CLASSIFICATIONS OF THE VERTICAL AND HORIZONTAL MOVEMENTS OF ELECTROOCULOGRAPHY (EOG) SIGNALS USING NEURAL NETWORK

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

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2015

I declare that this report entitle "Classification of the Vertical and Horizontal Movements of Electrooculography (EOG) Signals Using Neural Network" is the result of my own research except as citied in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ________________________

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Date : ________________________

To my beloved mother and father

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First of all, I want to thank to Allah S.W.T for giving me the chance of completing my Final Year Project successfully just in time. I had to face some challenges and problems throughout this final two semesters in completing this subject due to lack of knowledge and information between friends and lecturers about electrooculography, because it is a quite limited field and not everyone knows about it.

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And lastly, I am hoping that this project can be helpful to the next researchers in upgrading all the lacks that I did and help disabled people to have a more comfortable and easier life.

ABSTRACT

The study of Artificial Neural Network (ANN) in classifying electrooculography (EOG) signals for the vertical and horizontal movement purpose is mainly to validate that ANN is good in classifying data. Hoping that this study can contribute in helping other researchers in choosing the best classifier for their experiment or project in helping the community of an extreme disable society's life. Also, maybe that someday that this study can help other developer's project to function smoothly and comfortably in order to give a great service not just for disable users, but also to people that have the interest in trying something new. The two main objectives of this study are to classify the features of EOG specifically on cornea-retinal potential and also to evaluate and validate the features extracted using Neural Network. There are a few steps needed to be completed throughout this study before the ANN can be validated as the best classifier. These steps included the study on ANN, extracting the EOG signals on a few subjects, extracting the features of the signals, testing and training the network, and lastly analyze the results. There will be some hardware used in this study, which are NI MyRIO 1900, Muscle Sensor V3 kit and disposable electrodes. Mostly this study focuses more on analysis research on how the feature signal will be classified and analyzed. There are many methods that can be used in classifying EOG signals, but ANN is the simplest yet can give an excellent classification result.

ABSTRAK

Tujuan utama kajian tentang *Artificial Neural Network* (ANN) dalam mengkelaskan isyarat *electrooculography* (EOG) untuk pergerakan menegak dan mendatar adalah untuk mengesahkan bahawa ANN merupakan pengkelasan data yang baik. Dengan harapan bahawa kajian ini dapat menyumbang dalam membantu penyelidik-penyilidik untuk memilih pengkelasan terbaik yang boleh dipakai untuk eksperimen atau projek mereka dalam membantu kehidupan komuniti orang kurang upaya. Dan juga mungkin suatu hari nanti kajian ini boleh membantu pengkaji lain dalam mengembangkan projek mereka bukan sahaja untuk memberi keselesaan kepada orang kurang upaya, malahan juga untuk pengguna yang berminat untuk mencuba sesuatu yang baru. Terdapat dua objektif utama di dalam kajian ini iaitu untuk mengkelasifikasikan ciri-ciri EOG terutamanya pada potensi kornea-retina, dan juga untuk membuat penilaian dan pengesahan terhadap ciri-ciri yang telah dicapai dengan menggunakan ANN. Terdapat beberapa langkah yang perlu diambil sepanjang kajian ini sebelum ANN boleh disahkan sebagai pengkelasifikasi terbaik. Langkah-langkah ini adalah dengan membuat kajian tentang ANN, mengeluarkan isyarat EOG terhadap beberapa orang, mengeluarkan ciri-ciri isyarat, ujian dan latihan terhadap rangkaian, and akhirnya menganalisis keputusan. Terdapat juga beberapa perkakasan yang diguna pakai di dalam kajian ini, seperti NI MyRIO, *Muscle Sensor V3 kit* dan juga elektrod pakai buang. Sebahagian besar tumpuan kajian ini adalah pada kajian analisis tentang bagaimana ciri-ciri isyarat yang didapati kemudiannya dikategorikan dan dianalisis. Terdapat pelbagai cara yang boleh digunakan untuk mengklasifikasikan isyarat EOG, tetapi ANN merupakan yang termudah tetapi dapat memberi keputusan pengkelasifikasi yang terbaik.

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CHAPTER 1

INTRODUCTION

1.1 Overview

According to the Social Welfare Department, the number of registered disabled people in Malaysia had around 445,006 only in the year 2012 alone, but the number could be more than recorded nowadays since the registration is voluntary.

The Minister for Women, Family and Community Development, Datuk Seri Shahrizat Abdul Jalil did said that the needs of the disabled people must be fulfilled and supplied by the authorized department in order to make them feel comfortable to move anywhere and interact with other people freely.

Other than the disabled people, there are people who suffered not just with amputees, but also patients with extreme disability from muscular and neurological disorder like amyotrophic lateral sclerosis (ALS) and spinal cord injury. Even though most of the extreme disability patients can't move half or more of their bodies, but they can still make eye movements and some even interact with their families with just blinking their eyes.

Hence, there are several inventors and researchers starting to develop methods and set up applications that can be used by these patients to communicate with others comfortably without even using too much effort, by just moving their eyes. There are several methods that were developed in order to help these patients' life more independently by using signals from human body, such as electrooculography, electrocardiography (ECG), electroencephalography (EEG), and electromyography (EMG).

1.2 The Study Motivation

There are some people in this world with an extreme disability such as severe cerebral palsy or amyotrophic sclerosis (ALS) patients strip them of the use of their limbs and facial muscles except the eye. Electrooculography (EOG) interfaces let users who cannot move their body, mainly because of their extreme disabilities move a cursor on a computer screen or control the direction of their wheelchair just by moving the eyes and many more.

There are several studies before did a pattern recognition and classification of the EOG signals in order to detect the eye movement, this study will show how much the accuracy in percentage of the EOG signal classifications can get by placing electrodes around the eyes. Usually the electrodes were placed both above and below the eyes or on the left and right sides of the eyes.

The voltage difference is measured between the cornea and the retina and it is due to the large presence of electrically active nerves in retinal compared to the front of the eye. With the cornea acted as positive charged and retina as a negative charged show that the eye acts as a dipole that will result in a negative or positive signal.

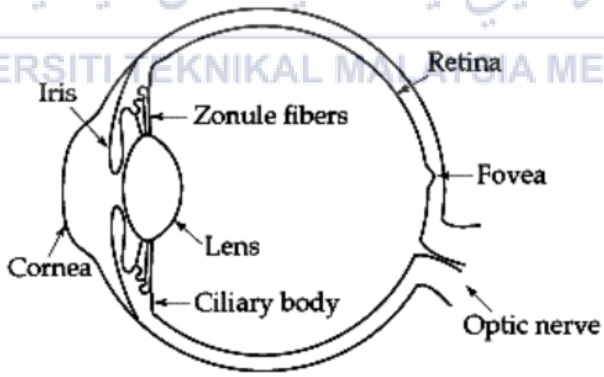


Figure 1.1: Structure of the eye (adapted from Google Images)

For this study, a Neural Network system will be proposed in order to classify the EOG signal gain from the movement of the eyes such as rolling upward, downward, left and right.

1.3 Problem Statement

Some researchers said that eyes are the organ of visions of sense the light and convert it into electro-chemical impulses in neurons and EOG is a very useful system in detecting the eye signal made by the movement of the eyes. Eye motions are sensitive and needs less utilization of physical strength. Specifically, for patients with extreme physical handicaps, eye movement is the last spontaneous movement for them to make a reaction.

Hence, in order to make their life more comfortable, many researchers and scientist shows their interest in recognition of eye motions in years. Hence, there are many methods that can be used to recognize eye motions such as Corneal Reflection Method [1], Limbus Tracking Method [2], Search Coil Method [3] and VTR Method [4]. Before they can recognize the eye motions, the signals must be validate and classified first.

When the eyes move, a potential difference will be generated that can be known as corneal-retinal potential (CRP) and most of the time, the polarity obtained is different for each different directions. To collect the data and record the signals can be quite challenging due to a very small range of the signal amplitude.

The neural network system used for validation and classifications after the features extracted from the obtained signals. In order to classify it, the data obtained must be arrange carefully because it can affect the accuracy percentage of the signals in order to know if the system were suitable or not in classifying the data.

1.4 Objectives

This study embarks on the following objectives:

- To classify the features of EOG specifically on cornea-retinal potential.
- To evaluate and validate the features extracted using Neural Network system.

For the first objective, the features of the EOG signals extracted by using MATLAB software. While for the second objective also using MATLAB software, but by using the neural network toolbox.

1.5 Scope of Work

This study used five subjects with three men and two women, respectively with healthy conditions, and their range of age between 22 to 24, and each subject were tested for five times but only the best signal out of five times of the test were recorded. While for the sensing element a Muscle V3 sensor will be used in order to sense the eye movements from up to down and left to right. To obtain the data, an equipment which is called NI MyRIO 1900 and LabView will be used as an interface to collect the data before it can be plotted as a signal by using MATLAB. And finally, in order to classify the data, the neural network toolbox (nnstart) were used.

1.6 Report Outline

For this study's report, there are five chapters included in order to explain everything. For Chapter 1 is introduction, shows the general information included in every other reports, such as introduction of the studies, problem statements, objectives and scopes.

While for Chapter 2 is the literature review, this chapter will share some previous studies that some are related about the classifications of EOG signals. In this chapter also explain the materials used to detect the eye movement.

Meanwhile in Methodology for Chapter 3 of this studies will explain the procedures from taking the signals of the eye movements, until classifying the data and finally analyze the performance of the classifications. This chapter is important in order to make sure that the work flow is accurate in order to bring out the expected outcome.

In chapter 4 cover the analysis and discussion of this study, and also shows the results obtained from classifying the data and shows some signals from the movement of the eyes.

Last but not least Chapter 5 that discuss about the conclusion for this study. Here, the conclusion was made based on the results obtained and some suggestion for references in the future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Topologies

For this chapter, some explanations about the theory and basic principles about this study will be given, especially about electrooculography, basic components used in obtaining the data, and some about neural network system. Lastly, this this chapter will make a review on some articles and journals of previous study on a similar subject.

2.1.1 Electrooculography (EOG)

Electrooculography is a new technology that record the eye movements by placing electrodes on user’s forehead around eyes and the technology’s principle are based on corneal-retinal potential (CRP). In a simple term, it is the resting potential between the cornea and retina also known as electrooculogram. An EOG detects eye movement when electrodes placed on the face and it measures the voltage between the electrodes.

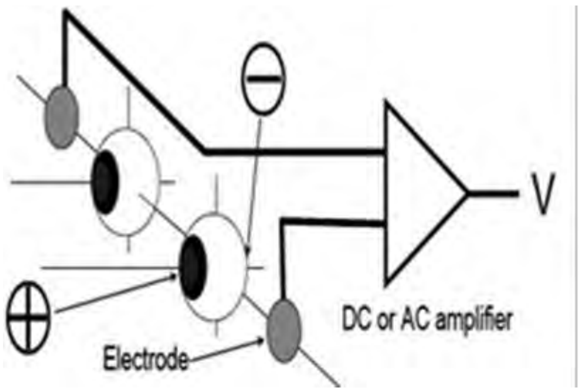


Figure 2.1: Principle of EOG

The electrical signal generate inside the eyeball by the metabolically active retinal epithelium, while the EOG monitor the movement of the eyes and the movement can be expressed as steady-electrical dipoles which are anterior and posterior pole. Anterior pole is the positive pole which is the cornea, while the posterior pole is the negative pole which is the retina.

Between the retina and cornea, there are a large amount of electrically active nerves present in the retina and this difference that people known ad CRP. The CRP produced when the eyeballs rotate, and the potential happened from hyperpolarization and depolarization between the retina and cornea [5].

In the past study, there are researchers did some similar study in developing the help system for people with extreme disabilities increased. Some of their systems are using the videooculography system (VOG) or infrared oculography (IROG) by detecting eye positions using a camera.

Also there is a voice recognition, simply give commands in order to control instruments or robots and the most popular methods is by using joystick to control different applications but it limited to upper body only and it is difficult to accomplish because it needs a fine control [6].

EOG interface has its own advantages because of its simple configuration, being inexpensive, easy to use, reliable and also let users handle it easier and more efficient. And there have been research groups developing and implementing eye gaze interfaces using various methods since 1980’s such as IROG, VOG and the limbus tracker.

Normally, EOG signals have the amplitude of 15 to 200uV and the waveform is easy to detect because of the linearity relationship between eye movements and EOG. In order to measure the EOG signal, there will be 4 electrodes placed around the eyes; above, below, right and left of the eye.

2.1.1.1 Hyperpolarization

Hyperpolarization happened when there are lights, then photons will strike the pigment molecules that will eventually cause photoreceptors to hyperpolarize. Hyperpolarize happens when the photoreceptors receive a photon of light that later causing the sodium gates in the membranes of the cell close. The bipolar cell eventually depolarize when photoreceptors get hyperpolarize and release a less inhibitory neurotransmitters. The number of calcium ion channels open is low when light is present causing the decreasing rate of neurotransmitter. An action potential is generated when bipolar cells depolarizing and this causes the ganglion cells to depolarize. [19].

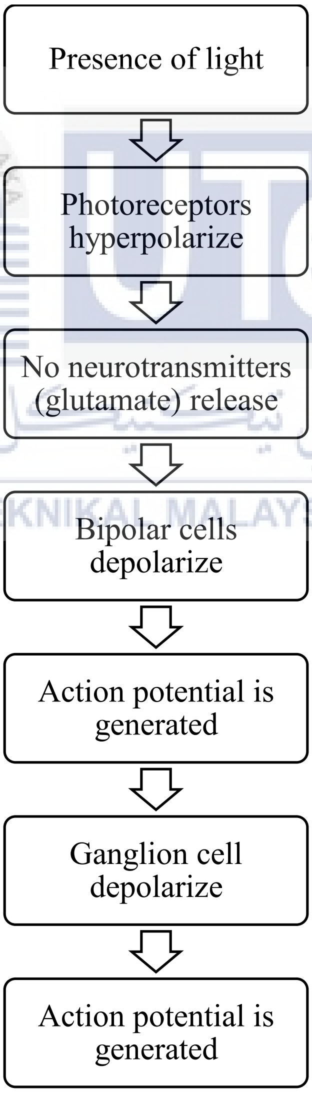


Figure 2.2: Hyperpolarization process

2.1.1.2 Depolarization

Depolarization mechanism happens when there are no light exist because photoreceptors do not receive photon in dark condition. Hence, the photoreceptors gets depolarized and this causing the discharge of inhibitory neurotransmitters that hinder the bipolar cells from depolarizing. When in the dark, higher neurotransmitters released when numbers of sodium ion channels opened at the synaptic terminal increase. Therefore, ganglion cells do not depolarize, hence no action potential is generated [20].

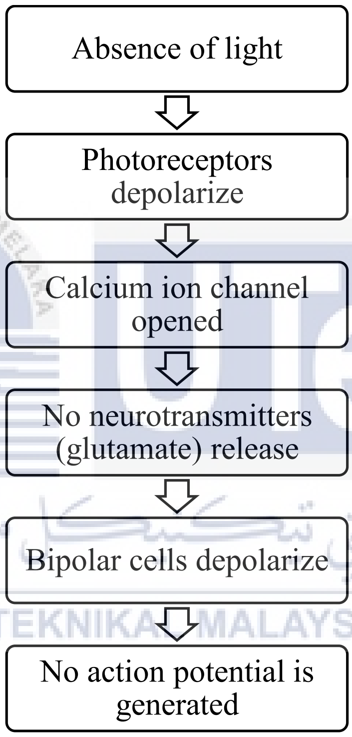


Figure 2.3: Depolarization process

2.1.1.3 Advantages of EOG

Below are the advantages when using EOG:

- It is linearly proportional to eye displacement.
- It is easy to use, especially for children and patients in bed.
- It can detect eye movements even with closed eyelids and during sleep.

- Eye movements' data are analog and the sampling rate of a following ADC can be chosen freely.
- It is the cheapest eye movement recording system.

2.1.1.4 Disadvantages of EOG

Below are some of the disadvantages when using EOG:

- The raw signal is a mix of a number of factors, including the rotation and movement of eyeball, movements of eyelid electrode placement, head movements, influence of luminance.
- The signal increase if the luminance increase.
- The signals easily contaminated with drift in long-term measurements.
- Variations in electrode slippage or polarization, skin resistance, even a variable CRP due to level awareness and light accommodation.

2.1.2 Types of EOG Signal

This section will explain about four basic types of eye movements.

2.1.2.1 Saccadic Eye Movements

Saccadic eye movement are inconsistent because of its rapid change of eye direction from one fixed point to another. It can be captured through a subject's head that is in stillness and relaxation mode while reading a book. As the subject is reading across the text, eyes will make larger voluntary movements which are known as saccades. Saccadic movement happens due to eyes cannot respond to the changes in the position of the target. When the target moves suddenly, there is a delay occurring before the eyes begin to move to the new target.

2.1.2.2 Smooth Pursuit Movements

Smooth pursuit movements are slower tracking movement of the eyes. This movement is under voluntary control which is not same as saccadic. Saccadic movement can be voluntary and also involuntary. Subject can determine whether or not to follow the moving target.

2.1.2.3 Vergence Movements

Vergence movements disengaged when two eyes are not moving in the same direction. This movement involves convergence or divergence of the lines of sight of each eye to see an object that is nearer or further, meaning that the subject gently focused on a target or distracted by another object.

2.1.2.4 Vestibulo-ocular Movements

Vestibulo-ocular movements happened in order to preserve images in the eyes while the position of the head change. Vestibular system will sense temporary changes in head position and swiftly produce corrective eye movements.

2.1.3 EOG Signal Detection

The range of the potential difference produced by the eye movements are very small, and it is also linearly proportional to eye displacement [7]. In order to obtain the signal, the disposable electrodes were placed on the outer side of the eyes in a horizontal and vertical positions. Figure 2.4 shows the position of the electrodes and Table 2.1 shows the function of each electrode.

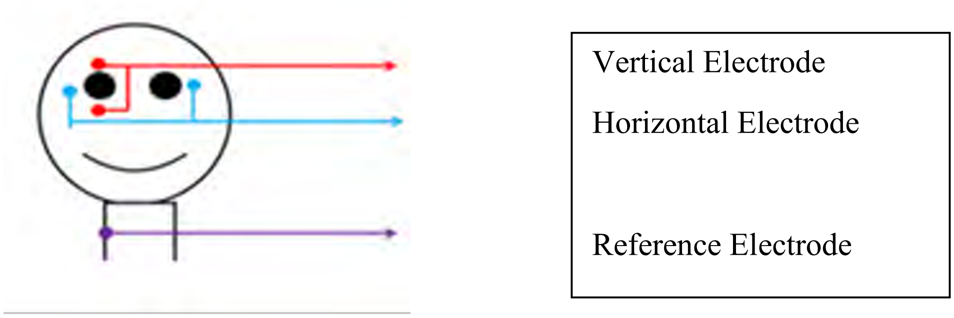


Figure 2.4: Electrode attachment position

Table 2.1: Function of each electrodes

Position of electrodes	**Functions**
Vertical electrode	Detect up and down eye movements
Horizontal electrode	Detect right and left eye movements
Reference electrode	Ground

2.1.4 Features Extraction

There are three main features that need to be extracted from the data of EOG signal before the classifications takes over. Features extraction has always been the first thing that need to be done before any analysis or classification of the data, and any disturbance and unwanted noise can be eliminated from here and only store the desired information.

The signals obtained in this study is time domain which is the signal's amplitude versus time and based on the previous research, the time domain has been widely used. The three main features that has been extracted were mean, maximum amplitude and root mean square (RMS) values. The Root Mean Square (RMS) is one of the most successful methods where it can be calculated as:

$$RMS = \sqrt{\frac{1}{T}\int_0^T EOG^2\, dt} \qquad (2.1)$$

2.1.5 Artificial Neural Network

Artificial Neural Network (ANN) is an information processing paradigm and a group of statistical learning models influenced by how biological nervous in processing information. The ANN learn by example just like people did, and it has a large number of highly affiliated processing elements of neurons working in unison to deal with certain problems [8].

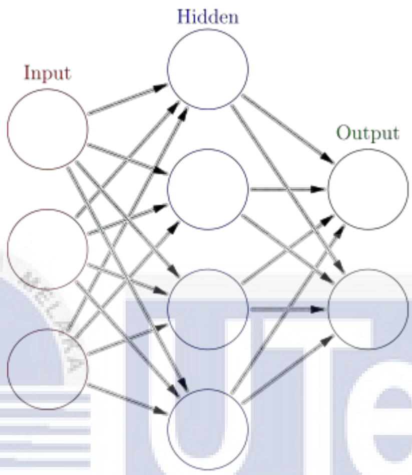


Figure 2.5: An interconnected group of nodes (adapted from Google Images)

By learning process, the ANN can be built up for a certain application such as classifying data or recognizing pattern. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. Neural network simulations appear to be a recent development and the first artificial neuron was produced in 1943 by the neurophysiologist Warren McCulloch and the logician Walter Pits.

2.1.5.1 Background

A simple artificial nodes that also known as "neurons", "neurodes", "processing elements" or "units" of an ANN are connected together in order to form a network. There is no single formal definition of what an artificial neural network is, but a class of statistical models can be called "neural" if they have these following characteristics:

- Have a sets of adaptive weight. Example: numerical parameters that are tunes by a learning algorithm.
- Capable of approximating non-linear functions of their inputs.

For an easy understanding, the adaptive weights are connection strengths between neurons that are activated during training and prediction.

Neural networks are similar to biological neural networks in performing functions collectively and in parallel by the units, rather than there being a clear delineation of subtasks to which various units are assigned. The term "neural network" usually refers to models employed in statistics, cognitive psychology and artificial intelligence [8].

In modern software implementations of Artificial Neural Network, the approach inspired by biology has been largely abandoned for a more practical approach based on statistics and signal processing. In some of these systems, neural networks or parts of neural networks (like artificial neurons) form components in larger systems that combine both adaptive and non-adaptive elements.

While the more general approach of such systems is more suitable for real-world problem solving, it has little to do with the traditional artificial intelligence connectionist models. What they do have in common, however, is the principle of non-linear, distributed, parallel and local processing and adaptation.

2.1.5.2 Why Use Neural Network

As most researches said, neural networks can be used can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques with their remarkable ability to derive meaning from complicated or imprecise data [9]. Here are some of the advantages why ANN is good in analyzing and classify data:

- Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.

- Self-Organization: An ANN can create its own organization or representation of the information it receives during learning time.
- Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
- Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage.

2.1.5.3 A Simple Neuron

Artificial neuron is a device that have many inputs but only have one output, and it has two modes of operation which are the training mode and the using mode.

- Training mode: neuron can be trained or not for particular input patterns.
- Using mode: the associated output becomes current output when the taught input pattern is detected at the input.

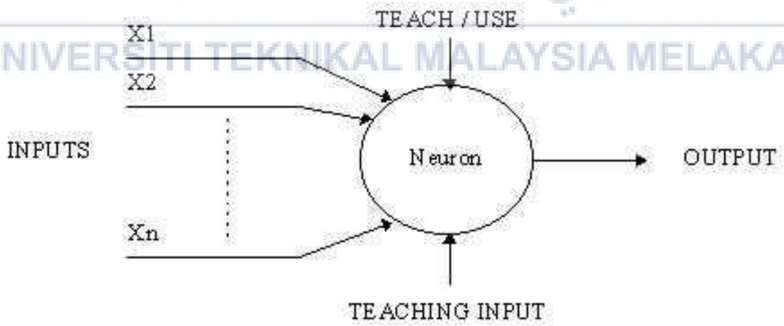


Figure 2.6: A simple neuron (adapted from Google Images)

2.1.5.4 Pattern Recognition

The most known application of ANN is pattern recognition and it can be applied by using a feed-forward neural network that has been trained first. During training, the network is trained to associate outputs with input patterns. When the network is used, it identifies the input pattern and tries to output the associated output pattern.

The power of neural networks comes to life when a pattern that has no output associated with it, is given as an input. In this case, the network gives the output that corresponds to a taught input pattern that is least different from the given pattern.

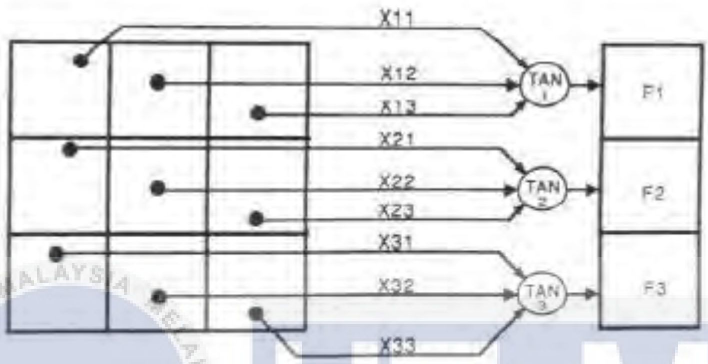


Figure 2.7: Feed forward neural network (adapted from Google Images)

2.1.5.5 Architecture of Neural Networks

There are four types of architecture of the neural network systems which are feed-forward networks, feedback networks, network layers and perceptrons. Based on Figure 2.7, the feed-forward ANN only allow signals to flow in one way only and there is no feedback. This type of network, also known as bottom-up or top-down, tend to be straight forward and they usually used in pattern recognition [8].

Meanwhile for feedback networks, it can have signals travelled in both ways by putting loops in the Figure 2.7 and the networks can be very powerful but extremely complicated at the same time. This kind of network can change continuously until they reach the desired equilibrium point.

The most common type of ANN architecture, network layers, consists of three groups or layers of units as shown in Figure 2.8 which are:

- Activity in inputs represents raw information that is fed into the network.
- The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units.
- The behavior of the output units depends on the activity of the hidden units and the weights between the hidden and output units.

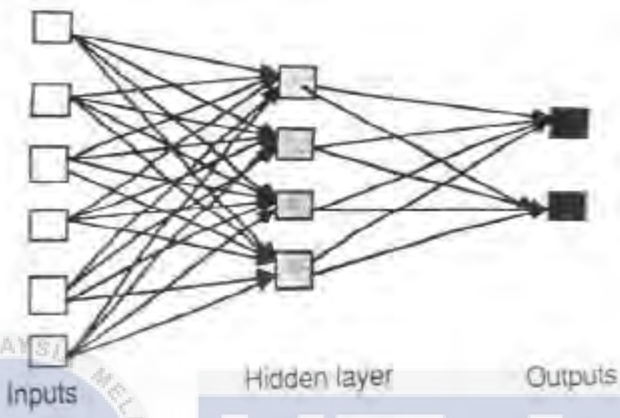


Figure 2.8: A simple feedforward network (adapted from Google Image)

The hidden units are free to construct their own representations of the inputs and the weights between input and hidden units determined when each hidden unit is active. The single-layer organization, in which all units are connected to one another, constitutes the most general case and is of more potential computational power than hierarchically structured multi-layer organizations. In multi-layer networks, units are often numbered by layer, instead of following a global numbering.

Perceptrons, the last type of ANN architecture, is the most influential work on neural nets in the 60s introduced by Frank Rosenblatt. Figure 2.9 shows how the perceptron turns out to have neuron with weighted inputs with some additional, fixed, pre-processing. Units labelled A1, A2, Aj, Ap are called association units and their task is to extract specific, localized featured from the input images. Perceptrons mimic the basic idea behind the mammalian visual system and they were mainly used in pattern recognition.

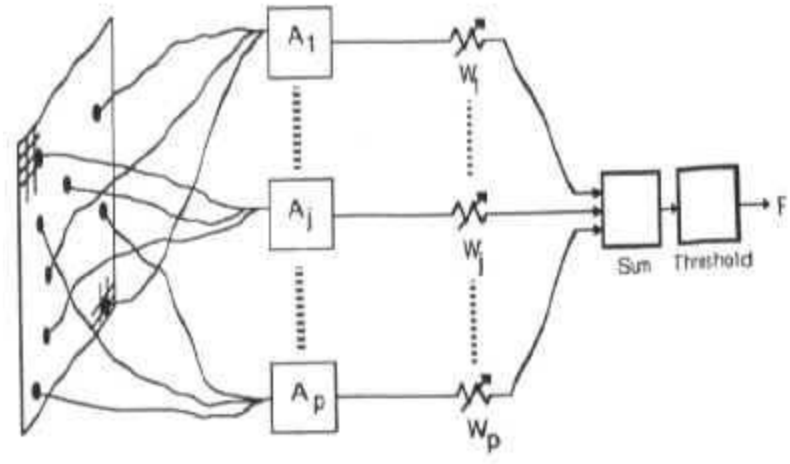


Figure 2.9: An example of peceptron system.

2.1.5.6 Training the Network

The supervised leaning trained the network with expected replies, each iteration modifies the connection weights in order to minimize the reply (expected value). Layer by layer the weight adjusted by calculating from output layer to input layer [10]. The weight adjusted by:

$$\Delta W_{ji} = \eta \delta_j f(a_i) \qquad (2.2)$$

Where ΔW_{ji} is the weight adjustment between j and neuron i from previous layer; $f(a_i)$ is the output of neuron i, η is the learning rate, and δ_j depends on the layer. For output layer, δ_j is:

$$\delta_j = (Y_j - \hat{Y}_j) f'_i(a_j) \qquad (2.3)$$

Where Y_j is the expected value and $\hat{Y}_j$ is the current output of neuron j. For the hidden layer, δ_j is:

$$\delta_j = f'_i(a_j) \sum_{k=1}^{K} \delta_k W_{kj} \qquad (2.4)$$

Where K is the number of neurons in the next layer. When the learning rate is low, the convergence of weight to optimum is very slow and when the rate is too high, the network can oscillate, or worse it can get stuck in a local minimum. To reduce these problems, a momentum α is used and ΔW_{ji} becomes:

$$\Delta W_{ji} = \eta \delta_j f(a_i) + \alpha \Delta W_{ji}^{Prev} \qquad (2.5)$$

Where ΔW_{ji}^{Prev} denotes the correction in previous iteration.

2.1.6 Filter

Having environmental disturbance in the EOG signal like any other bio-signal is a normal things to happen. That is why in many reasons that a filtering process is needed in order to eliminate the disturbance from the system. A high pass and low pass filter needed in order to remove high and low frequency noise signal. For high pass filter, the range of frequency is set at 0.5Hz or 1.0Hz. While for low pass filter is set at 40Hz and can reduce the power line noise, which is an electromagnetic interference, until 60Hz [11].

2.2 Previous Researches

EOG is one of a common method that has been applied to disabled people such as users that lost their limbs or ALS patients that has the problem to control electrical devices. The signal detected from the movement of the eyes derived from Cornea Retinal Potential (CRP) signal [12]. In order to validate the EOG signals, the neural network toolbox in MATLAB will be used to classify and validate the data.

Eye movements such as upward, downward, left and right, winks, and blink can produce electrical activities. All these activities can be recognize by using electrodes of bio signal devices positions at certain part around the eyes [13]. A thesis about bio-based HCI system did a study that HCI system has the possibility to help severely disabled patients to use computer directly by bioelectricity rather than physical force [14]. Their study stated that there are three main parts in order to develop the system which are EOG amplifying and acquisition, EOG pattern recognition and control command output.

A study about eye movement analysis has been made by recording the data from the movement of the eye just by using EOG system [15]. A method has been proposed based only from three basic eye movements which are saccades (rapid movement of the eye), fixations and blink to use person-independent (leave-one-person-out) training. This training will include 1 to 3 subjects (male/female) to use the EOG system for a few times until they'll get used to it and know how to control the system smoothly. Then they'll compare the results with another subjects that use the system for the just a few times, this will show the percentage of precision of 76.1% for subjects with training over all other participants.

Some classification methods do not always give a satisfactory results, but not with ANN. A study about classifying individual recognition of vocal characteristics in the behavioral sciences by using the backpropagation gradient, and they get a result of 100% recognition and 90% prediction success. Their performance became stable, even with more than 10 neurons, any changes were negligible.

Meanwhile, a study from Taiwan about using four kinds of ANN classifier in classifying underwater passive sonar signals radiated by ships. They are using the probabilistic based classifier-Probabilistic Neural Network (PNN), the hyperplane based classifier-Multilayer Perceptron (MLP), the kernel based classifier-Adaptive Kernel Classifier (AKC), and the exemplar based classifier-Learning Vector Quantization (LVQ) resulting with a 100% correction rate and a very good classifier. Based on their studies, the methods in extracting features and classification depends on the need in training speed and correction rate [9].

After all the classifications, training and validations, the data and network can proceed in developing a technology that can help disabled people. There are some researcher used the Eye Mouse to detect movements by developing the PC-based HCI system using eye detection and tracking [16]. It tracks the user's movements from a camera and translates them into the control messages of the mouse on the screen, then the system receives and displays a live video of the user sitting in front of the computer by using an internal camera on a laptop or camera that is mounted above the monitor of a PC computer.

While researcher from Poland stated that detecting the eye placement can be used to correct eye movement artifacts in electroencephalogram data. In this case, data coming from the eye tracking device cannot be corrupted by any electrophysiological signal [17]. They focused on eye gaze detection as a non-invasive tool for computer navigation.

2.3 Summary and Discussion

Chapter 2 explain in details about electrooculography and Neural Network. From there can see that both EOG and Neural Network are quite complicated and without any basic knowledge about any of the two, this study can never get finished.

This chapter also discuss about previous study that has been done by researcher for years related with EOG and ANN. Most of the used ANN as classifier, there are even some studies did about other types of classifier but the results are not quite good compared to ANN. There are many ways that can be used for this study just by according the studies of some journals such as wavelet, but ANN is the simplest but gives the best result for this study.

CHAPTER 3

METHODOLOGY

3.1 Principle of Methods

Chapter 3 will explain the steps and the process of the work that need to be taken in order to achieve the objectives from Chapter 1. There are several steps required to be taken in order to achieve the objectives for this study as stated in Chapter 1. Some of the ideas extracted from the literature review of the previous chapter.

From the previous study, normally they use five wet disposable electrodes around eyes in order to catch the signal when the eye moves. The positions of the disposable electrodes can be seen in Figure 2.4. Hence, this study will only focus on four eye movements, which are upward, downward, left and right.

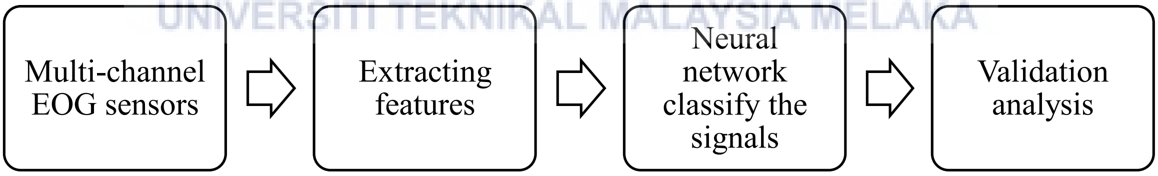


Figure 3.1: Flow of classification of EOG signals using neural network

From the block diagram in Figure 3.1 above shows the flow of classification of EOG signals using neural network. When multi-channel EOG sensors detect signals from the eye movements, the data recorded will then go to MATLAB in order to plot the signals. From there the features extracting can be done and compile it in Microsoft Excel. Hence, the features can be upload into neural network toolbox (nnstart) in order to classify the main four eye movements. Finally the validation analysis can be made based on the performance percentage obtained.

3.2 Hardware Implementation

In this section will explain the functions of some of the equipment used in conducting the experiment, such as disposable electrode, NI MyRIO 1900 and V3 muscle sensor in taking the signal from eye movements.

3.2.1 Disposable Electrode

The electrode sensor used in this study placed besides the eyes is the disposable electrodes. The sensors consist of three electrode connected with one 3.5mm plug connector, and each electrodes usually consists of a sensing element (snap) in contact with an electrolyte (gel). The function of electrolyte is to minimize the gap between electrodes and skins, and also to reduce resistance.

Once the electrode placed on the surface of the skin, the skin becomes an integral part of the circuitry, and the noise level in the signal can be high if there is a slightest air gap between skins and electrodes. Figure 3.2 below shows the three disposable electrodes connected in a single 3.5mm plug connecter and these electrodes connected to the V3 muscle sensor in order to obtain the signal.

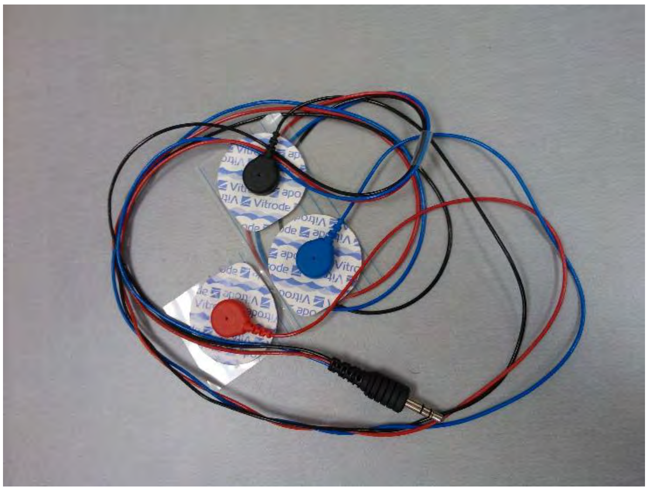


Figure 3.2: Disposable electrodes with a single 3.5mm plug connector

Meanwhile, a dry skin contributes to a good pad adhesion and trace quality and any hair should be minimized and removed before applying the electrodes. Alcohol pad, as shown in Figure 3.3 below, will be applied on the area of the skin, in order to clean it, where electrodes should be placed and wait for the alcohol to dry.

Figure 3.3: Alcohol pad

3.2.2 V3 Sensor Kit

A Muscle Sensor V3 kit has been used as the sensing element for this study. This sensor kit will detect the electrical potential produced by measuring the muscle activity when the eye moves. For EOG signals, it has a very low amplitude and sometimes with a poor condition signals, but this sensor kit can recover it by filtering and rectifying the electrical activity of the muscle around the eyes. Figure 3.4 and Figure 3.5 below shows the top and bottom layout of the sensor kit while Table 3.1 shows the description of the sensor kit.

Figure 3.4: Top layout of the Muscle Sensor V3 kit

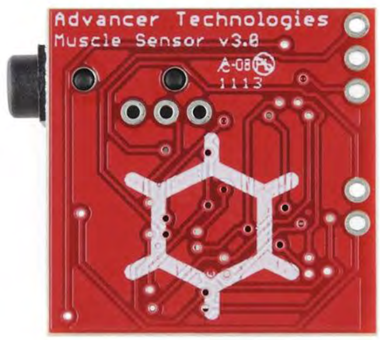


Figure 3.5: Bottom layout of the Muscle Sensor V3 kit

Table 3.1: The characteristics of the muscle sensor

Characteristic	**Description**
Features	• Small form factor (1 inch x 1 inch) • Specially designed for microcontrollers • With adjustable gain • On-board 3.5mm cable port • Pins fit easily on standard breadboards
Applications	• Video games • Robots • Medical devices • Wearable/mobile electronics • Powered exoskeleton suits
Power supply voltage (V)	±3.5V to ±18V

3.2.3 NI MyRIO

When the Muscle Sensor V3 kit sense the electrical potential produced by the eye movements, the NI MyRIO 1900 from National Instrument will act as the data acquisition equipment for this study. The main function of this equipment is as the interface between MATLAB and the sensor kit, and users can design systems such as control, robotics and mechatronics since this equipment is a portable reconfiguration I/O (RIO). For this study, MyRIO will be using LabView as the interface where it is complete with the de-noising system and the interface suitable for this study because of its real-time processing capability. Figure 3.6 and Figure 3.7 below shows the top and bottom layout of the NI MyRIO 1900.

Figure 3.6: Top layout of the NI MyRIO 1900

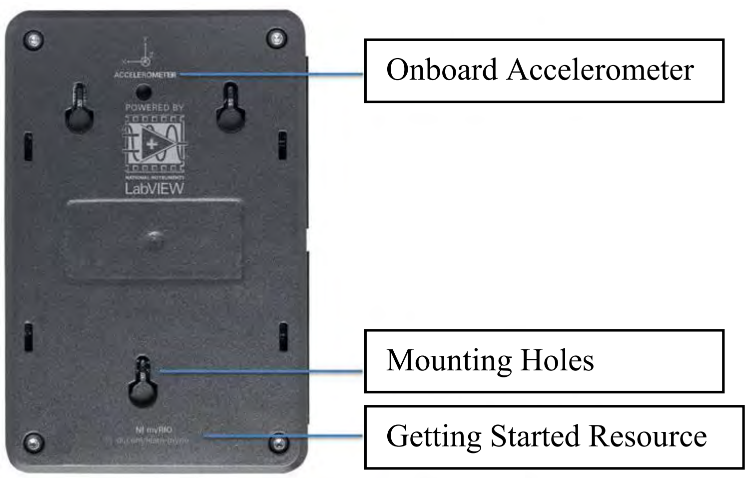


Figure 3.7: Bottom Layout of the NI MyRIO 1900

This data acquisition equipment build with a three types of connector which are Expansion Port (MXP) connectors A and B, and Mini System Port (MSP) connector C as can be shown in Figure 3.8 below, and Table 3.2 shows this equipment specifications.

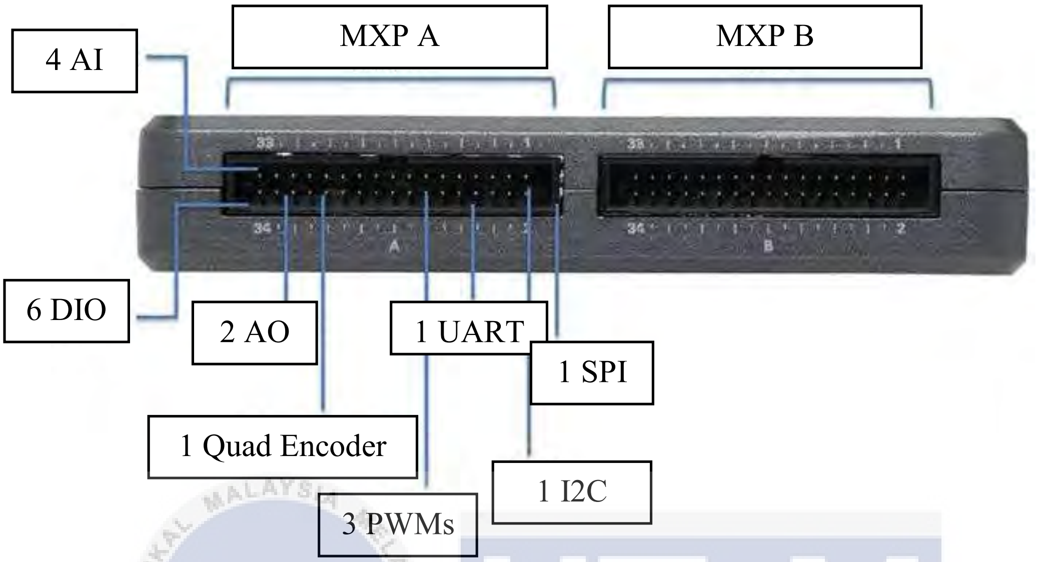


Figure 3.8: MyRIO MXP connectors

Table 3.2: Specifications of the MyRIO 1900

Specifications	Descriptions
SoC	Xilinx Zynq-7010 with a dual core Cortex A9 processor and FPGA with 28,000 cells
Memory	Unknown
Storage	Unknown
Expansion Port	• MXP - Two identical ports (MXP A and MXP B) with 4 analog inputs, 6 digital inputs/outputs, 2 analog outputs, 1 quad encoder, 3 PWMs, 1 UART, 1 I2C and 1 SPI

	by default. Ports configuration is customizable with LabView FPGA • MSP - ower, 2 analog outputs, 4 analog inputs, and 8 digital inputs/outputs by default. Ports configuration is customizable with LabView FPGA
Connectivity	Wi-Fi
USB	1x USB host port, 1x USB device port for connection to PC
Audio	Audio In, Audio Out
Misc	User and reset buttons, power, status and Wi-Fi LEDs, 4 user-defined LEDs, on-board accelerometer
Power	6V to 16V input, or battery

3.3 Experimental Approach

This section shows steps in conducting this study, and also included the explanation for the reliability and validity test.

3.3.1 Electrodes Placement

In order to obtain the CRP, the disposable electrodes are placed on the muscles around the eyes and these muscles also known as the extraocular muscle. Based on Figure

3.10 below shows the extraocular muscle consists another sixth type of muscle which are superior rectus, inferior rectus, lateral rectus, medial rectus, inferior oblique and superior oblique and Table 3.2 shows the muscle's function.

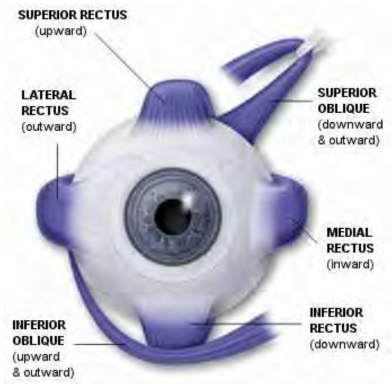


Figure 3.9: Eye muscles (adopted from Google Image)

Table 3.3: Function of the muscles

Muscle	Function
Superior rectus	Control upward movement
Inferior rectus	Control downward movement
Lateral rectus	Control outward movement
Medial rectus	Control inward movement
Superior oblique	Control downward and outward movement
Inferior oblique	Control upward and outward movement

Meanwhile, Figure 3.11 and Figure 3.12 below shows the electrodes placement in horizontal and vertical positions.

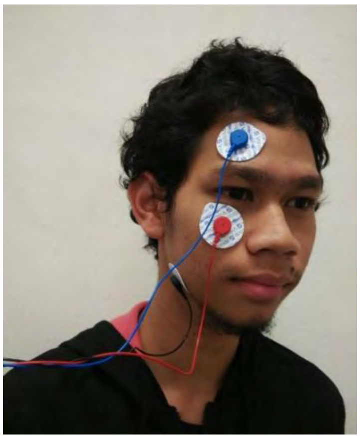


Figure 3.10: Electrodes in vertical position

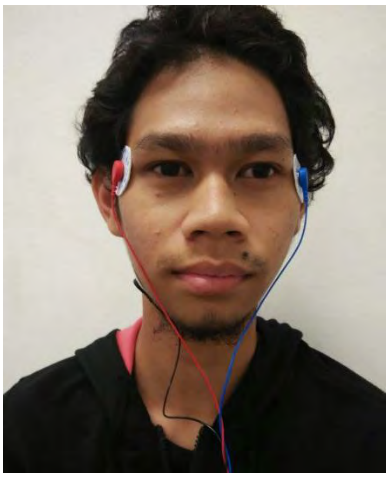


Figure 3.11: Electrodes in horizontal position

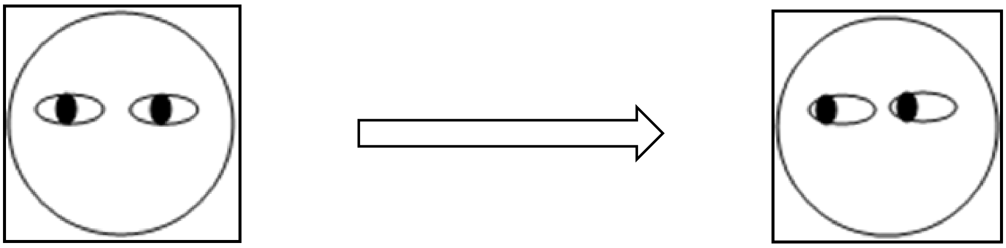
The blue cable electrode is a negative and the red cable electrode is a positive, while the black cable electrode is a ground. The ground electrode should be placed on the non-muscle area because contraction of muscles will contribute artifact to the signal obtained.

3.3.2 Experimental Steps

This study used 5 subjects and there are several requirements that the subjects need in order to fit to do the tests. The subject's age must be between 20 to 24 years old and the can be shortsighted or longsighted, but they can't have other void such as color blindness or night blindness. The test will be carried out in an indoor environment with a fluorescent light intensity.

First, as shown in Figure 3.13, the subject need to look at the center point for two seconds, and then look to the left for four seconds in order to obtain the left signal. The same method applied in order to obtain the right signal, by looking at the center point for two seconds, and then look to the right for four seconds as shown in Figure 3.14 and the same steps applied in obtaining up and down signals as shown in Figure 3.15 and 3.16 respectively.

For all of this tests, only eye movements involved and all the subjects need to remain stills in a sitting posture for the whole process. Even blinking needed to be avoided, and because it is an unconscious eye movement, the subjects need to pay their full attention.



Look forward for two seconds

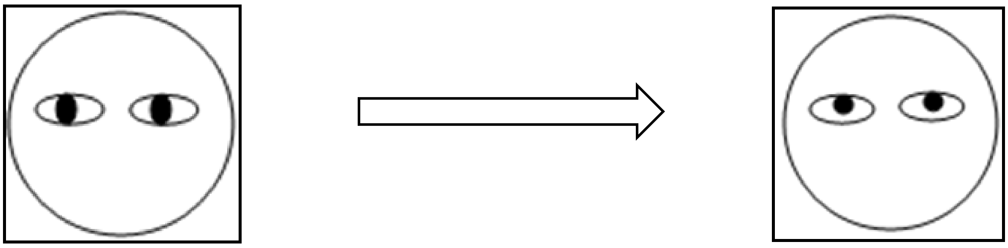
Look left for four seconds

Figure 3.12: Obtaining left signal

Look forward for two seconds

Look right for four seconds

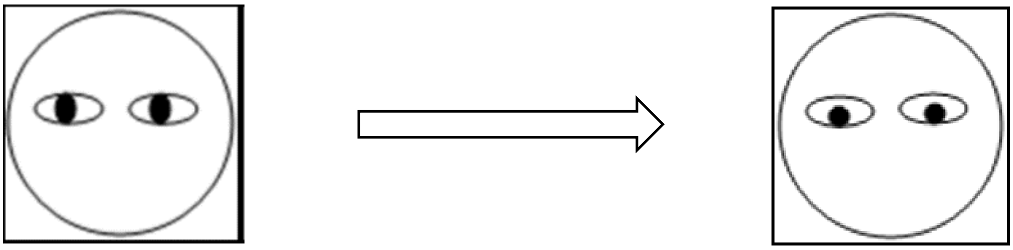
Figure 3.13: Obtaining right signal



Look forward for two seconds

Look up for four seconds

Figure 3.14: Obtaining upward signal



Look forward for two seconds

Look down for six seconds

Figure 3.15: Obtaining downward signal

3.3.3 Reliability Test

There are lots of methods that can be done in order to test the reliability of the data obtained but for this study will be only using one method, which is by repeating the process of obtaining left and right signal for five times. The reliability test need to be done in order to show the repeatability of the data obtained is still same even after the test conducted five times.

Just like the first test; look forward for two seconds and look right and look at the center again and look left; these steps will be repeated for four times on the same volunteer. The five times test conducted in order to make sure that the amplitude is in the same range and also to have a more accurate results with no disturbances. The same steps applied for obtaining the upward and downward direction tests.

3.3.4 Features Extracted

After done with the tests, the data of the eye signals are recorded in a .txt file and each signals have until 1000 data. In achieving one of the objective of this study, which is extracting the EOG signal by using MATLAB, all of the data need to be converted into Microsoft Excel.

After that, load the data into MATLAB and plot the signal for each of the eye movement. When the signal has been plotted, only then the features can be extracted and this study only focus on three main features, which are the mean of the signal, the maximum amplitude of the signal and the root-mean-square (RMS) of the signal. After obtaining all the features, then all four eye movements can be classified.

3.3.5 Neural Network Data Classification

After the features obtained, the EOG signals need to be classified. There will be four classes and each represent left, right, up and down. The features needed to be arrange in Microsoft Excel according to eye movements as an input data in representing the network. As for the target data in defining the desired network output can be seen in Table 3.3 below.

Table 3.4: Target output of the data

Subject	**Movement**	**Target Output**			
1	Down	1	0	0	0
2	Down	1	0	0	0
3	Down	1	0	0	0
4	Down	1	0	0	0
5	Down	1	0	0	0
1	Up	0	1	0	0
2	Up	0	1	0	0
3	Up	0	1	0	0
4	Up	0	1	0	0
5	Up	0	1	0	0
1	Left	0	0	1	0
2	Left	0	0	1	0
3	Left	0	0	1	0
4	Left	0	0	1	0
5	Left	0	0	1	0
1	Right	0	0	0	1
2	Right	0	0	0	1
3	Right	0	0	0	1
4	Right	0	0	0	1
5	Right	0	0	0	1

The Neural Network Start GUI can be found in MATLAB by typing nnstart command and a toolbox will come up just like Figure 3.17 below, and then choose Pattern Recognition Tool button in order to open the Neural Network Pattern Recognition Tool (nprtool).

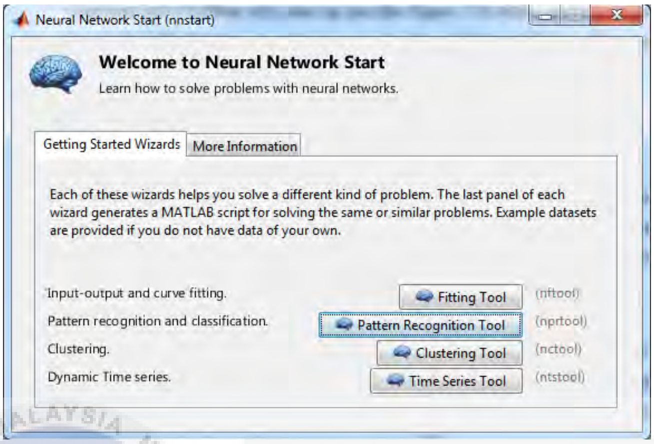


Figure 3.16: Neural Network Pattern Recognition Tool

From there, the nprtool window will come up and then can proceed by clicking next in order to open the Select Data window as shown in Figure 3.18. The Inputs can load the InputEOG that has been arrange in the workspace of the MATLAB, while for Targets can load the target data as shown in Table 3.3.

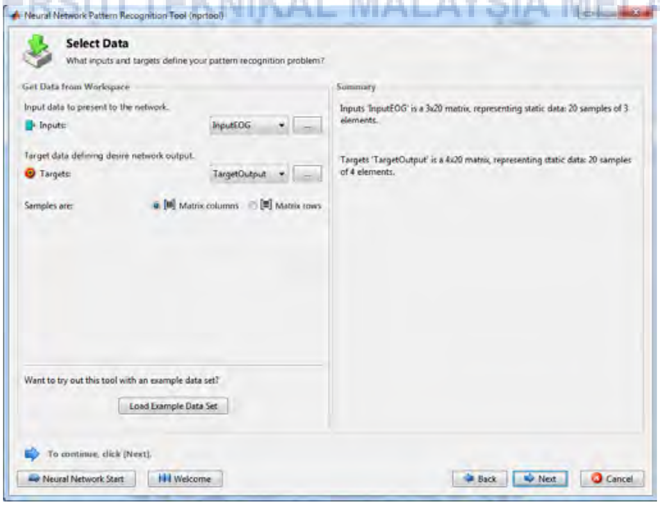


Figure 3.17: Loading target and input data

Then can click Next to continue to the Validation and Test Data window as shown in Figure 3.19. There are three kinds of sample which are Training, Validation and Testing.

The Training presented to the network during training, and the network is adjusted according to its error and for this study, training are sets to 70%.

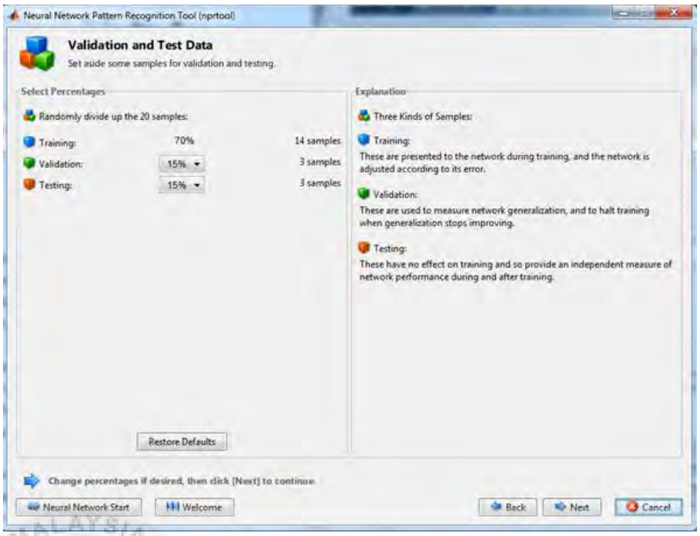


Figure 3.18: Setting the training, validation and testing samples

Meanwhile for Validation are used to measure network generalization and to halt training when generalization stops improving, while Testing have no effect on training and so provide an independent measure if network performance during and after training. For both of Validation and Testing data are sets to 15% each respectively of the original data.

After clicking the Next button, the Network Architecture window will open up and from here can see that the standard network used is a two-layer feed-forward network with a symmetric sigmoid transfer function.

The default number of hidden neurons is set to 10 for most of the trials. In order to see the differences if the result will show differently, the hidden neuron is set to 50 for another test. Figure 3.20 shows the pattern recognition neural network diagram.

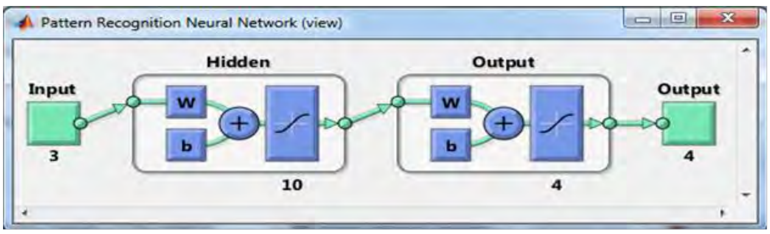


Figure 3.19: The pattern recognition neural network diagram

The number of Input is set to three because the input data has only three features, which are the mean, RMS and maximum amplitude. While the number of output neuron is set to 4, which is equal to the number of elements in the target vector (the number of categories). Next is training the network as shown in Figure 3.21 below by using a scaled conjugate gradient backpropagation.

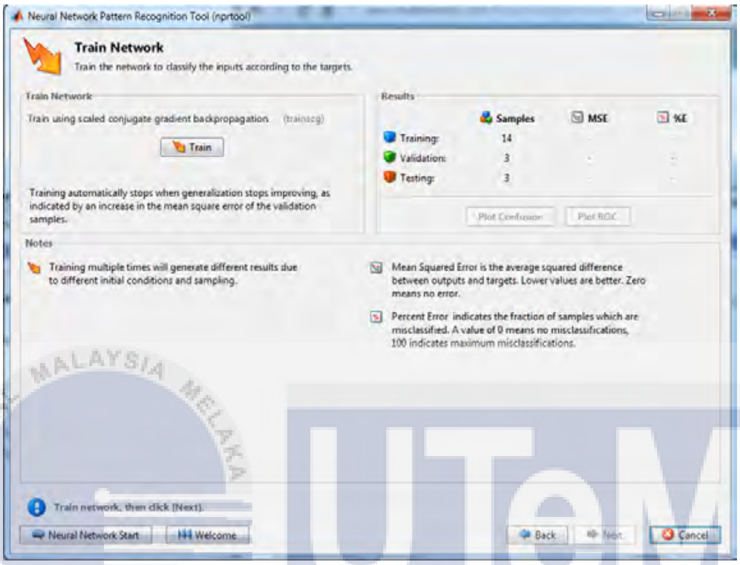


Figure 3.20: Training the network

After finished training, a Plot Confusion and Plot ROC (Receiver Operating Characteristic) will be showed in order to see the performance of the network. If the results are not satisfying, the network can retrain again until the desired results can be achieved. This can happen because every time the network get trained will generate different results due to differential conditions and sampling.

3.4 Project Flow Cart, Gantt chart and Key Milestones

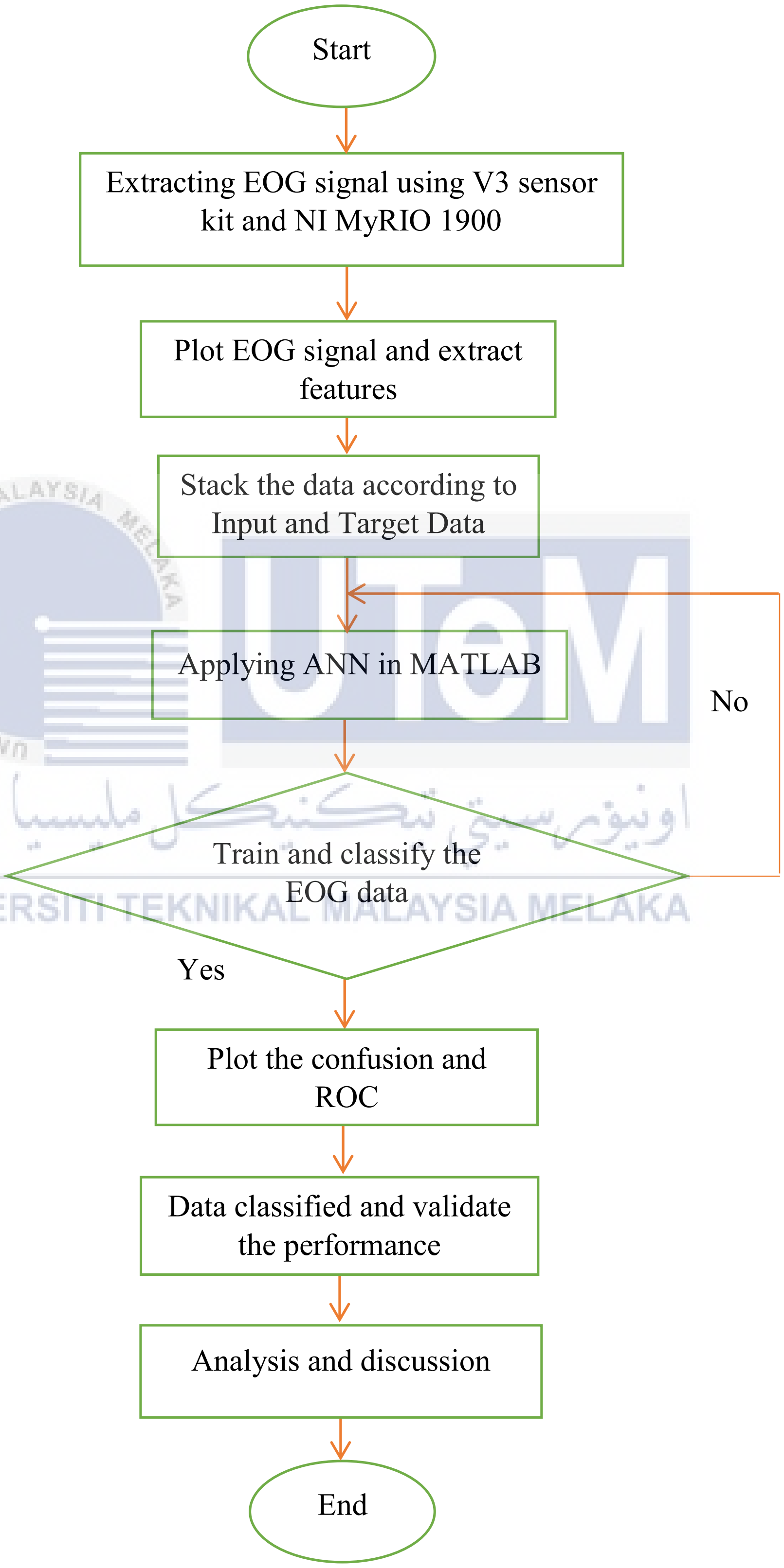
3.4.1 Project Gantt chart for FYP 1 and FYP 2

Chart 3.1: Gantt chart for FYP 1 and FYP 2

Project Task	Final Year Project 1					Final Year Project 2				
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Mei	Jun
Discussion with supervisor related to FYP title										
Search Journal and Literature Review about EOG signals & ANN										
Understand the theory and operation of previous work										
Project Proposal - Introduction & Literature Review										
Project Proposal – Methodology, Preliminary Result & Conclusion										
Extracting EOG Signal using V3 sensor kit, NI MyRIO 1900 and LabView										
Extracting features of EOG signal & stacking features according to the eye movement										
Classifying and validate the data using Neural Network										
Analysis & Discussion										
Report Writing										

3.4.2 Flow Chart of the Methodology for FYP 2

Chart 3.2: Flow chart of the methodology for FYP 2



3.4.3 Key Milestone

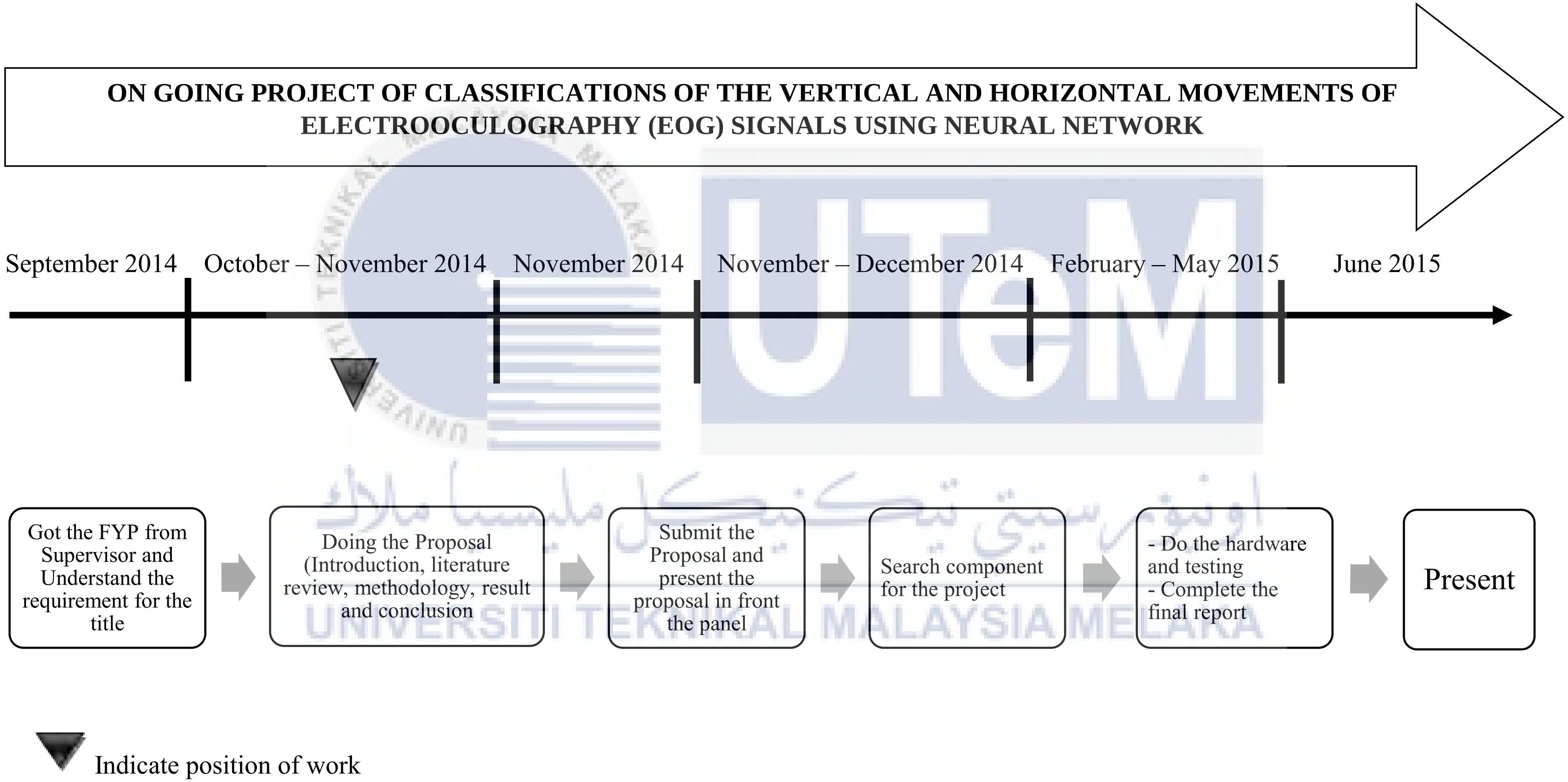


Figure 3.21: Key milestone for this study

CHAPTER 4

RESULT AND DISCUSSION

Chapter 4 will shows the results obtained that have been achieved throughout the whole semester. Some of the following tables and figures obtained from one volunteer only. The sampling time for this study was set to 0.001 second, hence the frequency set was 1000Hz and all the signal has been recorded for every 0.001 second.

4.1 Signal Obtained from Each Eye Movement

After a few tests, it is shown that when the cornea get a move near to the electrode, the signal will be positive. While if the cornea gets further away from electrodes and retina get closer to the electrode, the signal will be in negative. This section will show the plotted signal for each movement of the eyes only by one subject and also the features extracted for every subject in a single table.

4.1.1 Downward Signal

Based on Figure 4.1 below shows the down signal obtained from a subject. Based on the signal plotted, when the eyes move downward (blue signal) and the cornea get close to electrode resulting with positive signal. The peak occurred when the eyes started to change direction from looking forward to looking downward, and this indicates that there are eye movements. During the test, the subject have to look forward for two seconds and only then the subject can change direction by looking down.

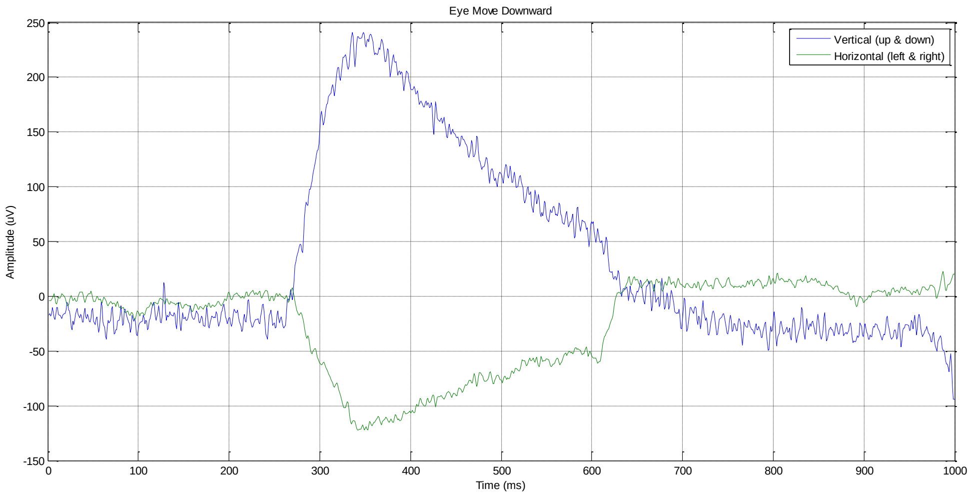


Figure 4.1: Eye move downward

4.1.2 Upward Signal

Figure 4.2 shows that when the eyes move upward (blue signal), the cornea moves away from the electrode resulting with a negative signal. Same like moving downward, the peak shows that there are muscle activities when the subject try to move his eyes upward. During the test, the subject have to look forward for two seconds and only then the subject can change direction by looking up.

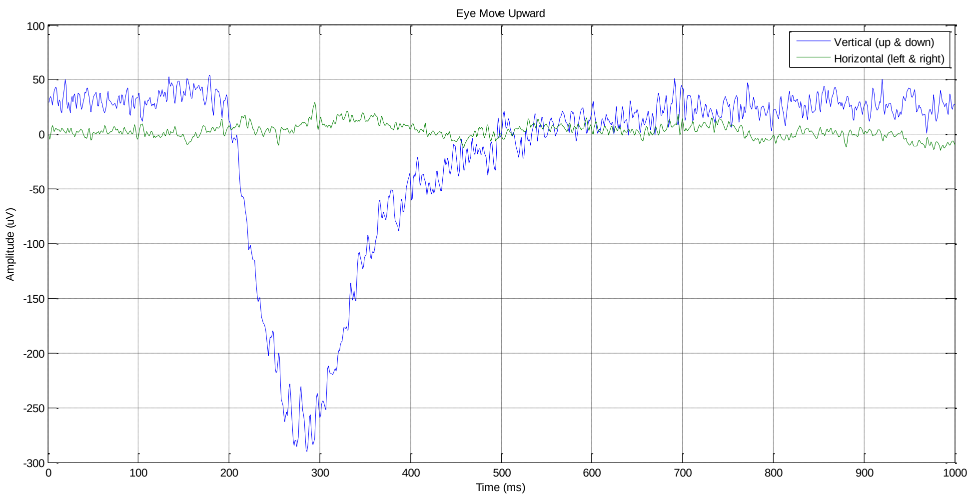


Figure 4.2: Eye move upward

4.1.3 Left Signal

In Figure 4.3 below shows the signal obtained by moving eyes to the left (green signal), making the cornea get closed to the electrode resulting with positive signal. As explained before, the subject need to look forward for two seconds and then make their eyes move to the left direction. As seen in the figure, the peak shows that there are muscle activities during the motions of the eye move to the left.

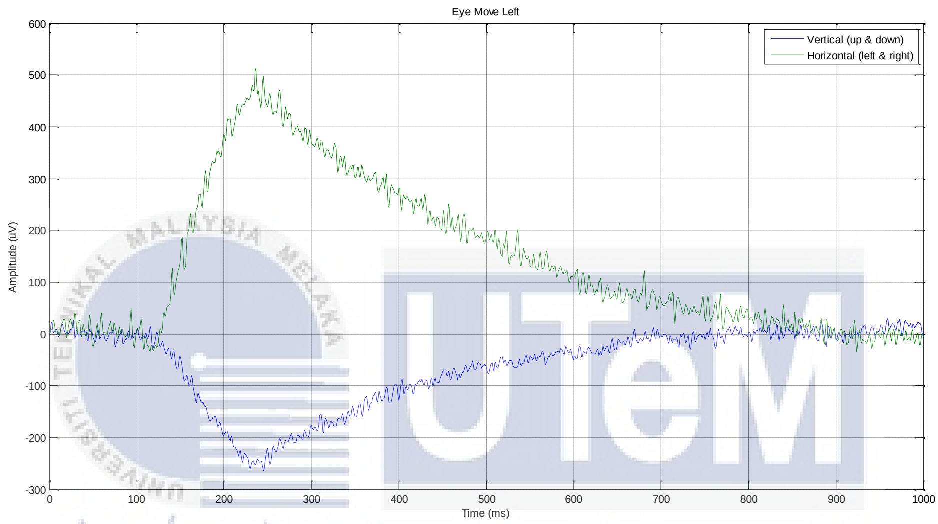


Figure 4.3: Eye move to the left

4.1.4 Right Signal

Last but not least, as shown in Figure 4.4 below that the signal obtained by moving eyes to the right (green signal) causing the cornea moves away from electrode and eventually resulting with negative signal. When the eye start to move to the right, the signal rise to the peak as shown in Figure 4.4 below. This shows that there are also muscle activities recorded.

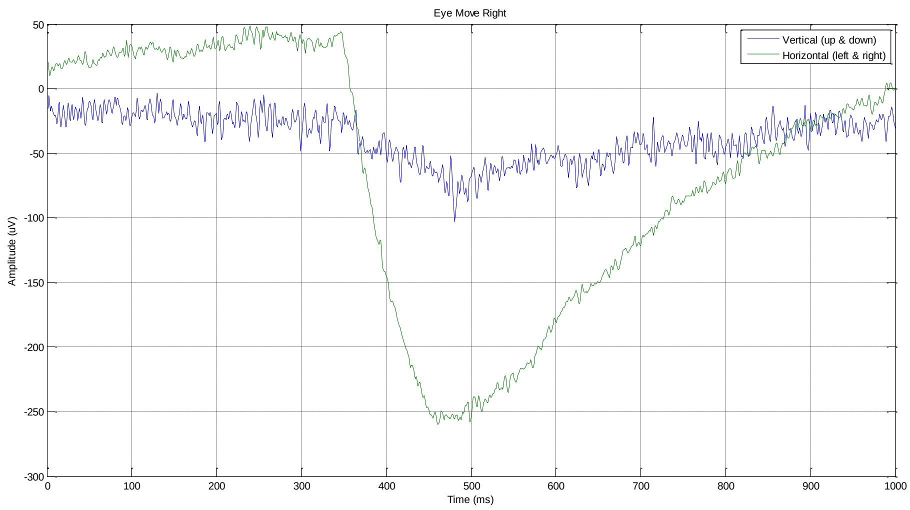


Figure 4.4: Eye moves to the right

Meanwhile, Table 4.1 below shows the amplitude of the signals according to Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 above.

Table 4.1: Amplitude of the signals

Channel	**Movement**	**Evoke Potential (uV)**
Vertical	Downward	240.9
	Upward	-290
Horizontal	Left	512,3
	Right	-102.7

4.1.5 Values of Features Extracted

This study has been tested on five subjects and as can be seen on the table below based on the features extracted, that the CRP is different for all five subjects because each of them have their own cornea-retinal potential. Table 4.2 below shows the combination of features extracted from all subject which are the mean of signal, RMS voltage of the signal and the maximum amplitude of the signal. Later, these features get separated as an Input and load it in the neural network toolbox.

Table 4.2: Features extracted from all subjects

Subject	Movement	Mean (uV)	RMS (uV)	Max (uV)
1	Down	35.555	70.177	228.02
	Up	-84.278	123.607	-395.23
	Left	-46.394	92.391	51.91
	Right	-108.994	163.83	-382.7
2	Down	33.148	90.503	240.91
	Up	-16.879	81.936	-290.01
	Left	140.905	201.837	512.25
	Right	-66.586	118.797	-259.74
3	Down	106.239	128.127	312.6
	Up	-102.263	150.953	-395.52
	Left	53.145	167.237	319.95
	Right	-144.55	161.562	-328.5
4	Down	49.104	80.18	282.02
	Up	-54.983	94.087	-264.95
	Left	138.861	199.886	457.86
	Right	-172.332	199.827	-398.59
5	Down	61.593	118.215	386.05
	Up	-61.195	99.986	-207.46
	Left	76.132	131.149	281.97
	Right	-118.871	172.175	-409.48

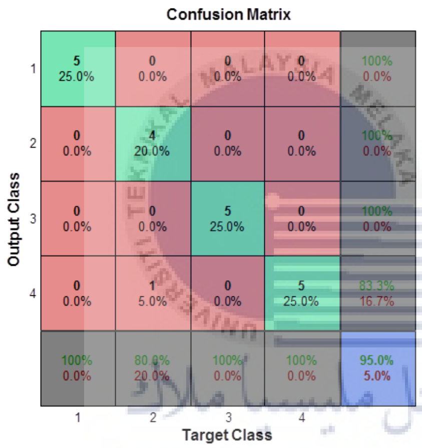
Hence, each subjects have their own and different CRP probably due to the muscle contraction because it each contraction is different for everyone. The amplitude produced can be affected by the strength of the muscle contraction, but there are other factors that also contribute in causing the difference of CRP. Such as noise generated between the contact of disposable electrodes and skins, metabolic rate of the tissues and also visual stimulation.

4.2 Classifications and Validation of the Network

For this study, the default number of hidden neurons is set to ten as it was standardize for every subjects. The Plot Confusion and Plot ROC are acceptable after the network get trained for a few times until the desired results achieved.

For the classification of the network, as can see from the confusion matrix below that there are four output classes and four target classes. The overall network outputs are quite perfect with 95% accuracy as can be seen in the blue squares. The green squares shows the high numbers of correct responses more than the low numbers of incorrect responses in the red squares.

For this study, the network were tested with two different set of neurons in order to see if the more neurons were sets, the more accurate the confusion matrix can be plotted. The first training were set with 10 neurons, while the second training were sets with 50 neurons and based on the observation shows that there are not much different to the accuracy percentage. Accept that for 50 neurons, it takes a longer training in order to get the desired accuracy percentage, while for 10 neurons, just a few times training to get the 95% accuracy percentage. The differences can be seen in Figure 4.5 and Figure 4.6 below.



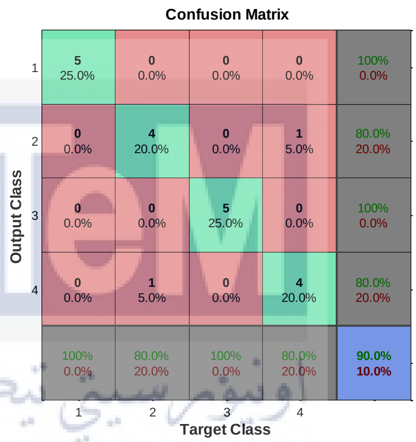


Figure 4.5: Plot Confusion for 10 neurons   Figure 4.6: Plot Confusion for 50 neurons

The classes above are combinations of features data from five subjects, and each class represents the eye movement directions. Class 1 represent for looking down, class 2 for looking up, class 3 for looking left and class 4 represent for looking right.

Meanwhile for Receiver Operating Characteristic (ROC) curve, it shows the performance of the network system and plots the ROC for each output class. The ROC plot consist the True Positive Rate against the False Positive Rate. The more each curve hugs the True Positive Rate and top edges of the axis of the plot, the better the classification. Hence, Figure 4.7 and Figure 4.8 below shows that the network can validate as a good classification since almost all of the curves are near the edge of the True Positive Rate.

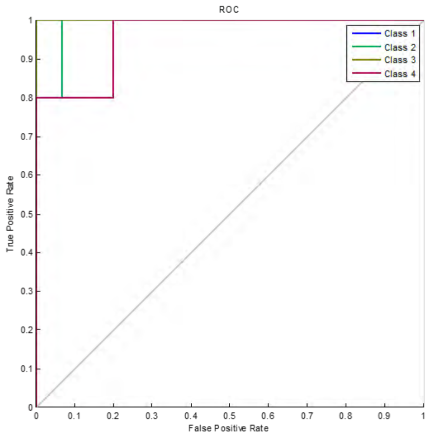


Figure 4.7: Plot ROC for 10 neurons

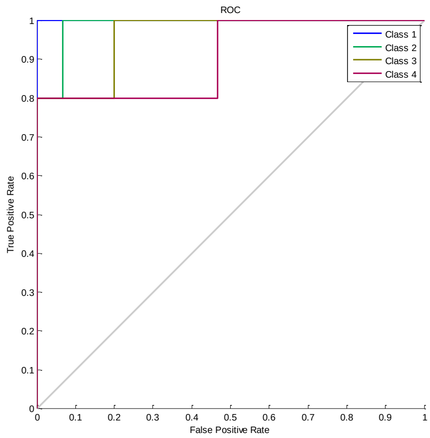


Figure 4.8: Plot ROC for 50 neurons

Just like Plot Confusion, there are not much difference between 10 neurons and 50 neurons. The only difference is that 10 neurons give a better result based on the ROC plotted, the curves in Figure 4.7 are more to the edges of the True Positive Rate indicates that it is a better classification than using 50 neurons.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Electrooculography (EOG) signal is a very interesting bio-potential technology that many people starting to show some interest at. Some even developed technology by using EOG signal in controlling wheelchair, control computer cursor and a lot more just by moving the eyes. But in order to ensure that these technology give their best service to users, the signal must be validate first. This is the main purpose of the study, to validate that ANN gives an accurate classification network of the eye movement.

The overall classification for five subject is a success with the accuracy of 95% of the direction of the eye movement, and the performance of the network is almost perfect. Based on the EOG signal obtained, the peak of the signal happened at the moment eyes change direction and when the eyes are in a static position, there will be no amplitude in the signal. Based on the features extracted and also on the signal obtained shows that each subject have a different amplitude. This shows that sometimes the muscle cannot be control at will, and the muscles can easily stressed out when too much movement happened and can cause the high amplitude on the signal too. Hence, it is best to let the subject to rest the eyes from any movement for thirty to sixty seconds before the next test.

Finally, this study can be concluded that based on all the tests on five subjects shows that the Artificial Neural Network can be considered as a good classifier of a network because with the feed-forward function, the tests can re-train until the most accurate results achieved.

5.2 Recommendations

This study focus on the ANN as a classifier because it is the most used classifier anywhere. There are several previous studies said that there is another classifier that gives the most accurate pattern recognition compared to any other classifier, which is called the Learning Vector Quantization (LVQ) algorithm.

Learning Vector Quantization (LVQ) is a prototype-based supervised classification algorithm in the world of computer science. From vector quantization, LVQ is the control version and can only be used when there are input data taken where in this case the EOG signal. A supervised neural network that utilizes a winner-take-all learning approach is called the LVQ algorithm. The algorithm mix competitive learning with supervision and can be used for pattern classification. LVQ usually consist layers that include competitive subnet, and a linear layer [18].

LVQ famous for a widely used approach to the classification adopted in the area of practical problems, as well as medical image and data analysis. LVQ strategies are not difficult to actualize and instinctively clear and the classification of information focuses on comparison with various prototype vectors.

The LVQ algorithm is like a more developed and complicated version of ANN, and the LVQ algorithm is in the Neural Network Toolbox (nntool) in the MATLAB software. But due to lack of information and references, ANN is a better choice for this study. So, hoping that future students and researcher can learn and develop more about LVQ algorithm and apply it to any classification studies.

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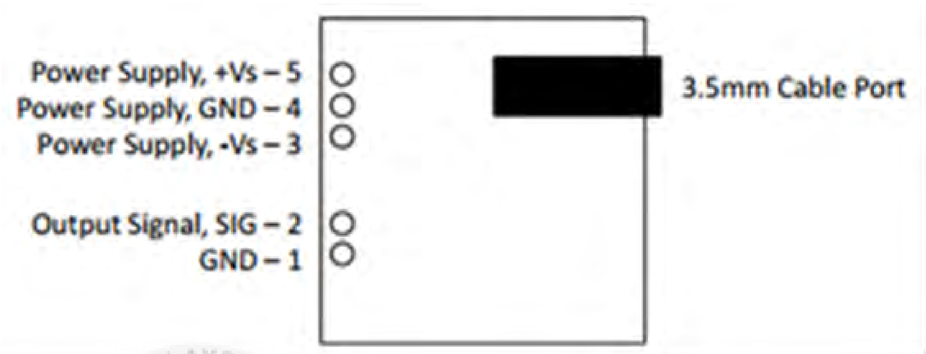
APPENDIX A

Pin layout of Muscle Sensor V3 kit



APPENDIX B

Physical dimension of NI MyRIO 1900