fourier Transform analysis.

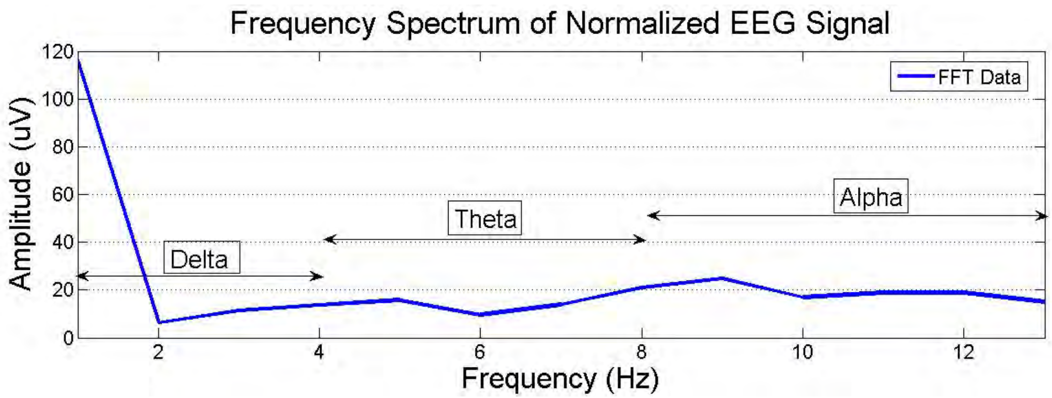


Figure 4.2 (a): Frequency Spectrum of Normalized EEG Signal (Delta, Theta & Alpha)

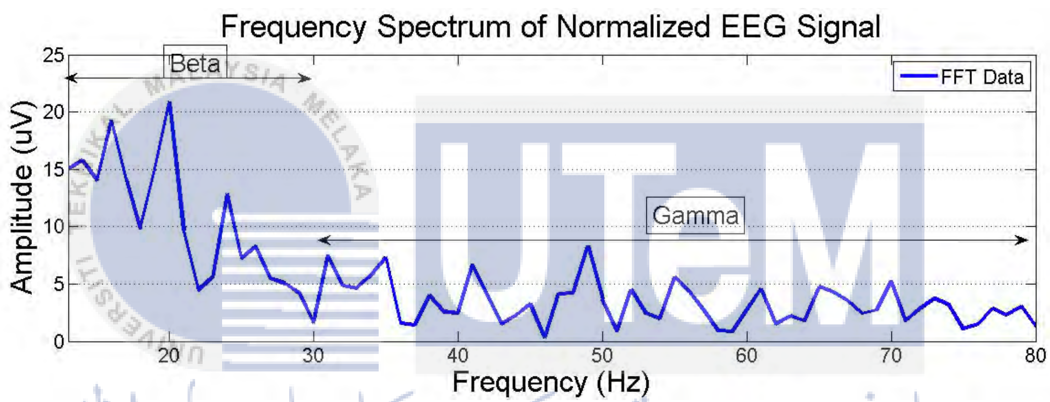


Figure 4.2 (b): Frequency Spectrum of Normalized EEG Signal (Beta & Gamma)

Figure 4.2 (a) and Figure 4.2 (b) show the features of EEG signal after Fast-Fourier Transform analysis was done. The ranges of wave are fixed according to previous research [18]. All ranges are distributed as shown in Table 4.1.

4.2 Features Extraction

After the Fast-Fourier Transform graph was obtained the graph is scaled down to 0-80 Hz because all EEG signal ranges are between 0.1 Hz-80 Hz [18]. An average for each range was calculated and tabulated for Pattern Recognition process in MATLAB software. Each range is classified as follows:

Table 4.1: Features of EEG signal

No	EEG Features	Range(Hz)
1.	Delta (δ)	0.1-4
2.	Theta (θ)	4-8
3.	Alpha (α)	8-13
4.	Beta (β)	13-30
5.	Gamma (γ)	30-80

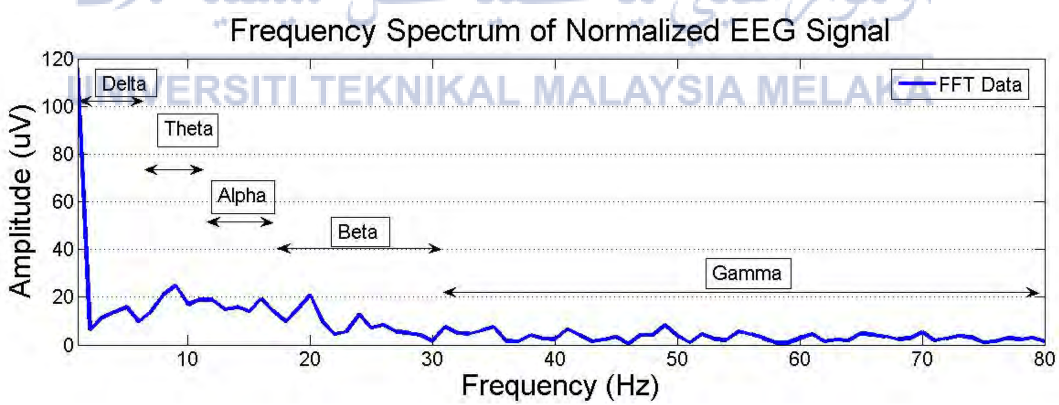


Figure 4.3: Illustration of the ranges of EEG signal ranged from 0.1-80 Hz

Figure 4.3 shows the range of each EEG signal respectively. After the Fast-Fourier Transform are finished. A set of data ranging from 0.1-80 was recorded. This data is then tabulated by the range explained previously. Every trial will produce 8 set of data which consists 4 forward actions and 4 stop actions. Every sample data are tabulated in set of number to form an input for Pattern Recognition Tool in MATLAB software.

4.3 Neural Network Analysis

By utilize the feature extraction value, the data will be authenticated by using Neural Network analysis. The figures obtained was trained by using feed forward back propagation neural network (FFBPNN) with Scaled Conjugate Gradient training utility. There are many alternative methods offered, but for this study, only Scaled Conjugate Gradient was involved. The training progression based on training data, tester data and validation data. After it completes the error goal, all the weight outcomes can be used for testing purpose.

4.4 Feed Forward Back Propagation with Scaled Gradient Conjugate Training Function

By using this technique, data gathered was trained to confirm either the features extracted data are adequate enough to turn into as input for Pattern Recognition tools. First, select the data which fit the inputs and aims to correct the problem. Input data signify the static data to the network whereas output data are target data chosen for network output.

After the data was organized, it then will be fed into Pattern Recognition tool for the final result of the study. For the percentage of the training, validation and testing is set to be different for each times of trial to acquire the best result.

Table 4.2: Example of Input data arrangement from average of each wave

	Name of wave (Range|Symbol)	Delta (0.1-4 Hz|δ)	Theta (4-8 Hz|θ)	Alpha (8-13 Hz|α)	Beta (13-30 Hz|β)	Gamma (40-80 Hz|γ)
	FFT reading / Notes					
1.	Forward	18.52	11.98	16.05	6.89	1.85
2.	Forward	22.83	3.87	8.84	4.60	1.99
3.	Forward	18.29	20.14	17.86	6.35	1.75
4.	Forward	21.14	3.64	2.56	2.15	1.47
5.	Forward	18.03	11.93	16.09	6.90	1.84
6.	Forward	20.05	6.01	4.71	2.91	1.59
7.	Forward	21.26	4.12	2.15	1.63	0.94
8.	Forward	23.06	5.68	4.52	1.49	0.97
9.	Forward	23.33	11.57	17.25	8.69	2.40
10.	Forward	20.08	6.84	5.72	1.89	1.05
11.	Forward	20.27	5.55	4.34	1.71	1.353
12.	Forward	19.87	4.74	3.12	2.18	1.36

Table 4.3: Example of output data organization

Stop		Forward	
0	1	1	0
0	1	1	0
0	1	1	0
0	1	1	0
0	1	1	0

Data organization will impact the output goal and unalike arrangement will yield dissimilar output values. After choosing the input and output for the evaluation, then trial data was randomly picked for the training, validation and testing task. Training is when data altered rendering to its miscalculation while validation used to measure network observation, and to cutoff training when generalization breaks developing.

Next is testing procedure, these testing have no influence on training and offer a self-regulating measure of network accuracy during and afterwards the training procedure. Afterward, is fitting networks. This network are feed forward neural networks use to fit an input-output relationship. Set the hidden neuron network conferring to preferred output because unlike figures of hidden neuron will create a not same value of Mean Square Error (MSE). MSE is the average squared difference among output and targets. The lower the value the improved its performance and zero means no error.

Apart from that, all percentage of training, validation and testing will be same for all the number hidden neuron used. For the analysis 70% of the data will be training data, 15% of the data will be validation and the last 15% will be training data. This is to ensure only number hidden neuron the manipulated variable in the neural network analysis.

4.5 Pattern Recognition and Classification Result

From the Pattern Recognition and Classification tools in MATLAB software a result of the data from input and output can be obtained directly. For this study only three result will be discussed which is Matrix Confusion, Mean Square Error (MSE) and Receiver Operating Character (ROC). From the result, the numerical value of the result keep changing even the parameters did not change. In order to archive the best result number of hidden neuron will set into three values which are 50, 500 and 5000. Each value will trained three times and the average result of Matrix Confusion, MSE and ROC are taken as the final result of the experiment. This action also will conclude what ranges of hidden neuron must be tuned to gain a consistent and high accuracy result.

4.5.1 Matrix Confusion

Matrix confusion comprises statistics about actual and expected classifications done by a classification structure. Performance of such systems is normally assessed using the figures in the matrix. Confusion matrix also can determine the number of how many testing data passed for the data classification. Besides that, confusion matrix can predicted the number of data that might be misclassified by the system.

Table 4.4: Confusion Matrix arrangement

		Predicted	
		Stop	Forward
Actual	Stop	*a*	*b*
	Forward	*c*	*d*

$$Accuracy(\%) = \frac{a+d}{a+b+c+d}\ x\ 100\%$$

Figure 4.4: Matrix confusion result from Pattern Recognition tools in MALTAB software

From Figure 4.4 an example of result displayed result of training, validation, testing and average of the result are acquired. This model is the will be trained 3 times with number of hidden neuron set to be 50,500 and 5000. Each overall performance for every number of hidden neuron are tabulated in Table 4.5.

Table 4.5: Final result of Confusion Matrix

Remarks / No. of Hidden Neuron	Training Percentage(%)	Validation Percentage(%)	Testing Percentage(%)	Average Percentage(%)
50	44.1	75.0	62.5	52.0
500	82.4	75.0	62.5	78.0
5000	85.3	62.5	75.0	80.0

From Table 4.5 it states that as the number of hidden neuron increase the overall performance also increase. This is because a high number of hidden neuron are important if the data classification is harder to distinguish. Besides that, the number of hidden neuron ranging from 1000-5000 might matching with this system effectively because the input data is slight.

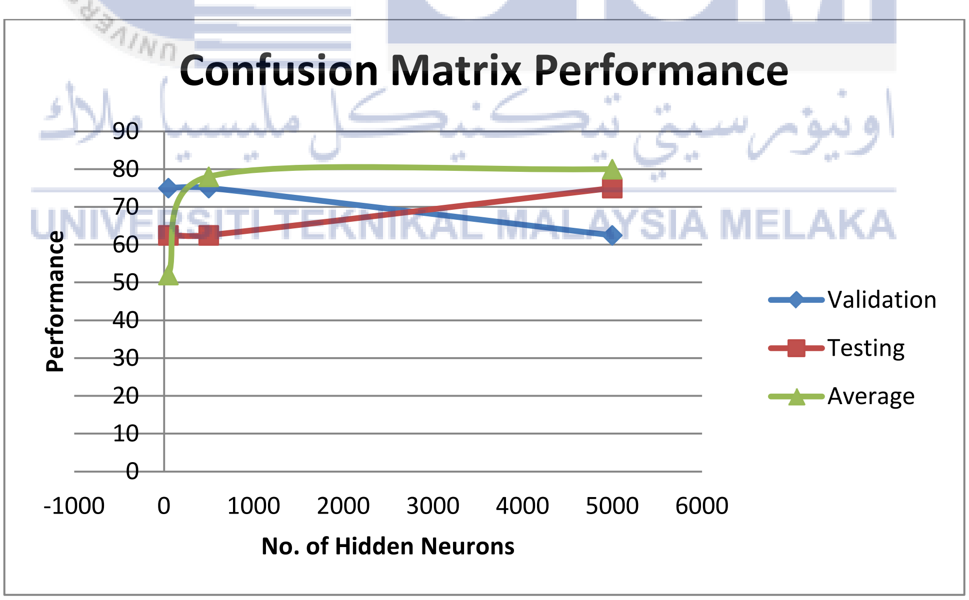


Figure 4.5 : Graph of Matrix Confusion Performance

Figure 4.5 shows the performance of validation, testing and average of confusion matrix result. For average and testing, as the number of hidden neurons increase the performance also increase. On contrary result was achieved for validation as the performance rate declining as number of neurons growing.

4.5.2 Mean Square Error (MSE) & Percent Error

Mean square error is defined as the average squared difference among outputs and targets. A best model or system will yield a lower values. If the value are 0 it means that the system are perfect, in other words no error of the performance of the classification. While percent error point out the fraction of trials which are disorganized. The lower the value the better the performance. For example, value of 0 means no misclassifications, 100 indicates maximum misclassifications. In the Pattern Recognization and Classification tools in MATLAB software, this result are automatically generated after a trial was made for a model.

For this result, a hidden neuron was set to three value which is 50,500 and 5000. The first three training for each value of hidden neuron was compared and the best classification performance was selected by referring to mean square error and percent error. The final result was tabulated in the Table 4.6 and example of mean square error performance was shown in Figure 4.6.

$$Percent\ Error = \left| \frac{Actual\ Value - Measured\ Value}{Actual\ Value} \right| x\ 100$$

$$Mean\ Square\ Error\ (MSE) = \frac{1}{no.\ of\ trial} \sum_{i=1}^{n} (Actual - Measured)^2$$

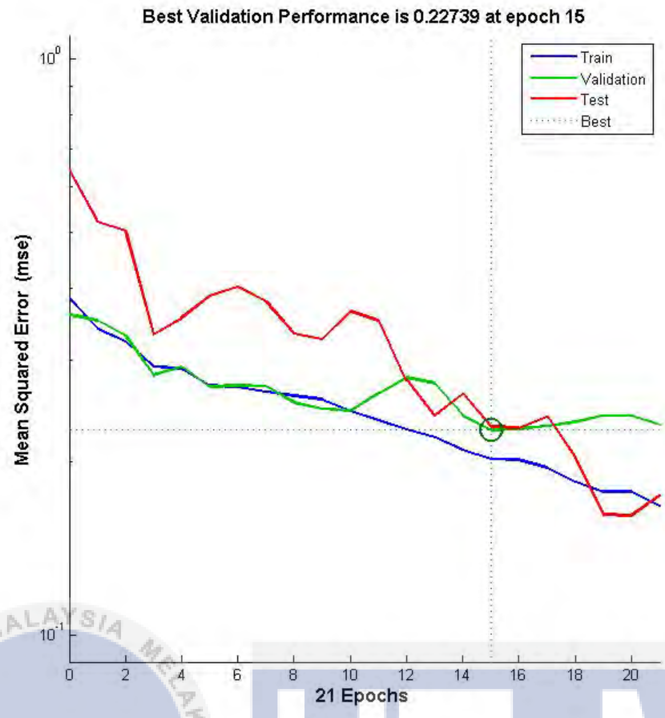


Figure 4.6: Example of Mean Square Error graph at epoch 15

Table 4.6: Final result of Mean Square (MSE) and Percentage Error

No. of Hidden Neuron \ Remarks	Training		Validation		Testing	
	MSE	Percentage Error (%)	MSE	Percentage Error (%)	MSE	Percentage Error (%)
50	4.0873e-1	55.8823e-0	2.2569e-1	25.000e-0	2.87358e-1	37.500e-0
500	1.3553e-1	17.6471e-0	2.3860e-1	25.000e-0	2.3252e-1	37.500e-0
5000	1.3481e-1	14.7058e-0	2.2727e-1	37.500e-0	1.9866e-1	25.000e-0

Based from Figure 4.6 it is shown that hidden neuron valued 5000 get the best performance compared to the other two values. Hence, for this result it can be conclude that a higher number of hidden neuron is matched for this system.

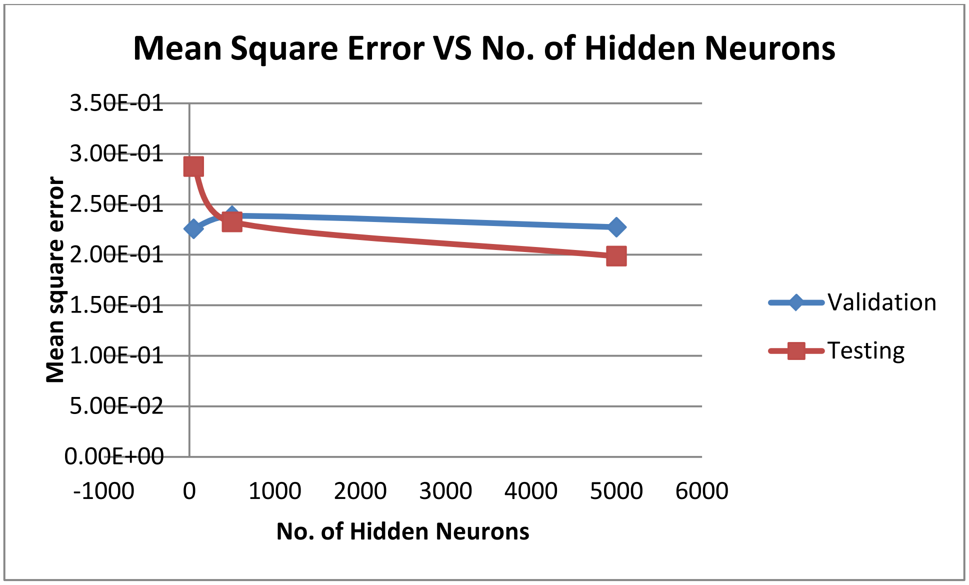


Figure 4.7: Graph of Mean Square Error versus No. of Hidden Neurons

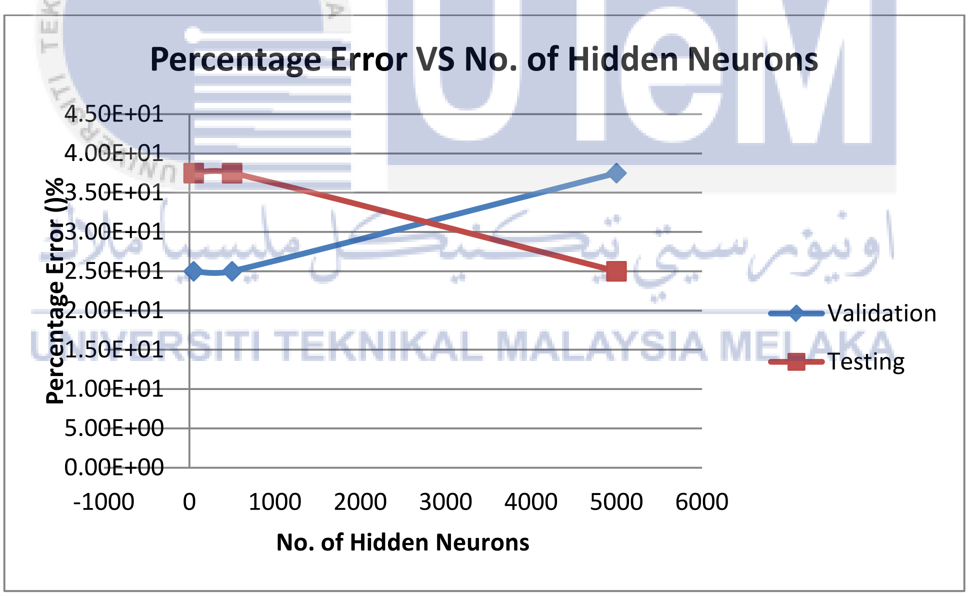


Figure 4.8: Graph of Percentage Error Versus No. of Hidden Neurons

From Figure 4.7 and Figure 4.8 have shown the MSE versus number of hidden neurons graph and Percentage Error versus number of hidden neurons graph. For testing classification, as the number of hidden neurons increase the performance rate also increase.

4.5.3 Receiver Operating Characteristic (ROC)

Receiver operating characteristic (ROC) is another ways to resolve the performance of neural network classification apart from confusion matrix. A ROC graph is a design with the false positive (FP) rate on the X axis and the true positive (TP) rate on the Y axis. The position (0,1) is the flawless classifier, it categorizes all positive cases and negative cases appropriately. It is (0,1) because the false positive rate is 0 (none), and the true positive frequency is 1 (all). The position (0,0) signifies a classifier that expects all cases to be negative, while the position (1,1) corresponds to a classifier that guesses every case to be positive. Point (1,0) is the classifier that is improper for all classifications. In many cases, a classifier has a constraint that can be adjusted to increase TP at the cost of an increased FP or decrease FP at the cost of a decrease in TP.

Each limitation setting provides a (FP, TP) pair and a series of such pairs can be used to plot an ROC curve. A non-parametric classifier is represented by a single ROC point, matching to its (FP,TP) pair. In a simple words a good classifiers graph will moves to top left corner directly. Theoretically, great model graph will show that the lines will climb quickly toward top left corner and if the lines lies underneath the diagonal line the system are inaccurate predicted the cases. Although, the best result failed to archive desired result the final result still managed to differentiate between stop and forward waves. For this result, three values of hidden neuron was set to gain the best hidden neuron value that suit with the model.

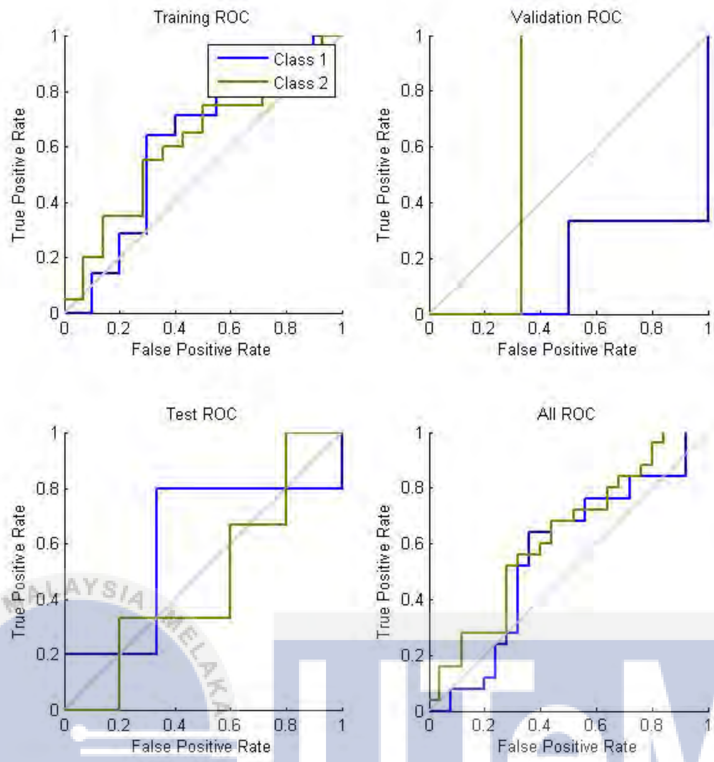


Figure 4.9: ROC curve of 50 hidden neurons

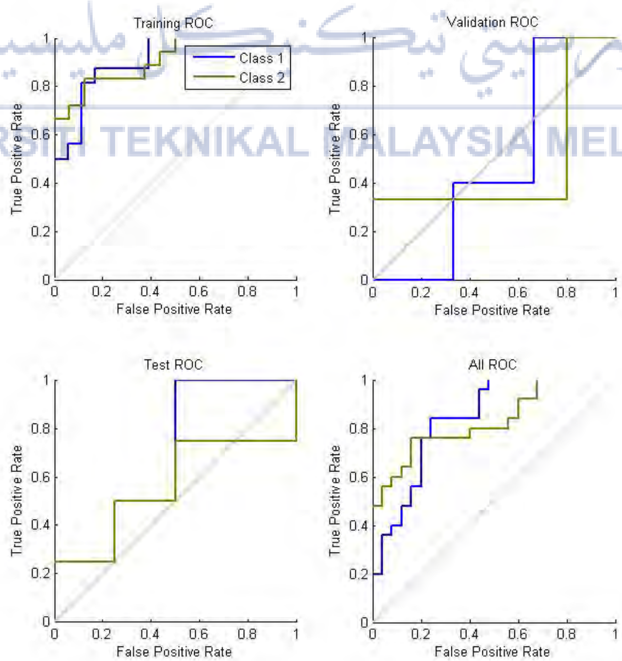


Figure 4.10: ROC curve of 500 hidden neurons

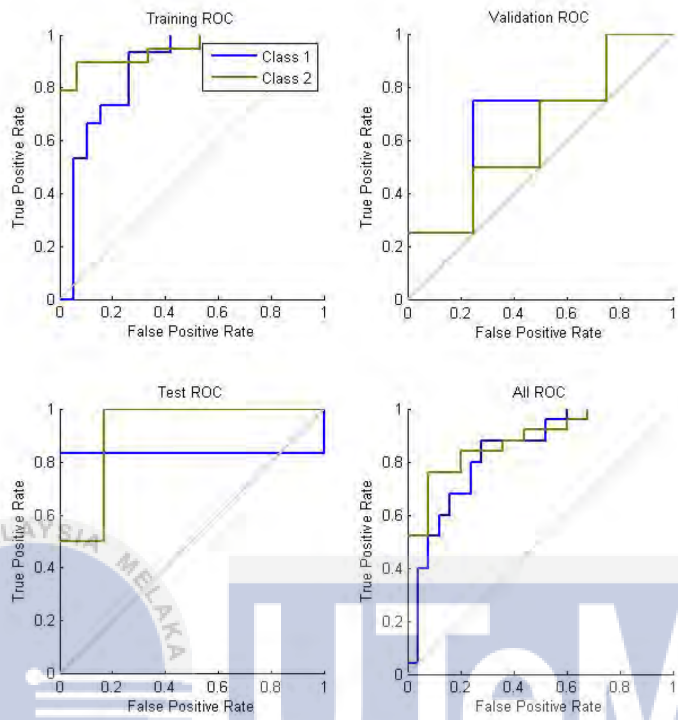


Figure 4.11: ROC curve of 5000 hidden neurons

From Figure 4.9- Figure 4.11 it clearly showed that as the number of hidden neuron increase the ROC curve also increasing directly towards top left corner. Compared the Figure 4.9 and Figure 4.11 it shows the improvement of the system between the *"All ROC"* curves for both of the figures. ROC curve also can be measured by the area under the graph. Hence, by taken Figure 4.11 area compared to others two curves it is obviously that a system with hidden neuron of 5000 more superior than hidden neuron valued 50 or 500.

CHAPTER 5

CONCLUSION

5.1 Conclusion

This section will determine all the outcome of the study, from the start of the study until the analysis of the data gathered.

EEG is a method for obtaining the electrical sign from the brain to observe the subject intention. Therefore, EEG signal brings treasured figures about the nerve system of brain. From the study, normalized EEG signals of stop and forward brain activity signal from subjects were successfully measured from the left frontal lobe using Neurosky Mindwave headset. Then, in order to gain the normalized EEG signals, the subjects need go through several measures like skin cleaning, tools set up and device location process to evade artifacts that surely will affect the reading. All of these measures are essential in order to obtain a improved value of EEG signals. By referring to preceding research, normally normalized EEG signals also contain an artifacts occur from the interior noise which is skin characteristic, skin impedance and blinking of an eye. While for the exterior noise, it's caused by the nearby environment condition such as public sight and operating machine. Engagement of electrodes too will affect to the noise if it was wrong placed and not on the left frontal lobe.

. For this research, the EEG signals collected by using Neurosky Mindwave headset was a normalize signal which means the output were already being filtered which will complete all the signals. Hence it makes easier to extract the features from the EEG signals.

After that, EEG ranges of waves was magnificently being take out from the normalize EEG data. All the features are suggested as input for a organization purpose by using neural network. Neural network classification is a supervise kind of classification that require a target to match among the input and output. From the extracted features, the figures will be classified into 2 groups, stop and forward. The data were effectively classified into 2 group, even though there were cross over among stop and forward movement of subjects.

For this model the manipulated variable was set to be number of hidden neurons. Mostly, for each result as the number of hidden neurons increase the performance of the model also improving. Generally, as the number of neurons increased the classification performance also increase but this theory are not practically can be applied to all model. As for the consequences, if the numbers of hidden neurons are high the system will be slow due to data processing take much longer time to complete. In other words, if a number of input and output for a model is high the models are not preferred to use a high number of hidden neurons. On the opposing case, for this study a high number of neurons did not affect the speed of the model due to slight number of data for input or output. A value 5000 performance's is more superior compared to 500 and 50 values.

5.1 Recommendation

There are several things need to be develop for future researches. While dealing with brain EEG devices used should be high specification and decent enough to detect the brain activity because the noise of from subject itself is different from each other. Then, the level of subjects with intention to stop or move forward also needs to more specific. It also can provide a data without any crossover while extracting the features for comparison purpose. In order to realize the main target for this study, a program that can process the preprocessing data must be made and use the neural network model that already trained. Besides that, this project can be operated online by accessing Simulink tools in MATLAB software and use this study neural network configuration as the system. Due to time constraint, this aspect did not manage to be completed. In advance, this project still can improve by classified the different intention of subject movement by using feed forward back propagation neural network with Levernberg-Marquardt training method or another training method that would make a better result.

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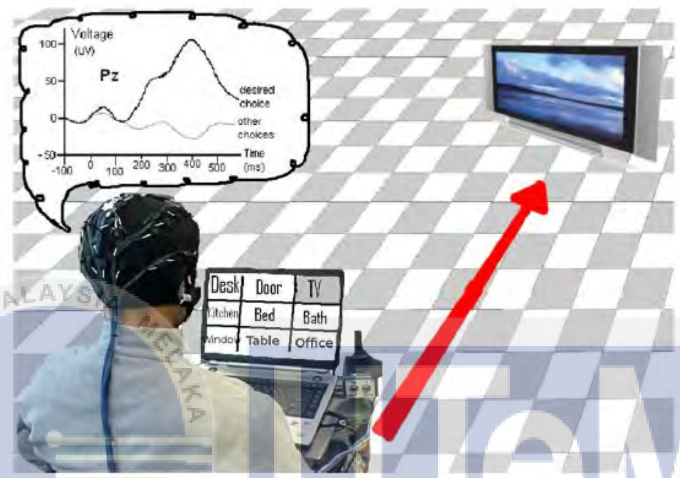
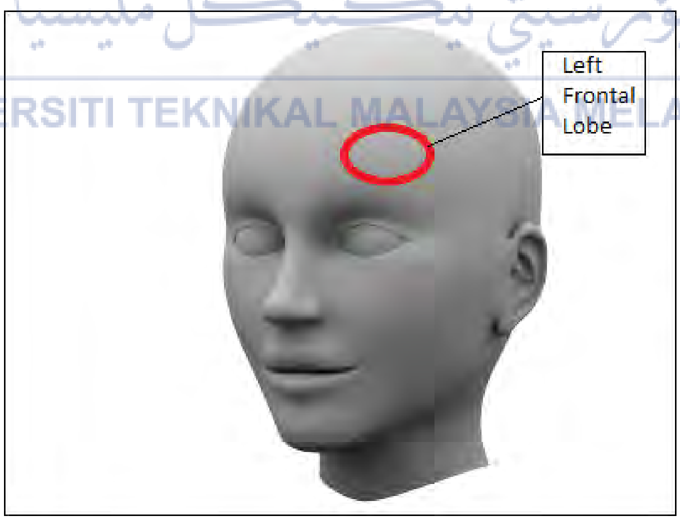
APPENDIX



A: Overview of the BCI where the user selects the destination on the TV [9]



B: Correct position to place electrode i.e. on left frontal lobe (Broca area).