ANALYSIS OF ELECTROOCULOGRAPHY (EOG) FOR CONTROLLING WHEELCHAIR MOTION

NOR AZURAH BINTI BAHAROM

A project report submitted in partial
fulfillment of the requirement for the award of the
Master of Electrical Engineering

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Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JUNE 2015

ABSTRACT

Rehabilitation devices are increasingly being used to improve the quality of the life of differentially abled people. Human Machine Interface (HMI) has been studied extensively to control electromechanical rehabilitation aids using bio signals such as EEG, EOG and EMG. Among the various bio signals, EOG signals have been studied in depth due to the occurrence of a definite signal pattern. Persons suffering from extremely limited peripheral mobility like Spinal Cord Injury (SCI) usually have the ability to coordinate eye movements. This project focuses on the analysis of EOG signals for controlling wheelchair motion. The EOG signal is obtained from the eye muscle by using disposable electrodes. For the acquisition of EOG raw signal, NI MyDAQ is used. The features are extracted from the conditioned EOG signal such as root mean square value and average rectifier value. The signals are usually non-repeatable and contradictory in nature. Therefore, to classify such kind of signal, a classifier able to withstand uncertainties in data is required. Fuzzy theory is well known for its capability to deal with imprecise environment. So, in this work a fuzzy classifier is designed and implemented using LabVIEW software. The classifier system is tested using 10 subjects. The simulation results have authenticated the capability of implemented system.

ABSTRAK

Peralatan pemulihan semakin digunakan untuk meningkatkan kualiti kehidupan orang kelainan upaya. Human Machine Interface (HMI) telah dikaji secara meluas untuk mengawal alat bantuan pemulihan elektromekanikal menggunakan isyarat bio seperti EEG, EMG dan EOG. Antara pelbagai isyarat bio, isyarat EOG telah dikaji secara mendalam kerana pola isyarat yang jelas. Orang yang mengalami mobiliti periferal terhad seperti kecederaan saraf tunjang biasanya mempunyai keupayaan untuk menyelaras pergerakan mata. Projek ini memberi tumpuan kepada analisis menggunakan isyarat EOG untuk mengawal pergerakan kerusi roda. Isyarat EOG diperolehi dari otot mata dengan menggunakan elektrod mudah guna. Untuk pengambil alihan isyarat EOG, NI MyDAQ digunakan. Ciri-ciri yang diambil dari isyarat EOG yang diingini seperti nilai punca min kuasa dua (root means square) dan penerus purata. Isyarat ini biasanya tidak berulang dan tidak menentu secara semulajadi. Oleh itu, untuk mengkelaskan apa-apa jenis isyarat, pengkelas yang dapat menahan keadaan tidak menentu dalam data diperlukan. Teori fuzzy terkenal dengan keupayaan untuk pengesanan dengan persekitaran yang tidak tepat. Jadi, dalam kerja-kerja ini pengkelas fuzzy direka dan dilaksanakan menggunakan perisian LabVIEW. Sistem pengelas diuji menggunakan 10 subjek. Keputusan simulasi telah disahkan keupayaan sistem yang dilaksanakan.

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LIST OF SYMBOLS AND ABBREVIATIONS

Hz	-	Hertz
s	-	seconds
mV	-	millivolts
ARV	-	Average Rectified
BCI	-	Brain Machine Interface
EOG	-	Electrooculography
EMG	-	Electromyography
EEG	-	Electroencephalography
HCI	-	Human Computerized Interface
HMI	-	Human Machine Interface
MAV	-	Mean Average Value
NI	-	National Instrument
SCI	-	Spinal Cord Injury
RMS	-	Root Mean Square
QOL	-	Quality of life

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CHAPTER 1

INTRODUCTION

1.1 Project Background

A rehabilitation device is one that assists a differentially abled individual to control his or her environment and communicate more effectively. These assistive devices promote greater independence by enabling people to perform tasks with the help of technology. [1]

Quality of life (QOL) for disable people and the user who has high level Spinal Cord Injury (SCI) can be improved by using assistive devices. Therefore recovering their mobility may significantly improve their QOL. Assistive devices such as a wheelchair are an important means of transport for these people. There are a few types of wheelchair such as manual wheelchair, powered wheelchair and smart wheelchair. Conventional powered wheelchairs are operated using a simple joystick. Recently, alternative means for the wheelchair operation have been studied, such as voice recognition, vision recognition, and bio potential signals [2].

In order to control smart wheelchair, there are several methods of using biological signals such as using brain signal by Electroencephalography (EEG), muscle signal by Electromyography (EMG) and eye muscle by using Electrooculography (EOG). The biosignal waveform of EEG, EOG and EMG are shown in Figure 1. Majority of those who suffer muscular and neurological disorders such as spinal cord injury still retain the ability to move their eyes, thus EOG suits well for the people with severe disabilities to control a wheelchair [3].

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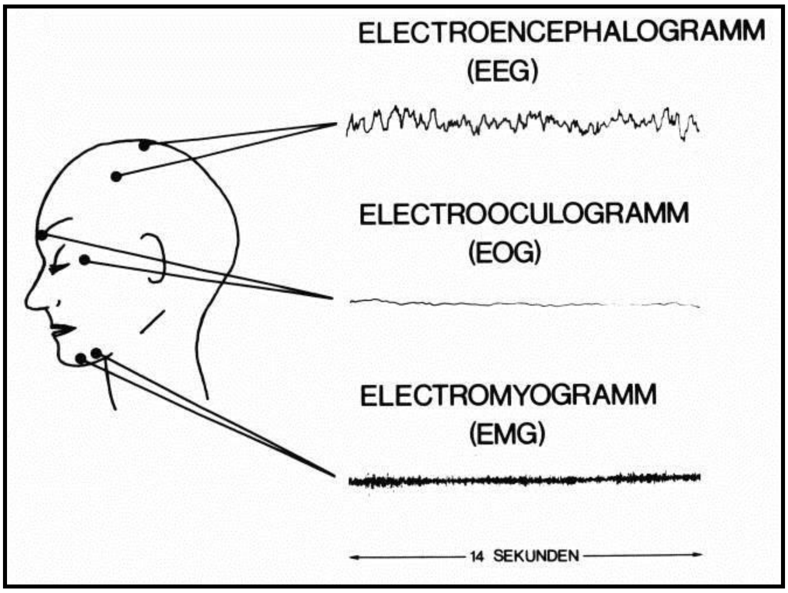

Figure 1.1: EEG, EOG and EMG Waveform [4]

1.2 Problem Statement

Assistive device such as smart wheelchair can improve the QOL for disable people. The extensive literature and research reports about the important of the development of smart wheelchair have been studied since 1980 [5]. Nowadays, there are many help systems to control and guide smart wheelchair. All this systems allow their users to travel more efficiently and with greater ease. In the last years, the applications for developing help systems to people with several disabilities are increased, and therefore the traditional systems are not valid. There are many different circumstances that will lead to a person requiring the use of an assistive device to communicate with others or to control their environment. Paralysis can result from spinal cord injury following a road traffic accident or other trauma. It can be caused by damage to the brain due to a brain haemorrhage or a tumour. Motor neurone diseases, which cause wasting of the muscle tissue, may eventually lead to paralysis, and necessitate use of a communication and control device. A major focus of this project is on exploring a range of available options, so that a suitable assistive technology system may be identified for each individual user, based on their capabilities and requirements that will allow all severely disabled people to use a control and communication device [1].

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1.3 Aims and Objectives

The main aim of the work presented in this thesis is to develop a reliable and easy to use Electrooculography (EOG) system to control the wheelchair motion. In order to achieve the aim there are three objectives to be done:

1.3.1 Develop a data acquisition system for acquiring EOG signal.

1.3.2 Develop an algorithm for controlling the wheelchair motion.

1.3.3 Classify the signal based on the direction using Fuzzy Network.

1.4 Scopes and Limitation

The scope and limitation for this project are:

1.4.1 Three surface electrodes are being use on eye muscle at horizontal channel.

1.4.2 The data acquisition are obtain from the EOG are based on eye muscle movement.

1.4.3 Three modes of operations for controlling the wheelchair motion, the modes are forward, right, left.

1.5 Outline of Thesis

The presented work organized in 5 chapters. First chapter is an introduction of project background, aims and objectives, scopes and limitations and outline of the thesis.

Chapter 2 consists of literature review, study of EOG signal and classification from previous work, summarize different type of wheelchair, principle of EOG and eye muscle.

Chapter 3 summarized the material and methods used for acquisition of signal and classification, setup of placement electrode, signal acquisition, feature extraction, signal processing and design classifier for EOG signal.

In chapter 4 results are presented and designed classifier is tested with EOG signals so that the success rate of the classifier can calculate.

Chapter 5 concludes the presented work and recommendation is summarized.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 will be discuss about the generation and development of wheelchair and the history and applications of controlling a smart wheelchair by using Electrooculography (EOG) signal from a past few decades. In this chapter also includes the principles of EOG and eye muscles.

2.2 Wheelchairs

The rapidly growing older adult population is demanding greater access to improved health care and assistive technologies in order to improve QOL. Also, the increasing numbers of people that suffer from disabilities due to accidents, neurological disorders, and brain damages contribute to the demanding of care-givers for day to day activities including mobility, communication with environment, controlling the house hold equipment and the difficulty of getting a care-giver resulting the need of assistive technology. This kind of assistive technology will be alternative way to improve communication, accessibility, mobility and cognitive domains of the patient. One the example of assistive technology is the smart wheelchair that allows the person to move freely and independently [6]. There are a few types of wheelchair such as manual wheelchair, power or electric wheelchair and smart wheelchair.

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2.2.1 Manual wheelchair

Manual wheelchairs provide mobility to individuals with physical impairments but are poorly suited for individuals with a combination of physical and cognitive or perceptual impairments. Manual wheelchairs are more physically demanding than powered wheel-chairs; however, powered wheelchairs require cognitive and physical skills that not all individuals possess. [7].

2.2.2 Powered wheelchairs or Electric Wheelchair

The next invention of wheelchair is powered wheelchair. Powered Wheelchair is the ultimate choice to the elderly and disabled patients. The user needs to control the wheelchair by using the joystick. However the joystick can be a limiting factor since it can be used only by people who still have some sort of control, enough for manipulating it.

Power wheelchair is often prescribed to older adults who no longer have the physical capabilities to walk and the strength to use a manual wheelchair. However, the safe control of a powered wheelchair requires a significant level of skill, attention, judgment, and appropriate behaviour. Older adults with the afore-mentioned types of impairments, especially cognitive impairments, often cannot maintain the skills needed to safely operate a powered wheelchair. Therefore, in the interest of safety for the operator and by standers, these users are generally not permitted to use a powered wheelchair, even when manual wheelchair use is difficult or ineffective. As a result, many impaired older adults experience greatly reduced mobility [8]. Electric or power wheelchairs make use of either gears or belts, or sometimes both. Power wheelchairs with belt drives are usually quiet, but tend to be high-maintenance. Gear drives are fairly low-maintenance, but tend to wear out quickly and getting noisy in the process. [9]

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2.2.3 Smart Wheelchair

The smart wheelchair is the latest technology of wheelchair. Usually this type of wheelchair will be used for a patient that suffers from severe motor dysfunction which only can move body parts located above their shoulders.

A smart wheelchair is a typically consists of either a standard power wheelchair to which a computer and a collection of sensors have been added or a mobile robot base to which a seat has been attached and its purpose is to assist a user with a disability or anyone who is not able to operate a regular power wheelchair and to reduce or eliminate the user role of driving. It provides navigation assistance to the user in a number of different ways, such as assuring collision-free travel, aiding the performance of specific tasks, and autonomously transporting the user between locations.[5]

Most patients who will use smart wheelchair is patients with high-level Spinal Cord Injury (SCI), nervous system diseases, cognitive impairment, and blindness, presumably in conjunction with mobility impairment [10]. A smart wheelchair can restore autonomy to patient with sensory-motor disabilities by enabling them to move around freely without depending on the care givers.

The different between smart and manual or powered wheelchairs is the ability of the machine to interact with the user. This interaction is steered by sensors that have been installed to the wheelchair. This sensor must be accurate, inexpensive, small, lightweight, consume little power and robust to stand up to environmental conditions [11].

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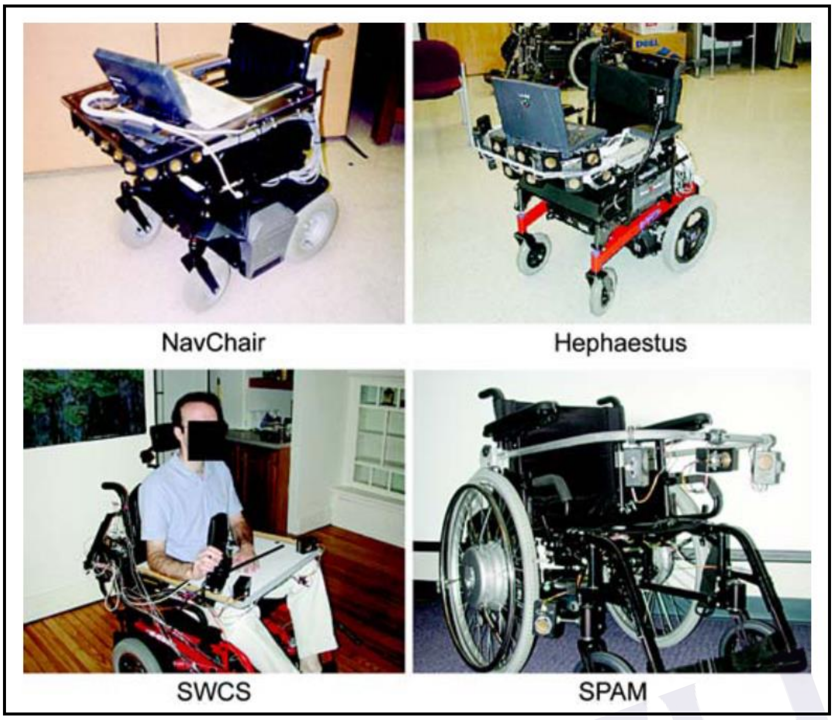

Figure 2.1: Example of Smart Wheelchair, SWCS = Smart Wheelchair Component System, SPAM = Smart Power Assistance Module

2.3 Wheelchair Motion Control Methods

Electric motors direct the power-driven wheelchair, as a replacement for the handicapper's arms. A joystick acts as a control input to drive the wheelchair electric motors. On the other hand, alternative control inputs such as eye movements and voice are adopted, to support the users whom are not able to move their limbs[12].

A powered wheelchair is driven by electric motors, instead of the user's arms. It is normally controlled with a joystick. However, other input devices such as voice, EOG and EMG are used if the user has restricted limbs movements. This work has proposed an eye tracking based on EOG signals to control the wheelchair. Wheelchair motion control using eye tracking has been applied in many research studies. In [2] and [13] used EMG to control the direction and EOG to control the speed of the wheelchair.

While other researches has focused on Human Computer Interfaces (HCI) based on EMG and EOG signals, where the user will be allowed to perform other simple tasks beside wheelchair motion control in [14] and [15] . Although, only few focused on using EOG signals solely to control the wheelchair in [16] and [3] . Other

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than that, in [12], [17] and [18] the design is approaches for gaze control, where the user controls the wheelchair by gazing directly at the physical target point.

2.4 Brain Computer Interface (BCI)

Another method that can be used in controlling the wheelchair is by using BCI. BCI is a communication system in which an individual sends commands to the external world by generating specific patterns in brain signals and a computer detects and translates the brain signal patterns into commands that accomplish the individual's intention. It is an alternative communication and control solutions for individuals with severe disabilities especially those who have lost all voluntary muscle control (locked-in). Users can control BCI just by thinking. It is well-known that EEG signals, particularly in EEG-based BCI systems, are non-stationary and low in signal to noise ratio. The non- stationarities may be caused by the subject's brain conditions or dynamically changing environments. Therefore, careful design of signal processing, feature extraction, classification and adaptation is required. [13]

2.5 Human Computerized Interface

HCI can be used and connected with many electro-biological signals. Some of the more commonly bio-signals are EMG, EEG and EOG. The HCI systems translate these signals into electrical signals that control external devices such as wheelchair. They can represent the only technology for severely paralyzed patients to increase or maintain their communication and control options [15] . HCI can be used to improve the capacity of the movement of individuals with motor dysfunctions. In this study EOG is used to develop the HCI aiming those people who can only communicate through eyes. EOG is an efficient alternative for HCI without speech or hand movements. [19]

2.6 Principle of Electrooculography

Electrooculography (EOG) signal is the electrical potential which is generated due to the movement of the eyeballs in the surrounding region of eye. It is acquired

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noninvasively from the surrounding region of eye. Different characteristics of EOG reveal its potential to be implemented for controlling different rehabilitation aids.[19]

The eye is a place of a steady electric potential field that is quite unrelated to light stimulation. This field can be detected even with the eyes closed or eyes in total darkness. This steady electric potential can be viewed as a fixed dipole with positive pole at the cornea and negative pole at the retina. The magnitude of this corneoretinal potential is in the range 0.1-3.5mV. This potential is not generated by excitable tissue but it is due to the occurrence of higher metabolic activity in the retina. For the invertebrates, the polarity of this potential difference is of opposite to that found in vertebrates such as human beings. This corneoretinal potential is roughly aligned with the optic axis and hence rotates with the direction of gaze, which can be measured by surface electrodes placed on the skin around the eyes [20]. Rotation of the eye and the corneoretinal potential form the basis for a signal measured at a pair of periorbital surface electrodes. The signal is known as the Electrooculogram (EOG) the retina.

When the eyes are rolled upward or downward, positive or negative pulses are generated. As the rolling angle increases, the amplitude of the pulse also increases and the width of the pulse is in direct proportion to the duration of the eyeball rolling process. The EOG is the electrical recording corresponding to the direction of the eye and makes the use of EOG for applications such as HCI very attractive. EOG-based techniques are very useful for patients with severe cerebral palsy or those born with a congenital brain disorder or those who have suffered severe brain trauma[21]. Figure 2.2 shows the example of EOG Waveform.

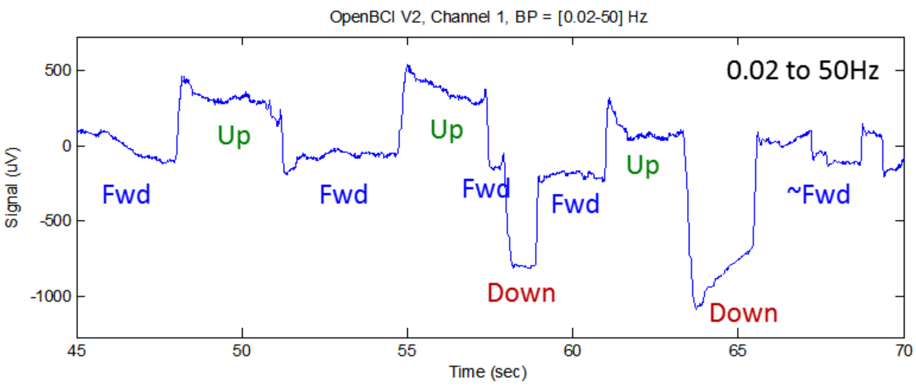

Figure 2.2: The example of EOG Waveform

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2.7 Eye Muscle

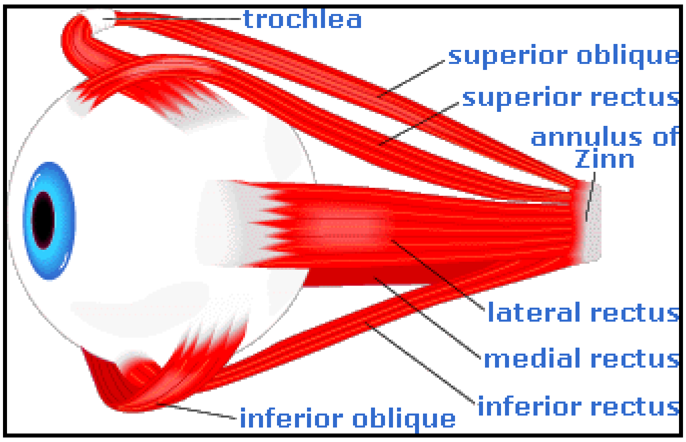

Figure 2.3: Eye Muscles [22]

The eye muscles as Figure 2.3 is divided into two, there are the Extrinsic and Intrinsic. This project only focuses on the extrinsic muscle for EOG signal. The function of this muscle is to stabilize and move eye. During movements, certain muscle will be contracted and the other will be relaxed. The movement of each eye is controlled by four rectus and two oblique eye muscles[23]. There are shown as in Table 2.1 and Figure 2.2 below :

Table 2.1: Eye muscle,insertion and action of the eye muscle [23]

Muscles	Insertion	Action
Superior rectus (rectus =fascicles parallel to midline)	Superior and central part of eyeballs.	Moves eyeballs superiorly (elevation) and medially (adduction), and rotates them medially.
Inferior Rectus	Inferior and central part of eyeballs.	Moves eyeballs inferiorly (depression) and medially (adduction), and rotates them medially.
Lateral Rectus	Lateral side of eyeballs.	Moves eyeballs laterally (abduction).
Medial Rectus	Medial side of eyeballs.	Moves eyeballs medially (adduction).
Superior Oblique	Eyeball between superior and lateral recti. The muscle inserts into the superior and lateral surfaces of the eyeball via a tendon that passes	Moves eyeballs inferiorly (depression) and laterally (abduction), and rotates them medially.

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	through the trochle	
Inferior Oblique	Eyeballs between inferior and lateral recti.	Moves eyeballs superiorly (elevation) and laterally (abduction) and rotates them laterally.

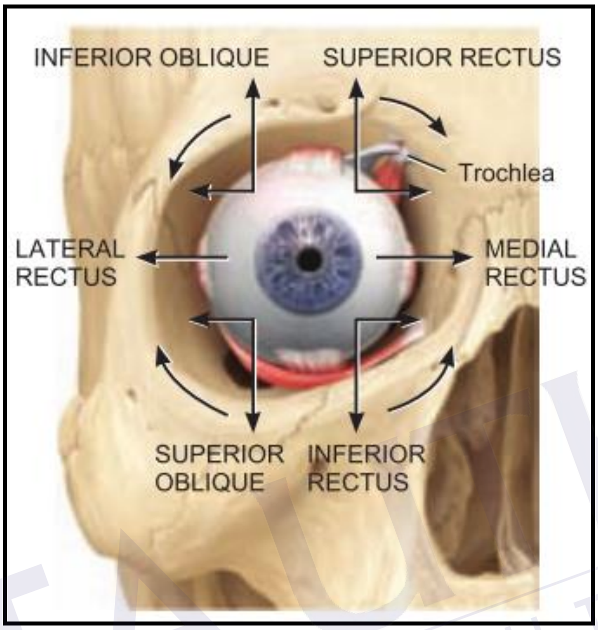

Figure 2.4: Movement of right eyeball in response to contract of extrinsic muscles [23]

2.8 Conclusion

In this chapter, it can be summarize that there are a lot of applications have been developed using EOG signal. The use of powered wheelchair also can be replaced using smart wheelchair which the use of joystick are replaced by bio signal from eye muscle.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will discuss about the methodology for controlling wheelchair using EOG signal. It begins with analysing the project workflow from the block diagram follow by data acquisition, software and hardware of the system design.

3.2 Block Diagram

The block diagram for the methodology of this project is shown as in figure 3.1. The data signal from the EOG surface electrode will be doing signal conditioning by using KNH KL-720. The signal will be amplify and filter before it can be processed. The signal will be feed into the National Instrument (NI) My DAQ Data Acquisition and interface between the circuits and the. In this project LabVIEW will be function as a signal processing tool and also as a training tool to classify the mode operation of the signal of the wheelchair. The processing signal will be feed to the electrical wheelchair an again through the microcontroller and motor driver.

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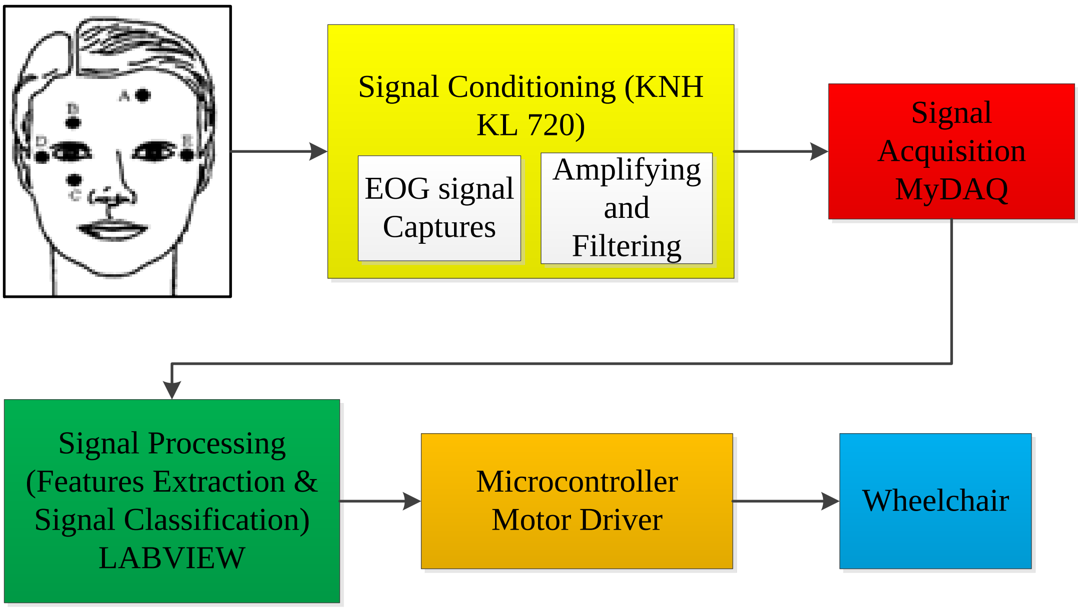

Figure 3.1: Block diagram

3.3 Electrode Selection

The basic requirements for wearable body sensors focus very much on convenience of operation, bio-compatibility, and miniaturization. The electrodes were chosen with the concern of protecting the eyes from hazardous elements. ECG disposable electrodes are easily available. But they cannot be used repeatedly. The main feature that is making Ag/AgCl electrodes superior to other metals is their low offset potential. Ag/AgCl electrodes are stable regardless of the direction of current flow, since as the AgCl is ionized, chlorine ions from the electrode are exchanged for similar ions in the tissue or electrolyte. Easy to use when compared with standard hydrogen or saturated calomel electrodes. Ag/AgCl electrodes were chosen considering low cost, convenience, proper signal acquisition, accuracy and reliability. [3]

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3.4 Electrode Placement

EOG observes the eye-movement by recording the corneal–retinal potential polarity from de-polarizations and hyper polarizations existing between the retina and cornea[18]. EOG signals were measured by placing electrodes on the region surrounding the eye. The signals were recorded from horizontal channel. Horizontal electrodes were for detecting horizontal eye movements (left and right eye movement) [24]. Three to five electrodes were used to acquire the EOG signals. Figure 3.2 shows the five electrode placement in EOG. For this project, only three electrodes are being use that is for horizontal channel. Electrodes are placed on the forehead was for reference electrode, and electrodes D and E were horizontal electrodes.

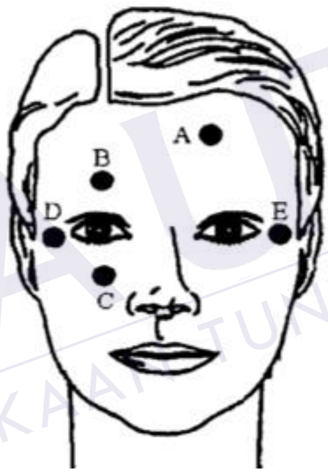

Figure 3.2: Electrode Placement

3.5 Signal Acquisition

This module amplifies the EOG signals to the level which can be processed on a microcontroller. The EOG signal has a frequency range between 0.1Hz and 30Hz and amplitude between 100μV to 3500μV. EOG signal amplitude depends significantly on the position of the eyeballs relative to the though there are few conductive environment of the skull other contributing factors. The EOG signal, like the other is usually contaminated by the environmental bio-signals interferences and

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biological artifacts. Figure 3.3 show the National Instruments (NI) MyDAQ are being use for data acquisition.

Figure 3.3: NI MyDAQ

3.6 Read Biosignal EOG

The block diagram use for read EOG signal as show in Figure 3.4. This function is to read biosignal from files that have been saving. This VI read biosignal block by block and supports reading multiple channels and reading annotations. The signal was taken for 5 seconds only. Figure 3.5 shows the amplitude of the raw signal from KNH KL 720.

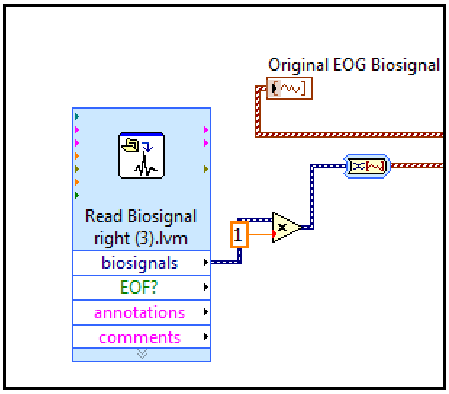

Figure 3.4: Block diagram of Read Biosignal

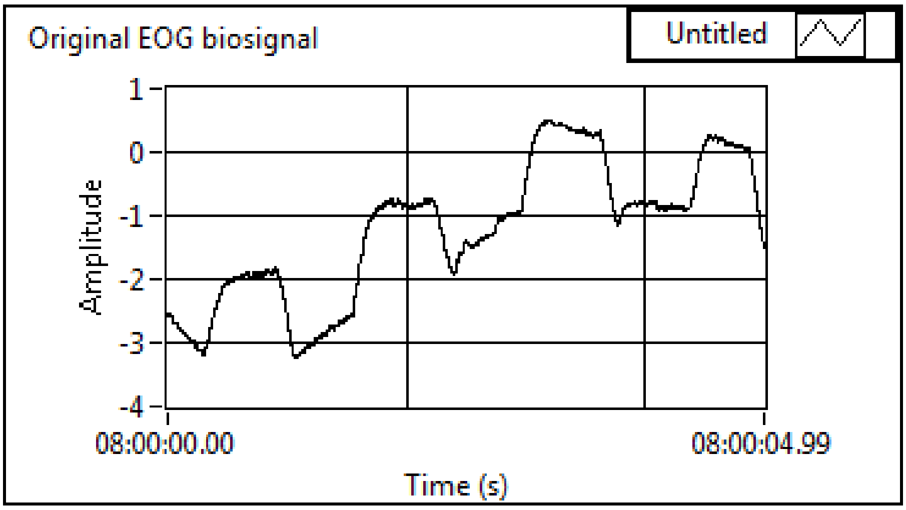

Figure 3.5: EOG Raw Signal

3.7 Signal Processing

The next step of processing the EOG signal is Signal Processing. This to make sure that the quality of EOG signal is extracted and at the same time the unwanted parts of EOG signal are removed.

In this project, all techniques will be done in frequency domain. All data will be analysed in mathematical function or a signal with respect to the frequency. Frequency domain analysis mostly can be done to the signals or functions that are periodic over time. Frequency domain will represent the amplitudes and frequencies of the waveforms present in the signal being measured. This type of representation is also known as the spectrum of the signal.

Since the signal in the time domain, then it should be converted to frequency domain using Fast Fourier Transform (FFT). The equation of FFT is shown below. In this frequency domain, two aspects will be covers which are Digital Filtering and Feature Extraction.

$$DFT(FFT):$$

$$X(k)=\sum_{n=0}^{N-1} x(n)\cdot e^{-j\left(\frac{2\pi}{N}\right)nk} \quad (k=0,1,\ldots,N-1)$$

$$IDFT(IFFT):$$

$$x(n)=\frac{1}{N}\sum_{k=0}^{N-1} X(k)\cdot e^{j\left(\frac{2\pi}{N}\right)nk} \quad (n=0,1,\ldots,N-1)$$

3.8 Features extraction

The objective of feature extraction is to use the method in signal processing to extract the specific features or information from the signal that will useful to classify into types of classes that represent specific motion. There will be four mode operations which are forward, right, left and stop. The mode operation is depending on the eye movement of the user.

The mode operation in features extraction is :

o FORWARD: When the eyes look straight and blinking 5 times in 5 second.

o RIGHT: Move eyes to right and the dc motor/ device is 90° moved in right direction

o LEFT: Look towards left while the system is on. Dc motor/device moves 90° left.

3.8.1 Root Mean Square (Vrms)

The root mean square (abbreviated RMS or rms), also known as the quadratic mean, is a statistical measure of the magnitude of a varying quantity. It is especially useful when variants are positive and negative. The RMS value of a set of values (or a continuous-time waveform) is the square root of the arithmetic mean (average) of the squares of the original values (or the square of the function that defines the continuous waveform).

$$V_{rms} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} {x_n}^2}$$

where,

Vrms – the root mean square value

Xn – value of samples

n- no. of samples

The mean value of the rectified EOG over a time interval T is defined as Average Rectified Value (ARV) or Mean Amplitude Value (MAV) and is computed as the integral of the rectified EOG over the time interval T divided by T.

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3.8.2 Average Rectified Value (ARV)

Average rectified value (ARV) is similar with Mean Absolute Value (MAV). It can be calculated using the moving average of full-wave rectified EOG. In other words, it is calculated by taking the average of the absolute value of EOG signal. It is an easy way for detection of muscle contraction levels and it is a popular feature used in the myoelectric control application.

$$ARV = \frac{1}{N}\sum_{i=1}^{N}|x_i|$$

where x_i are the signal samples, and N the number of samples in the epoch considered.

3.9 Fuzzy Classifier

Many approach can be done in order to classify the EMG signals. In this work, the rule-based approach is applied for the EMG signal classification. For this purpose, a fuzzy logic toolkit of LabVIEW is used and a classifier is designed with the help of this toolkit. For this project, the rule-based approach is applied for the EOG signal classification. For this purpose, a fuzzy logic toolkit of LabVIEW is used and a classifier is designed with the help of this toolkit. To classify the signal, a fuzzy logic toolkit of LabVIEW is used and a classifier is designed with the help of toolkit in Labview which is Fuzzy System Designer. The fuzzy system designer has three components that is variables, rules and test system.

3.9.1 Creating Input/output Variables for Fuzzy System

Variables of fuzzy system designer have input variables and output variables. Three features of EOG signal are selected for input variables. These features are Maximum Raw Signal (MAX RAW) and Root Mean Square (RMS). The output variable is the movement. The input and output variables are as in Table 3.1 and 3.2.

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Table 3.1: The input and output variables

Input Variables	Output Variables
Maximum Raw Signal (MAX RAW)	Movement
Root Mean Square (RMS)	

Table 3.2 : Terms for the input and output variables

Input/ Output Variables	Terms
Maximum Raw Signal	Small, Medium, Large
Root Mean Square (RMS)	Small, Medium, Large
Movement	Move Forward, Turn Right, Turn Left,

3.9.2 State membership function

For designing of membership function of maximum raw signal (MAX RAW) variables, triangular function is used and input variable has three fuzzy sets or three classes that are small, medium and large. Value of these fuzzy sets is shown in Figure 3.6.

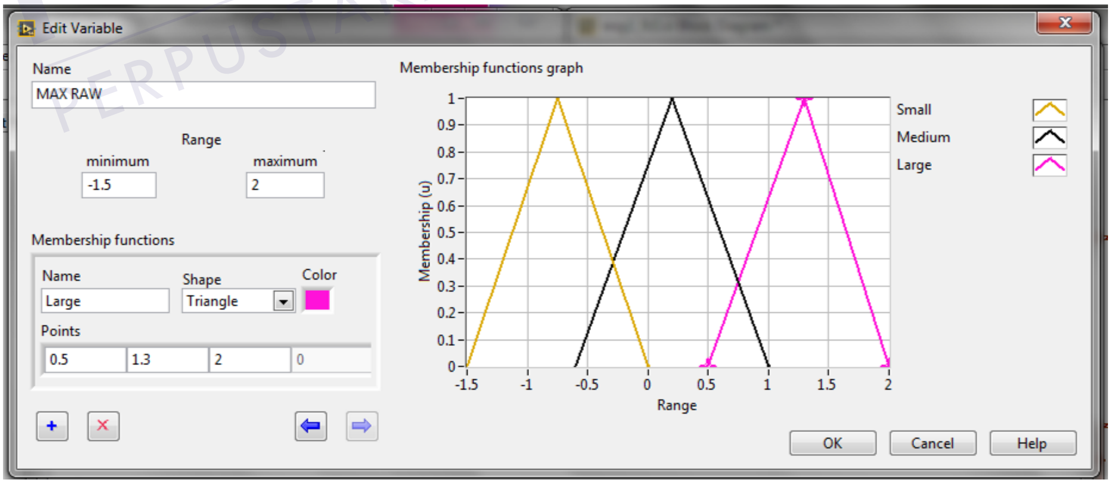

Figure 3.6: Membership function values of maximum raw signal

For designing of membership function of Root Mean Square (RMS) variables, triangular function is used and input variable has three fuzzy sets or three classes that are small, medium and large. Value of these fuzzy sets is shown in Figures 3.7.

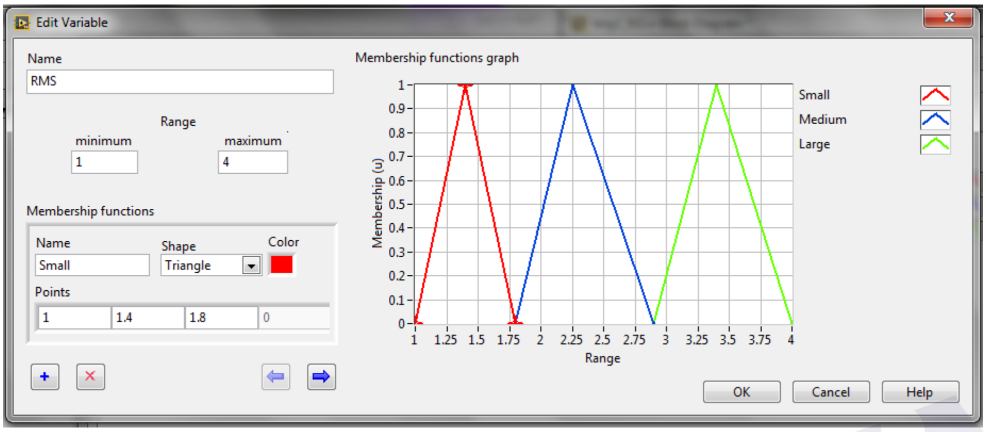

Figure 3.7: Membership function values of root mean square

For designing of membership function of MOVEMENT variables, triangular function is used and output variable has three fuzzy sets or three classes that are Forward, Left and Right. Value of these fuzzy sets is shown in Figure 3.8 .

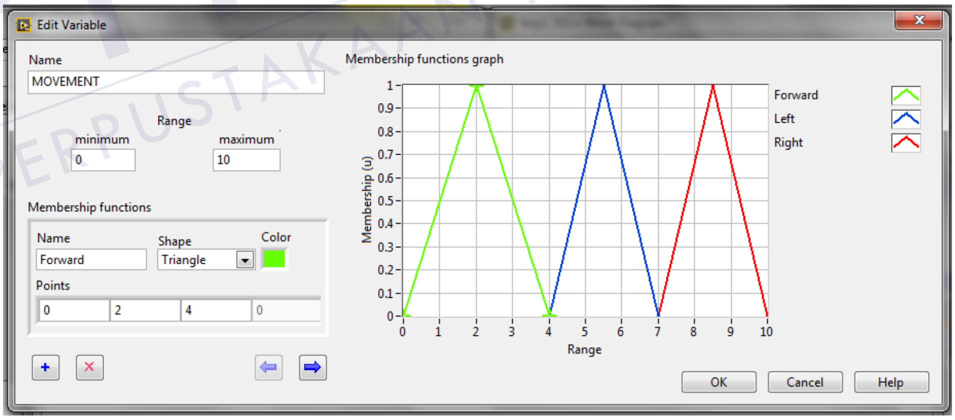

Figure 3.8: Membership function values of movement

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3.9.3 Creating Rules

Rules describe, in words, the relationships between input and output linguistic variables based on their linguistic terms. A rule base is the set of rules for a fuzzy system. Since each input linguistic variable has the same number of linguistic terms, the total number *N* of possible rules is defined by the following equation:

$N = p^m$

$p =$ number of linguistic term for each input linguistic variable

$m =$ number of linguistic variable

Based on this project, the possible rules are:

$p = 3$

$m = 2$

$N = 3^2 = 9$

$\therefore$ 9 possible rules

These rules are in the form of IF-THEN and rules are listed in Table 3.3

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Table 3.3 : Rules of Different Maximum Value for Different Movement

Rule	MAX RAW		RMS		MOVEMENT
1	Small	AND	Small	THEN	FORWARD
2	Small	AND	Medium	THEN	FORWARD
3	Small	AND	Large	THEN	LEFT
4	Medium	AND	Small	THEN	FORWARD
5	Medium	AND	Medium	THEN	RIGHT

6	Medium	AND	Large	THEN	LEFT
7	Large	AND	Small	THEN	FORWARD
8	Large	AND	Medium	THEN	FORWARD
9	large	AND	Large	THEN	LEFT

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will discuss the initial result that gather from K&H KL 720 Module, to get the initial biosignal waveform of EOG. In this chapter, the result of the project is presented and analyzed. The result includes the signal conditioning by using KNH KL 720, the signal processing result by using Fuzzy Labview. The suitability of eye muscle as the location of the placement of the surface electrode is examined and discuss.

4.2 Placement of Electrode

To achieve the target of analysis EOG signal, three surface electrodes were used, two of them was placed on the left and right of eye and the last one was placed on the forehead as the reference. Therefore by placing electrodes to the left and right the eye, horizontal movements can be obtained. EOG signal is recorded using disposable electrode. EOG signal is recorded about 1000 samples per second and the particular EOG signal saved in PC using LabView software. A file *.jpg and *.lvm (file format) is generated by the system, which can be used by PC for analysis purpose.

As in Figure 4.1, positive electrode and negative electrode was placed on the eye. The subject is required to move eye for 60 degree from left to right respectively. From this experiment, the signal EOG has been observed.

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Figure 4.1: EOG Electrodes Placement

4.3 Signal Conditioning of KNH KL720

From the EOG Module KNH KL 720 on Figure 4.2, the experiment have been done by using only one channel that is Horizontal channel. Figure 4.2 shows the K&H KL 720 Module and Figure 4.3 shows the block diagram of EOG measurement. For the module, the signal EOG are obtained and it give the EOG signal from different eye movement such as when normal eye condition, eye blinking, eye move to right and left and when eye move to up and down.The EOG signal is have been amplify and filter. The signal on figure 4.4 is the EOG signal after band reject filter, Figure 4.5 is the EOG signal after isolator, Figure 4.6 is signal EOG after high pass filter, Figure 4.7 is signal eog after amplifier and Figure 4.8 is signal EOG after low pass filter.

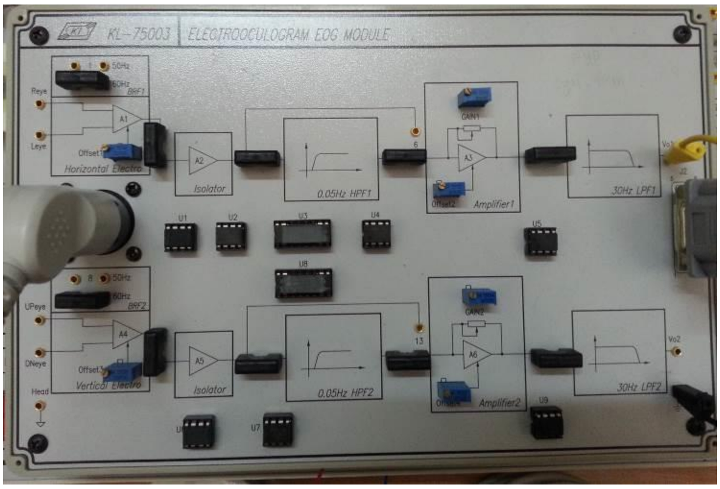

Figure 4.2: EOG Module

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