"I hereby declare that I have read through this report entitle "Classify EMG data for upper limb muscle based on different movement of arm rehabilitation device" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

Signature : ....

Supervisor's Name : Mr. Mohd. Hafiz Bin Jali

Date : 16/6/2014

CLASSIFY EMG DATA FOR UPPER LIMB MUSCLE BASED ON DIFFERENT MOVEMENT OF ARM REHABILITATION DEVICE

‘IFFAH MASTURAH BINTI IBRAHIM

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle "Classify EMG data for upper limb muscle based on different movement of arm rehabilitation device" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....[signature]..........

Name : 'Iffah Masturah Binti Ibrahim

Date : ....16/6/2014..........

For my beloved Mama and Abah,

To my dearest Brothers and Sisters,

Hasanuddien, Mohd Hafiz, Muhammad NorHelmi,

NurulMuallimah, IffahAmirah.

Thanks for all the pray, supports and loves.

Your girl loves you.

Lots.

ACKNOWLEDGEMENT

Alhamdulillah, Thanks and Praise to Allah S.W.T;
I take this opportunity to express my profound gratitude and deep regards to my guide supervisor Mr. Mohd. Hafiz Bin Jali for his abundantly helpful and offered invaluable assistance, support and guidance. The blessing, help and guidance given by him time to time shall carry me a long way in the journey of life on which I am about to embark.

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ABSTRACT

Rehabilitation device is used as an exoskeleton for people who experiencelimb failure. Arm rehabilitation device may easethe rehabilitation programme for those who suffer arm dysfunctional. The device used to facilitate the tasks of the program should improve the electrical activity in the motor unit by minimising the mental effort of the user. Electromyography (EMG) is the techniques to analyse the presence of electrical activity in musculoskeletal systems. The electrical activity in muscles of disable person are failed to contract the muscle for movements. To prevent the muscles from paralysis becomes spasticity or flaccid the force of movements has to minimise the mental efforts. To minimise the used of cerebral strength, analysis on EMG signalsfrom normal people are conducted beforeit can be implement in the device. The signalsare collect according to procedure of surface electromyography for non-invasive assessment of muscles (SENIAM). The implementation of EMG signals is to set the movements’ pattern of the arm rehabilitation device. The filtered signal further the process by extracting the features as follows;Standard Deviation(STD), Mean Absolute Value(MAV), Root Mean Square(RMS), Zero Crossing(ZCS) and Variance(VAR). The extraction of EMG data is to have the reduced vector in the signal features for minimising the signals error than can be implement in classifier.The classification of time-domain features only can be applied for three types of time-domain features are Mean Absolute Value(MAV), Root Mean Square(RMS) and Standard Deviation(STD).Thearm movements of 60˚, 90˚ and 120˚ are classified into their own class of degrees movements by using SOM-Toolbox for MATLAB are visualized in U- Matrix form.

ABSTRAK

Alat bantu pemulihan digunakan sebagai rangka luar bagi membantu individu yang mengalami kegagalan fungsi anggota tubuh badan. Alat bantu pemulihan tangan mampu memudahkan individu yang mengalami kegagalan anggota tangan menjalani program dipusat pemulihan. Alat bantu yang digunakan bagi memudahkan aktiviti di dalam program tersebut perlu meningkatkan aktiviti elektrik di dalam unit motor dengan mengurangkan penggunaan mental pengguna. Electromyography(EMG) merupakan kaedah untuk menganalisa kehadiran aktiviti elektrik di dalam sistem otot manusia.Aktiviti elektrik dalam tubuh pesakit tidak mampu untuk mengecutkan otot. Bagi mengatasi otot tersebut dari menjadi kaku atau lembik, daya tujahan untuk menggerakkan alat bantu tidak boleh melebihi kemampuan mental. Bagi mengurangkan penggunaan kekuatan mental, analisis isyarat EMGdari individu yang normal perlu dijalankan sebelum digunakan pada alat bantu pemulihan. Isyarat-isyarat tersebut dikumpulkan melalui kaedah penilaian otot menggunakan permukaan electromyography bukan invasif(SENIAM).Isyarat EMG ini digunakan bagi menetapkan jenis pergerakan terhadap alat bantu pemulihan.Isyarat signal yang ditapis seterusnya di proses bagi mengekstrak ciri-ciri seperti berikut; Sisihan Piawai(STD), Nilai Min Mutlak(MAV), Punca Min Kuasa Dua(RMS), Lintasan Zero(ZCS) and Varian(VAR). Ekstraksi dari data EMG ini bertujuan untuk mengurangkan vektor dalam ciri-ciri isyarat bagi mengurangkan ralat dalam isyarat untuk digunakan dalam pengelas. Pengelasan dalam domain masahanya boleh digunakan terhadap ciri-ciri Nilai Min Mutlak(MAV), Punca Min Kuasa Dua(RMS), dan Sisihan Piawai(STD). Pengelasan. Pergerakan lengan pada sudut 60˚, 90˚ dan 120˚ dikelaskan mengikut peringkat kelas pergerakan menggunakan SOM-Toolbox untuk MATLABdiperlihatkan dalam bentuk U-Matrix.

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CHAPTER 1

INTRODUCTION

1.1 Background

Human support system is known as an endoskeleton. Endoskeleton plays a role as a framework of the body which is bone. Our daily movements are fully depends on the functionality of our complex systems in the body. The disability one or more of the systems in our body will reduce our physical movements. Exoskeleton device is known as rehabilitation device to facilitate disable person. The functionality of the rehabilitation device has to smooth as the physical movement of normal human.

People who have temporary physical disability have the chances to recover. The rehabilitation programs provide the suitable plan for conducting the nerve and stimulate the muscles. Nowadays, rehabilitation program are using rehabilitation devices in their tasks. The functionality of devices depends on muscle contraction. Electromyogram studies help to facilitate the effectiveness of the rehabilitation device.

The technique of measuring electrical activity that produced by muscles during rest or contractions known as electromyography (EMG). The electrical signal generates from the brain and sends to the muscles via motor neuron. The EMG could detect the dysfunctional of the muscles or failure in signals transmission from nerves to muscles. The failure of sending the electrical signal from the brain to the conducting nerves requires electrical stimulation from the external source to muscles. Electrodes are used for signal detection of electrical activity in muscles. The study of this electrical activity is important for combination of electromyogram into the rehabilitation device.

1.2 Motivation

Nowadays, increment number of accidents' victim who suffer the failure of the upper limb, demands for the affordable arm rehabilitation devices. Rehabilitation centre will cost the patients a lot amount of money to precede the training course. Besides that, the patients who can survive for unsupervised course are preferable to possess their own rehabilitation device. The unsupervised rehabilitation will facilitate the user to use with convenient. In order to help the needy, the studies on rehabilitation device are carried out.

Electromyography is a technique that has been commonly applied in the electromyogram studies into the rehabilitation device. Nowadays the development of exoskeleton for human performance is trending in this country. The government provides a lot of platform and provision of funds to share the findings and future development in the applied mathematics and engineering fields as well as to encourage collaborations between mathematical research and engineering applications. In attempt to welcoming of this move, the idea and research works of the rehabilitation device have to focus on these EMG signals processing for a smooth performance of the device. The study is carried out to understand the importance of the rehabilitation device and the development of the rehabilitation device to facilitate the user. Thus, the electromyogram studies including the extract features and the classification of the EMG signal is a goal of this study.

1.3 Problem Statement

The rehabilitation device is a tool that used to help movements in daily life activities of the patients who experienced the failure of muscle contractions. Due to failure of muscles contractions the movements is limited. The ability of the patients to do the tasks in the rehabilitation programs need to be measured. The rehabilitation programs have to ensure either the tasks is effective or harmful to the patients. Historically, the rehabilitation tasks have been avoided due to a belief that it would increase spasticity. [3] However, the spasticity is one type of failure in muscle contraction. In this study, the focus is on the patients who suffer the paralysis either flaccid or spasticity. In this study, the analysis of the data will be focusing on upper limb consisting of biceps brachii muscles only. The experiment is limited to several degrees of upper limb movements that use in the training.

EMG is divisions of bio signal analysis. The bio signal analysis is the most complex analysis. Thus, the signal analysis is a complicated process.The EMG signals must be reliable to include in the signal processing process.Therefore, the challenge of this study to ensure that signal processing is conducted properly towards reducing the environment noise during collecting data. The reliable signals is continued to extract the features that will use in movement classification. The study is succeeded when the EMG signals can be classify into the movements than soon will use in rehabilitation device and may not harm the user.

1.4 Objectives

The objectives of this research are to extract the time domain features of biceps brachii muscles based on different degree of arm movements using MATLAB and SIMULINK software. Subsequently, the extracted features are to cluster into several degrees of arm movements usingSelf-Organising Map technique.

1.5 Scope of Research

In achieving the objectives of this study, the experiment has to be conducted within the scope of study. The EMG signals are collected from the healthy subjects based on BMI standards without any medical history within 20 to 30 years old. The EMG signals is acquired from the muscles at the upper limb which is biceps brachii. The muscles biceps is taking into consideration for this experiment due to arm feed forward stretching movements that include the contraction of biceps muscles. The feed forward stretching movements' are set up with angle of 60˚, 90˚ and 120˚ by estimation. The studies of muscles contraction of normal and healthy subjects are important for better understanding before it can be applied to abnormal subject. The data is collected by using surface electrodes which is non-invasive method. The collected data are used for signal processing to carry out the extraction of signal features to be classified. The analysis of the EMG signals are conducted in powerful tool which are MATLAB 2013a, SIMULINK and SOM-Toolbox developed byEsaAlhoniemi*et al.* The features are classified by using Self-Organising Map technique.

1.6 Contribution of Research

After completing this research, the studies may contributes in rehabilitation field involves; extracted features in time-domain of the EMG signal of upper limb for several degrees of movement and the classified movements by using Self-Organising Map technique.

1.7 Outlines of the Report

This research comprises of five chapters. Chapter 1, the background and the idea of this research is proposed for better understanding. This chapter consists of the objectives and the scope of this research. Chapter 2, general reviews of the idea that related to this study. This chapter also include the flow of strategies that used in this research. Methodology has been briefly explained in Chapter 3; the study will begin with the experimental setup. Preparing the subject and collecting the data due to the angle degree of movements. The results of the raw EMG signals, features extraction and classifier are presented in Chapter 4. Finally, the conclusion of this study, experiment, recommendations towards the future works is covered in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews related to this research title. This review is referred from several research papers, books and journals that much related to engineering, muscle anatomy, signal processing and software.

2.1 Introduction

Hand consists of arm, forearm, wrist and fingers for physical movement. Arm is located at shoulder joint, while forearm is located at elbow joint. A physical arm movement is less complex compare to forearm, wrist and fingers motion. This is because when it refers to musculoskeletal, the largest muscles involved with the motion are biceps and triceps only. However, when the musculoskeletal system is failed on the arm it will disable the motion of the forearm and fingers. Nowadays, people who suffer from stroke(hemiplegic), flaccid and paralysis they have lost the limb function.[9] As the failure of upper limb, they still can feel the presence of the arm because it still there but cannot move it. Thus, their intention to move the arm is generated from their brain. The brain transmits the signal and this signal called electrical activity is send via neurons. This electrical activity is known as myoelectric signal. The signal that generates from the muscle contraction can be recorded by electromyography. This technique shows the muscles are active and able to do the physical movements.[4]

2.2 Arm Rehabilitation Device

Rehabilitation Engineering is a field for engineer and designer to share the idea and come out with the solution that may ease the disabled person to live their daily life such a normal people. The development of the rehabilitation device is improved gradually. The brilliant ideas and work pieces from these engineer and technologist helps to achieve the multifunctional rehabilitation device. The efforts by them bring a lot of enhancement in rehab's world. Nowadays, spill over rehab devices in marketplace helps the disable person to make a choice from the cheapest to the most expensive device that suits their finances. The devices rank always put the cheapest devices with the less function or motion while the expensive devices with multifunctional or more degree of motion. Therefore, the rehabilitation devices contribute into the entrepreneur technologies and establish the competency by implementing the devices.

Furthermore, to fulfil the demands from the user, engineer and designer should create the device to facilitate their movement and user-friendly. Currently, the superficial device is the best design to expand for the purpose of unsupervised modes. By referring to the United States Patent for Arm Rehabilitation and Testing Device documents by Reddy *et al.*, to invent the rehabilitation device, the design should provide:

i. a portable and extremely convenient device.
ii. a device that may use to measure the degree of recovery.
iii. an adjustable size or length of individual arms.
iv. a desired speed and force depending on patient's deficiencies.[23]

The mechanism of rehabilitation device is automatic without any force from the user and comfortable. This mechanism helps the disable person to train their muscle for rehabilitation in supervised or unsupervised modes.There are some beliefs that the rehabilitation device may harm the user.[3] Depending on the muscles either flaccid which is no muscle tone or spastic that has too much muscle tone. Flaccid patient needs the rehabilitation device to increase the muscle tone, while spastic patient may need the device to reduce the muscle tone. However, the spastic patient is the case where the technologist had to consider the force and speed in the device to preclude the spasm in the muscles.

Therefore, as an engineer the invention of a new thing have to follow the etiquette and the rule for the effectiveness and the user convenience.

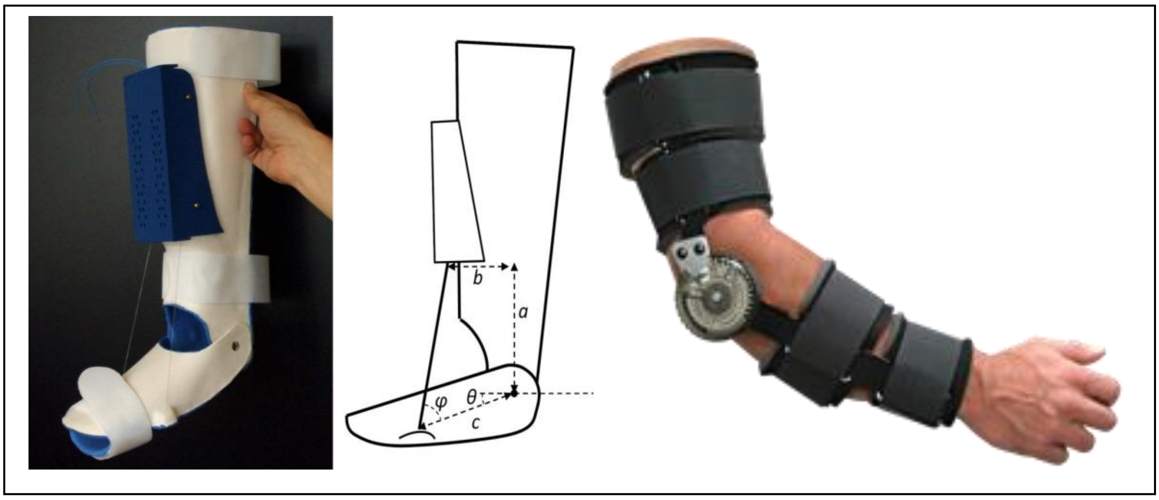


Figure 2.1 Example some of the arm rehabilitation device.

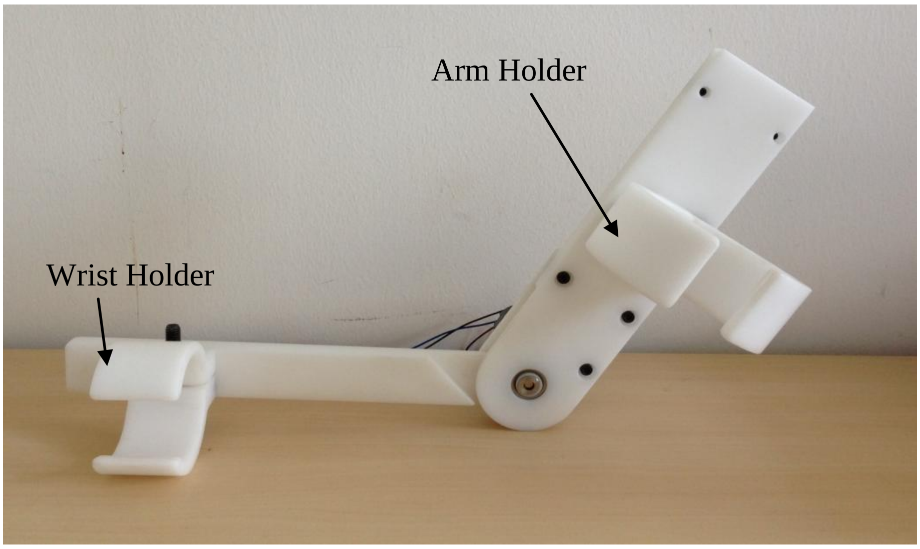


Figure 2.2 The arm rehabilitation device that used in this research.

2.3 Signal Processing

The output of the system commonly is defined by the input. The output is the main achievement of the system. However, the input is always raw signals that need to be process into several plants until it can produce the desired output. EMG signal is one type of bio signal that contains lot of noise from many factors. The noise may come from the skin at the electrode placement, type of electrode that may use for data collecting and also the environment. There are various type of size and pattern of electrodes(Figure 2.3), depends on the muscle area would like to detect and the thickness of the skin layer. The EMG noise signal can be reduced by choosing the gelled electrode which were Silver – Silver Chloride(Ag-AgCl) as the substance. Ag-AgCl introduces less electrical noise into the measurements. However, these noise should be eliminate to have a better signal for analysing purpose, the noise can be eliminate by many factors such as control environment, electrode placements and signal acquisition circuitry and configuration.[7][13] As for the features extraction there were various types in terms of frequency domain, time frequency domain and time scale domain. These types are chose based on the purpose of the analysis of the signal. In signal conditioning for time domain analysis, there is some features that can be applied. These features are described briefly as follows:

i) Root-Mean-Square (RMS)

RMS is the square root of the mean over time of the square of the vertical distance of the graph from the rest state. It much related to the constant force and non-fatiguing contraction of the muscle. In most cases, it is similar to standard deviation method. [3]

$$RMS = \sqrt{\frac{1}{N}\int_{i=1}^{N} EMG(i)^2}$$

ii) Mean Absolute Value(MAV)

Mean absolute value is calculated by taking the average of the absolute value of EMG signal. Since it represents the simple way to detect muscle contraction levels, it becomes a popular feature for myoelectric controlled applications. [3]

$$MAV = \frac{1}{n}\sum_{i=1}^{n}|(x_i - \bar{x})|$$

iii) Standard Deviation(STD)

Standard deviation is a measure of the dispersion of a set of data sample from its mean. The more spread apart the data, the higher the deviation. Standard deviation is calculated as the square root of variance.

$$STD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

2.4 Maximisation of EMG Signal

Signal is condition that always affected by the factors that make it unstable and non-linear. As EMG signal, the non-linear of the signal mostly came from the noise factor. There have a lot of noise factor that can be categorized as follows;

i) *Causative Factors:* This is the direct affect on signals.

a. *Extrinsic* – The signal get affected by the electrode placement, structure, surface detection, distance between electrode(bipolar configuration), and location of the surface detection on the skin.

b. *Intrinsic* – It may due to physiological, biochemical and anatomical factors.

ii) *Intermediate Factors:* This is the phenomena of influencing by one or more causative factors.

iii) *Deterministic Factors:* This is influenced by the intermediate factors.

Figure 2.3 The various type of wet electrodes that may used to detect the EMG signal.

By minimizing all these factor of noises, the quality of EMG signal will be much better and the analysis of the information will be less of error and easy to obtained. However, the precautions of handling the hardware and the electrode are needed. Figure 2.3 shows the several of electrodes that may use in collecting the EMG signals. This various type of electrodes depends on the size, radius and shape that might be use on skin surface. The shape and the size are depending on the area of muscles to detect and the thickness of the skin. If the skin is thick and the area of belly muscle is large, larger area of electrodes might be use for a better signals detection. Acquisition data play the important role to maximizing the quality of the EMG signal, such as minimizing the distortion in EMG signal, using any filtering tools are not recommended. In terms of signal-to-ratio(SNR) the information that carried in SNR should contain the maximum information of EMG signal [6][17]. Moreover, the quality of EMG signal is affected by the environment, also known as control environment. The environment has to set with minimizing the noise factor. The ambient noise sourced by electromagnetic devices such as radio transmission devices, fluorescent lights and power line interference from electrical wires.[17][10] These ambient noise and motion artifact can be reduced by the proper electrode placements, circuit configuration and control environment.

The flow of signal processing in this study based on the Figure 2.4. The placements and type of electrodes are important to ensure the electrical activity in muscles can be detected. The raw EMG signal from the electrodes goes into phase of signal and data acquisition for minimising the signal error. The raw EMG signal is need to reduce the vector to come out with extraction of signal features. Finally, the signal features can be classified into the classifier.

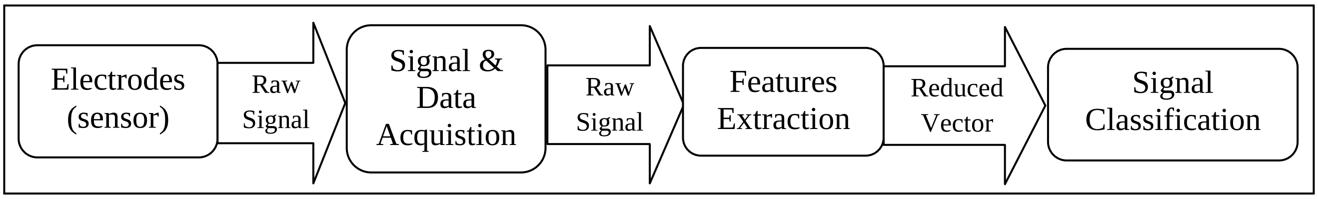


Figure 2.4 Flow of Signal Processing

2.5 Self-Organizing Map (SOM)

The Artificial Neural Network(ANN) analysis is one of the computer science's branch. The ANN's are significant in problem solving such as pattern recognition and classification. ANN analysis is a dominant tool to analyze data and tointerpret the results of the analysis, followed bysketchingthe conclusions on a structure of analyzed data. Self-organizing map(SOM) is well known as one type of neural network model that were commonly used for visualizing the data and to cluster the data. SOM was introduced by T. Kohonen in 1982, his exploration into this model to preserve the topology of multidimensional data. SOM is learns as unsupervised manner, which means no human intervention is needed throughout the learning. The SOM is a bundle ofnodes, attached to one another via a rectangular or hexagonal topology in Figure 2.5.

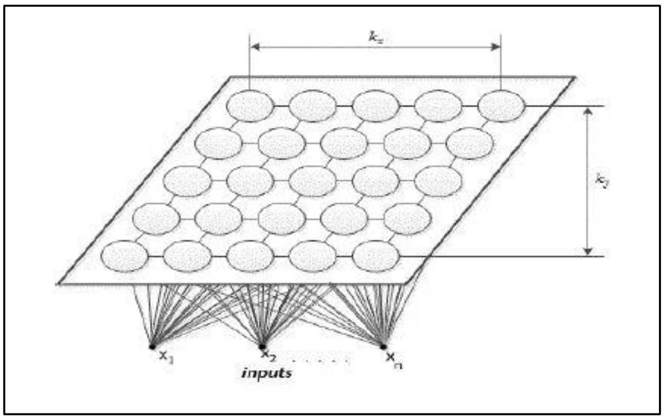


Figure 2.5 Rectangle Topology (Two-Dimensional SOM).[19]

The learningstarts from the components of the vectorsMij initialized at random. If *n*-dimensionalvectors X_1, X_2,...,X_m are needed to map, the components of these vectors x_1, x_2, ..., x_n are passed to the network as the inputs, where *m* is the number of the vectors, *n*is the number of components of the vectors. At each learning step, an input vector$X_p \in \{X_1, X_2, ..., X_m\}$ is passed to the neural network. The vector X_p is comparedwith all the neurons M_{ij}. Regularly the Euclidean distance $|| X_p - M_{ij}||$ between the inputvector X_p and each neuron M_{ij}iscalculated. The vector (neuron) M_c with the leastEuclidean distance to X_p is electedas a winner. [19][22]

Training the SOM network after carrying out the learning step is to evaluate the quality of the learning. Two types of errors which are; topographic error, $E_{te}$and quantization error, $E_{qe}$are calculated. The quantization error E_{qe} shows howwell neurons of the trained network adapt to the input vectors. Quantization error (1) isthe average distance between the data vectors X_p and their neuron-winners $M_{c(p)}$.[19]

$$E_{qe} = \frac{1}{m}\sum_{p=1}^{m}\left\|X_p - M_{c\,(p)}\right\| \tag{1}$$

Meanwhile the topographic error E_{te} shows how well the trained network keeps the topography of the data analyzed. The topographic error (2) is calculated by the formula:

$$E_{te} = \frac{1}{m}\sum_{p=1}^{m} u\left(X_p\right) \tag{2}$$

The distance of the neighbouring neurons can be visualized by using the visualization technique so-called unified distance matrix (U-matrix). U-matrix shows the distance of neighbouring neurons and the number of neighbours. The SOM is visualized by u-matrix as presented in Figure 2. 6.

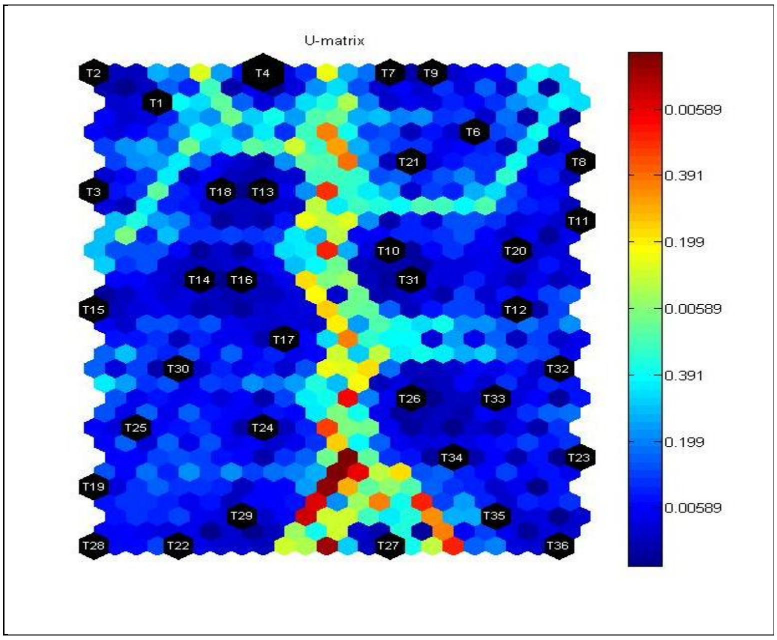


Figure 2.6 U-Matrix representations in SOM

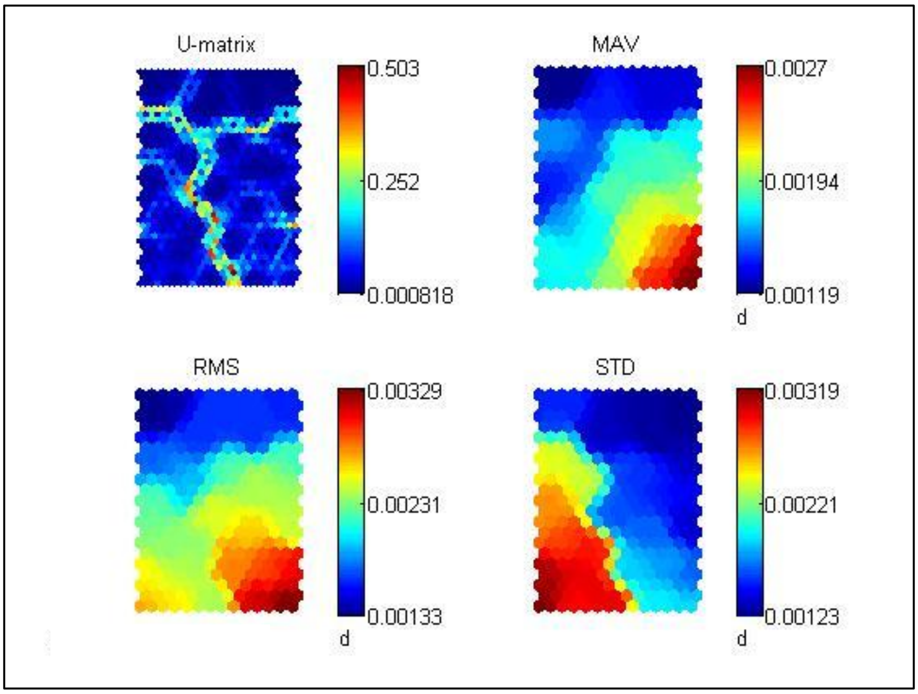


Figure 2.7 The features' distance in their own class of features.

The U-matrix elements in SOM is coloured by different colour to differentiate the distance of the neurons neighbour. The dark blue colour represents the clustered neurons while the red colour represents the most long distance between the neurons.[24] The numbering bar colour next to the U-matrix in Figure 2.6 denotes the distance between the U-matrix elements. The SOM algorithm is applied using SOM-Toolbox created by EsaAlhoniemi*et al.*usingMATLAB software. PavelStefanoviˇ*et al.* investigation in his study proved that SOM-Toolbox had most advantages of possibilities such as:

i. Amount of data items and dimensions.
ii. Represent class names of all neuron winners in the same cell of map.
iii. Easy data file preparation.
iv. Represents distance between neurons in a map.
v. Can be used some neighbouring function and any learning rate.
vi. Can be used different learning step (epochs or iterations).

SOM-Toolbox has a lack of losing the possibility for represent proportion of different classes of neuron winners in the cell of a map. The new system of SOM is the only model has this possibility, which previously improved.

2.6 Related Research Work

The movements of arm rehabilitation devices are limited to several motions. Development of rehabilitation device covers unilateral, bilateral and up to multilateral motion. The multilateral motion gives the advantages to the rehabilitation device and the user to perform the task without difficulty.

However, the beginning of the superior and multilateral rehabilitation device is beganfrom the electrical activity detection in muscles. The technique proposed by M.B.I Reaz*et al.*(2006) shows that EMG signal carries valuable information. Technique of detection, decomposition is highlighted in this research. Use of right technique for detection brings a lot of valuable information that might be use for signal processing and classification. Knowing the factor of the noise and the obstacles for minimising the error during detection and maximising the signals will help for a better analysis of EMG signals.

The technique discussed by Sachin Sarma*et al.*(2012) shows various technique for features extraction used to extract the features from the recorded EMG signals. The features are in forms of time-domain and frequency domain. Both of these domains have been used for classification of EMG pattern recognition. The time-domain features will be extracted in this study to be applied in the classifier is given by this reference.

Meanwhile, the recognition technique that will lead to classification is discussed by Guanglin Li *et al.*(2010). From his studies, pattern recognition for controlling the multifunctional rehabilitation device requires surface EMG signals to provide accurate information for classification of intended movements. The accuracy of information in the signals is valued by the percentage accuracy of sampling rate. The sampling rate below 1 kHz is possible for accurate classification by 11 types of motions.

Software library developed by EsaAlhoniemi*et al.*(1997) for MATLAB is used for signal classification. The software library is known as SOM-Toolbox used by researcher to classify the several of data into the classifier. Comparative study for Self-Organising Map classifier conducted by PavelStefanovic e*t al.* (2011) shows that the SOM-Toolbox provides 6 out of 7 possibilities of unsupervised learning in the algorithm. The SOM-Toolbox loses the possibility to represent proportion of different classes of neuron winners in the same cell of a map. The software library of SOM-Toolbox is used in Matlab for this study.

2.7 Research Strategies

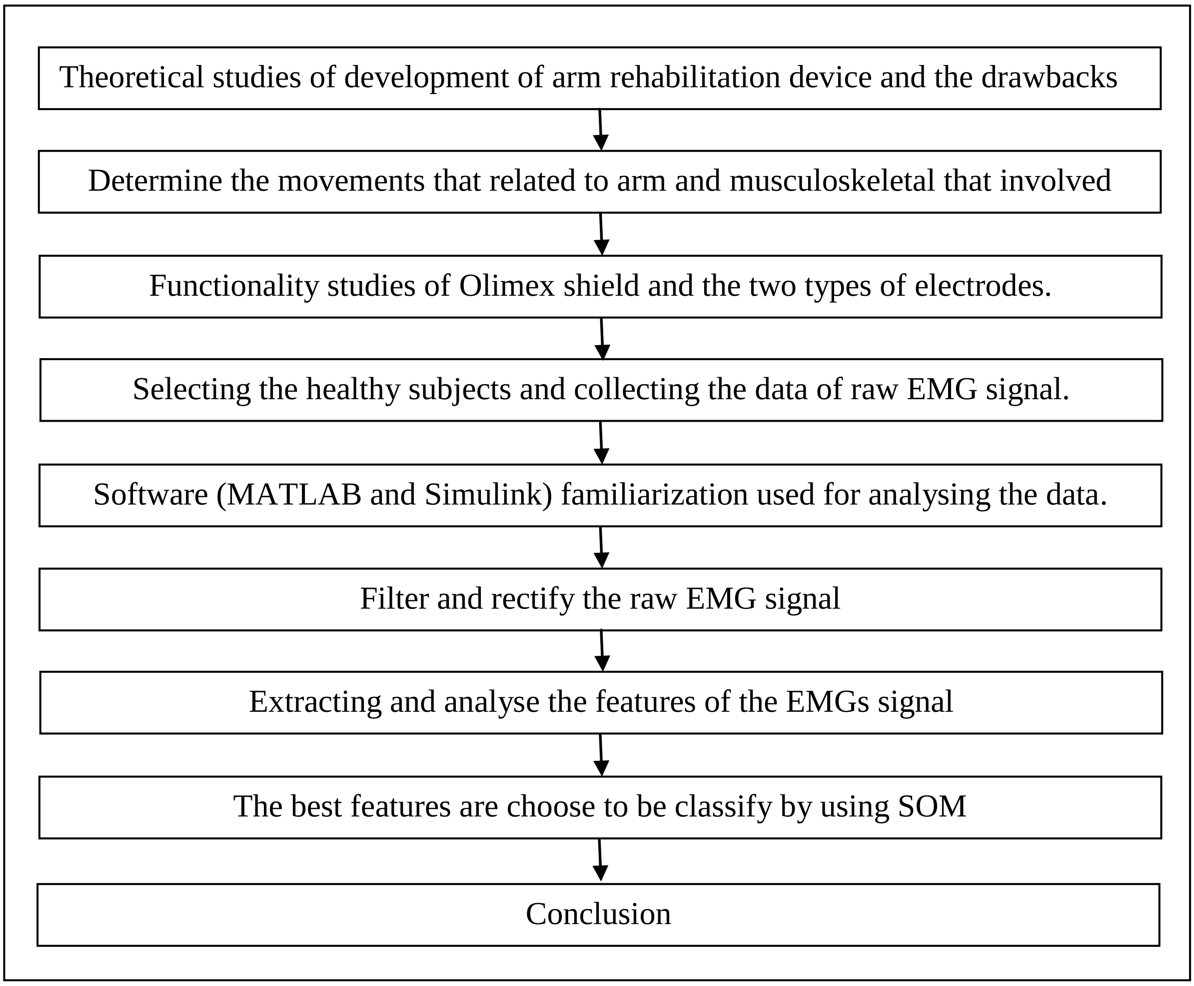


Figure 2.8 The work flow of this research.

The strategies of this research are drafted in Figure 2.8. The research is begun by studying the theoretical of arm rehabilitation device and the drawbacks of the device that will be preclude on this study. Though, the movement of the arm is limited to several degree of motion that could be pattern into the device. Thus, the functionality of the hardware and the software is familiarized before the experiment is begun. The hardware and software are used in analysing the EMG signals for extracting the features and classification the EMG signal. The features are important to determine the classification of the several degree movements.

CHAPTER 3

METHODOLOGY

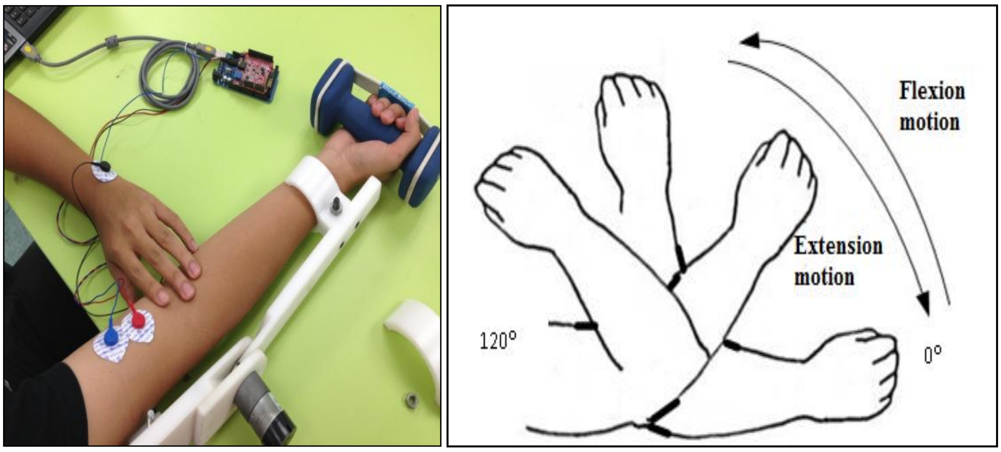
Methodology is the most important structure that needs to be firm as for understanding purpose. In this chapter the whole step from collecting the data, analysis, summary and output will emphasise in detail.

3.1 Introduction

Implementation of arm rehabilitation device based on different angle movement is recorded from the EMG signal of healthy subjects. From the human anatomy studies, different angle movements of upper limb are depends on relation of agonist and antagonist. In this study is focusing on the behaviour of biceps muscle as agonist. Muscle that only involved in this study is bicepsbrachii.

3.2 Procedure and Experimental Setup

The experiment's environment is in a room with low lighting especially the fluorescent light, any electromagnetic devices is away from the experiment equipment and the environment is in soundless room. Then, the experimental is set up with the subject sit on the chair while the hand is on the table. The subject has to complete the task of lift up the dumbbell with 2.27kgs of weigh in Figure 3.1 for 10 times. Mostly, the EMG signal is obtained after several trials of the movements. Normally, the appearance of EMG signal is chaos and noisy depends on the type of electrodes also the noise factor. To simplify the difference of amplitude response's motion, the dumbbell is functioned to amplify the amplitude in analyzing the electrical activity during rest and contract. The rehabilitation devices(white in colour on Figure 3.1(a).) helps to keep the position of the elbow joint and the wrist joint in line without being affected by the weight of the dumbbell during lift up motion. These movements are specified from angle of 0°(arm in rest position), up to 120°(arm is fully flexion). The experiment will go through several phases as explained in the next section.

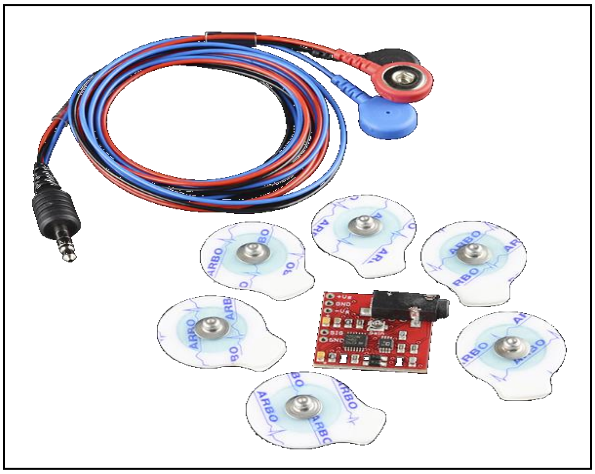


(a) (b)

Figure 3.1 Subject is set-up with arm rehabilitation assistive device for experiment (a). Simulation of subject has to lift up the dumbbell 2.27 kgs of weight (b).

i. Phase 1: Skin Preparation and Electrode Placements.

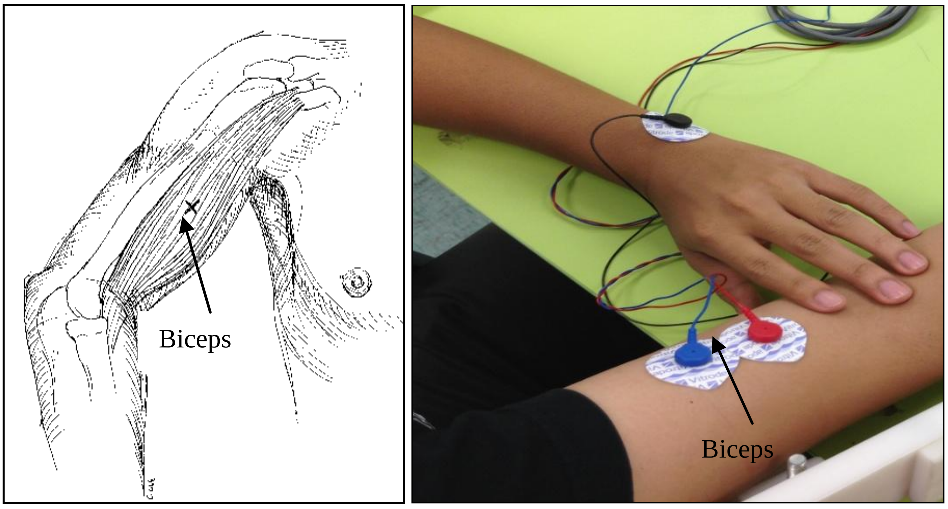
The placement of the electrode is followed after skin preparation. The preparation of the skin is needed before placing the electrodes. The subject's skin has to shave using small electrical shaver and cleaned with sterile alcohol swabs saturated with 70% Isopropyl Alcohol as shown in Figure 3.2(a). This step is to be taken for minimising the noise and to have a good contact with the electrodes of the skin. The skin has to be clean from any contamination of body oil, body salt, hair and the dead cells. The preparation of skin can be done by wipe the alcohol swab into the area of skin that electrode placement to be applied. The placements of the electrode have to be at the belly of the muscles not in the tendon or motor unit. Electrode leads and gelled electrode (Figure 3.2(b)) is used to collect the data.The combination of Arduino Mega and the OLIMEX shield, simplified the hardware. As the EMG signals are too sensitive towards magnetic devices, the neatness of the hardware is needed. The neatness ensured the electrode leads and the detecting surface intersects most of the same muscle on subject as in Figure 3.3 at biceps, and as a result, an improved superimposed signal is observed. Reference electrode has to be at the body where no muscles exist as the ground signal, for this experiment it placed at wrist on the unaffected hand(refer Figure 3.3(b)).



(a) (b)

Figure 3.2 The alcohol swab(a) and the gelled electrode(b) that used in this experiment.

ii. Phase 2: sEMG Signal Acquisition



(a) (b)

Figure 3.3 The biceps brachii muscles for electrode positions(a), The electrode placements on subject skin(b)

Gelled electrode has two leads detecting surfaces and one lead as reference electrode. These two detecting surface need to be placed in range of less than 1-2 cm from each of it at the biceps muscle as pointed in Figure 3.3(b). The gelled electrode for the blue lead and red lead are placed at the biceps skin for detection purpose, meanwhile the gelled electrode with black lead is placed at area with no muscles exist and unaffected hand.[7] The grounded electrode hand is placed at the leg to have a better grounding purpose.From Figure 3.4 these EMG signals will go through into high voltage protection to protect any electrical surge that may bring harm to the user and the hardware. These signals are available for signal conditioning process as the next step to be taken. The circuitthat be used in this experiment is provided by the OLIMEX shield. The signals via the OLIMEX shield through the analogue circuit are very weak the voltage is around 10μV, full of noise and contain primarily 60Hz of frequency. The signals are next need to be filter and rectify, reducing the noise and amplifying the signals for analysis purpose. After the signal is filtered and amplified the signal is sent to the digital board and yet ready to display into the MATLAB software. The full circuit diagram of OLIMEX shield can be viewed in AppendixA.

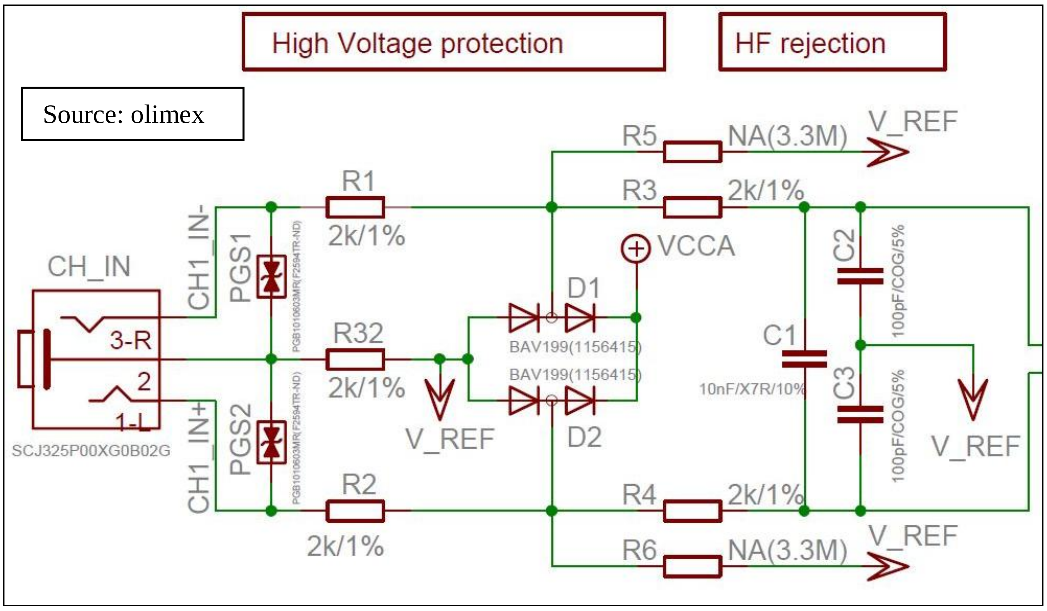


Figure 3.4The electrical diagram of electrode sensor, high voltage protection and frequency rejection.

iii. Phase 3: Signal Conditioning

The signals from the board are gathered in the SIMULINK software(refer Figure 3.5). Signals from the OLIMEX shield need to be filtered by using the peak notch filter and the high pass filter. Peak notch filter is used for filtering the interference from the line AC and radio frequency from the devices frequency nearby. Meanwhile, the high pass filter is used for placed the baseline of EMG signals display in the scope(SIMULINK) at the zero line, also known as DC offset. Block diagram for collecting the EMG signal is showed in Figure 3.5. The disadvantage by using these two types of filter will affect the originality of EMG signal, might be some information will be removed during passing the filters. This project are using low-end product which is inexpensive, truly helpful in understanding the basic study of EMG signal. The raw EMG signals is next to filter by using Butterworth filter. The Butterworth filter is set to 5^{th} order and 10/1000 Hz frequency. The filtered signal is accessed for features extraction. This EMG signal evaluated in time domain features. The analysis of this study soon to be applied in real-time application. Thus, the time-domain suits this study for better future work. These features are Root-Mean-Square(RMS), Mean Absolute Value(MAV), Standard Deviation(STD), Variances(VAR), and Zero Crossing(ZCS). This statistical information of the features evaluations were run in the MATLAB R2013a. The signals that gathered from the SIMULINK is next to be apply for features extraction. The features are extracted using MATLAB 2013a programming. Features extraction by the subjects is gathered in AppendixB.

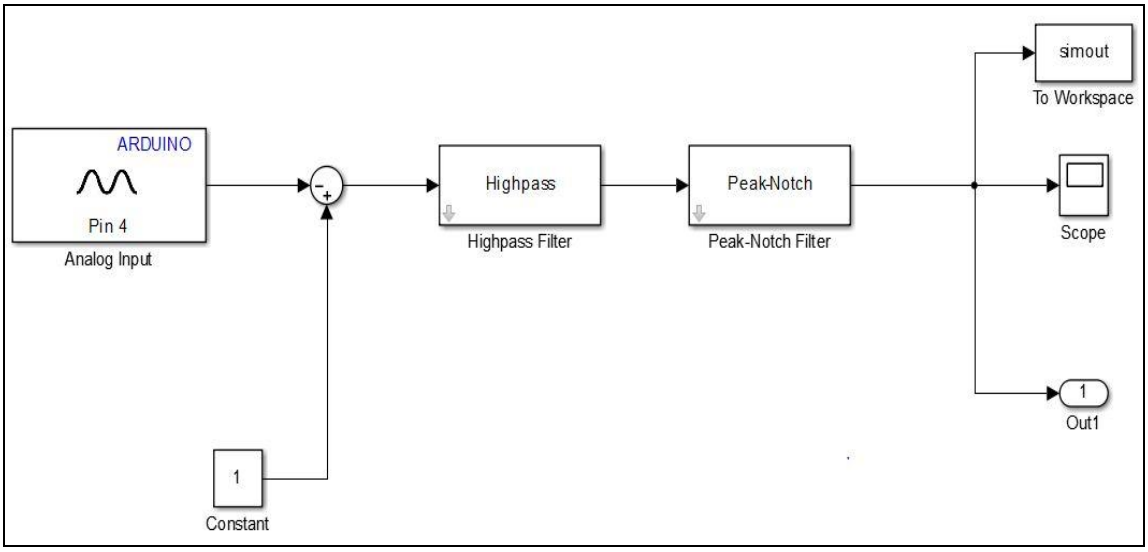


Figure 3.5 Block diagram in SIMULINK software for collecting the EMG signals.

iv. Phase 4: Signal Classification

Subsequently, the EMG features is analysed for classification process. The features are to be chose either it suits in classification process or not. The classification process is conducted by using unsupervised artificial neural network technique, which is Self-Organizing Map(SOM). The SOM is simulated using MATLAB software to classify the angle movement of the subjects. This is to achieve the objective of this study which is to classify the extracted features of EMG signal base on the angle movement. The classification signal can be further analyse for arm rehabilitation device implementation. The SOM-Toolbox need the user to organize the data(features) in column form to be analysed. The user also needs to set up the number of neuron to be use in the analysis. This number of neuron is important to determine the training time, size of map, and the error. Then, the data were called to run the analysis. From the analysis, the SOM-Toolbox gave the number of two types of error which mention in Chapter 2, quantization error and topographic error. The analysis by the SOM is recorded. The recorded analysis is next to be proved by the features either the pattern is recognized by the features or unrecognized and yet this study cannot be proved.

3.3 Experiment Work Flow

The experiment started by selecting subjects with BMI standards, healthy and without any medical history. The subjects are doing the experiment with voluntary and willing to do the tasks given. The subjects' skin is prepared for electrode placements. The gelled electrode is placed at the biceps brachii muscle for detecting the electrical activity in the musculoskeletal system. The EMG signal from the biceps brachii is observed to see the contraction during flexion and extension movements. The signals from the subjects are collected and compiled into the table for signal conditioning process. The feature extracted from the conditioning process is evaluated either the features falls into the same range of value or not. The suitable features used for classification process by using SOM-Toolbox. The number of neuron is updated until the features are classified into their class of movements. The work flow of this experiment can be view in Figure 3.6.

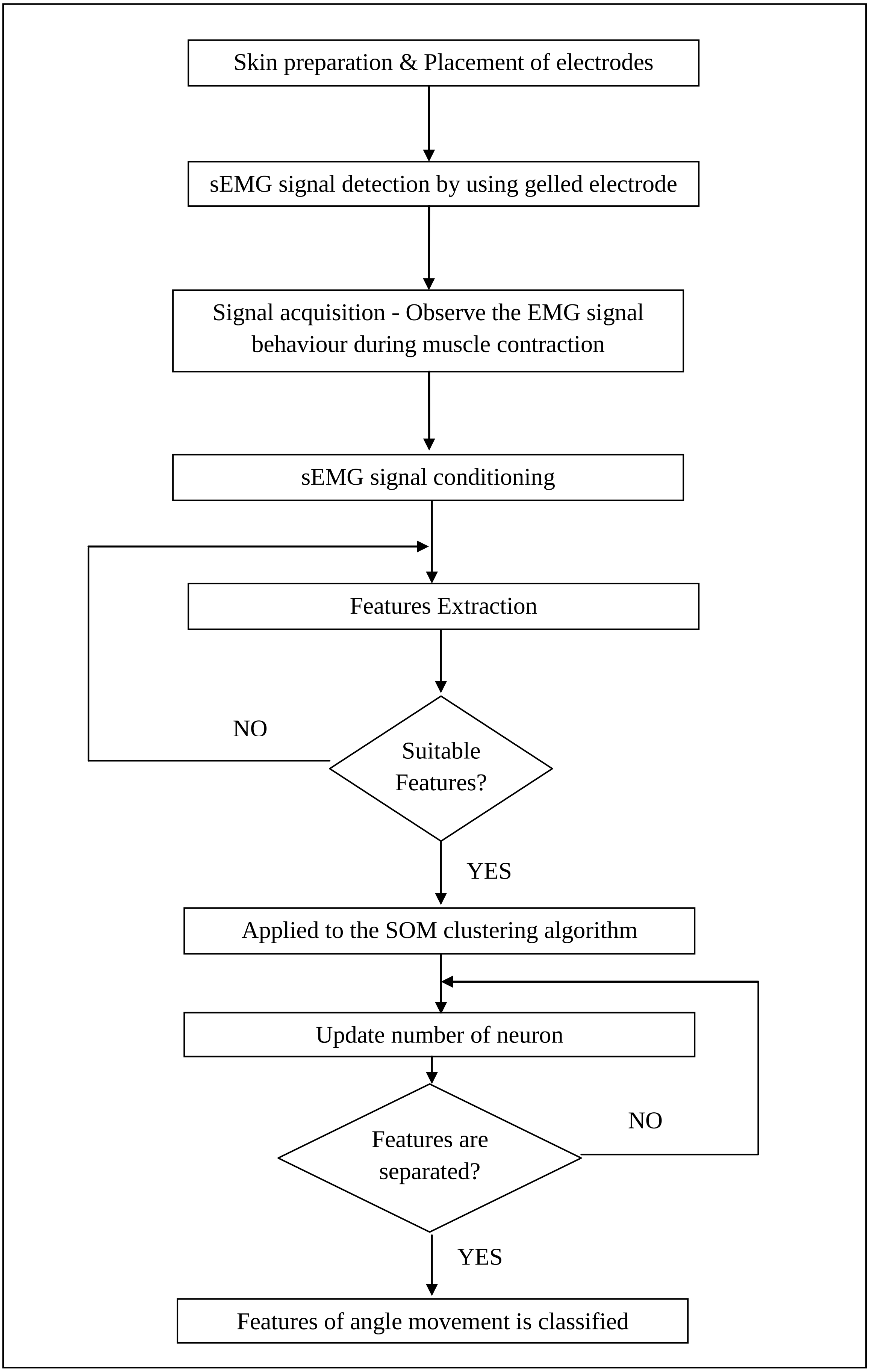


Figure 3.6 Flow of the experiment

3.3 Summary

Methods to apply from initialization of this research until the reduced vector of EMG data have been thoroughly explained in this chapter. The purpose of the features extraction of the EMG signals is to classify the pattern of the arm movement by degree of angle. This is important for future works of arm rehabilitation device application. The methodology is based on the literature review from other researchers who suggested the precaution to take before and during the experiment is conducted. Finally, this chapter help to achieve the objectives of this research.

CHAPTER 4

RESULTS & DISCUSSION

This chapter describes the results and discussion of the research finding. The signals are collected from hardware which is, ArduinoMega256 and OLIMEX shield. Hardware is connected to electrodes and the recorded EMG signal is shown in MATLAB 2013a. Further analysis on the signal conditioning, time domain feature extraction and classification is also conducted in MATLAB software.

4.1 Raw EMG Signals

EMG signals from the Arduino and OLIMEX is displayed in software MATLAB 2013a. The raw EMG signals from the hardware circuit board had through the phase of filtering and amplifying. The signal is contain lot of noise, not at the zero of y-axis and less sensitive to the movement of muscle. From the study, the experiment is conducted in the room with lot of fluorescent light, magnetic devices(i.e, handphone, tablet and line AC power) and the room is not good at grounding purpose. Moreover, the placement and the type of electrode leads are not good at detecting the muscle contraction. The result in Figure 4.1 obtained by using dry electrodes has some disadvantages. The EMG signals has a higher inherent noise level and do not have the long-term stability because of the changes in dielectric properties are the disadvantages of using the dry type of surface electrodes. Thus, the utilization of dry electrodes is wary and requires particular care of electrodes.

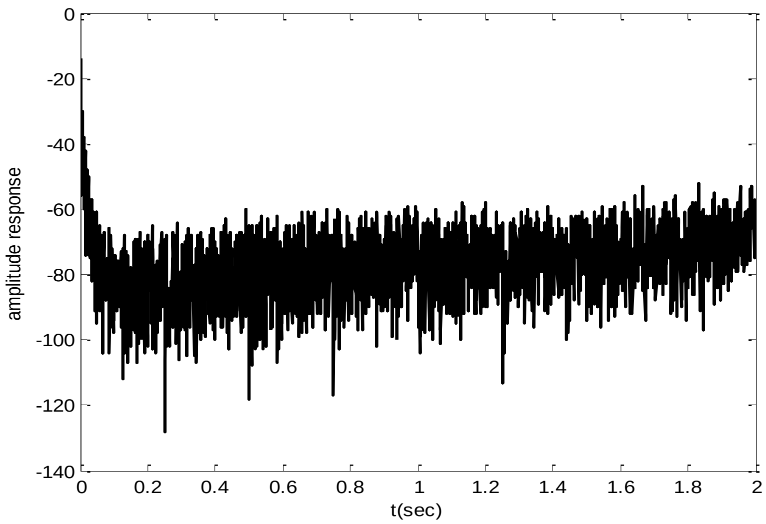


Figure 4.1The raw EMG signal affected by the placement of bipolar electrodes not within 1-2cm and without environment control (ambient noise).

Thus, the study is proceeded to improve the quality of the EMG signal. The raw EMG signal in Figure 4.2 is obtained by improvement of the methodology for data collection. The signal is obtain from the additional of two types of filter in SIMULINK block as stated in Chapter 3 in Figure 3.4. These filters are needed for signal dc offset and to reduce the noise from the AC power line. The importance to filter the noise and to set the signal at dc offset is to maximize the raw EMG signals. The muscle contraction is easy to observe when the EMG signal has less of noise and maximized. The amplitude of raw EMG signal is easy to observe during the muscle contraction. The amplitude is increasing gradually in Figure 4.2.

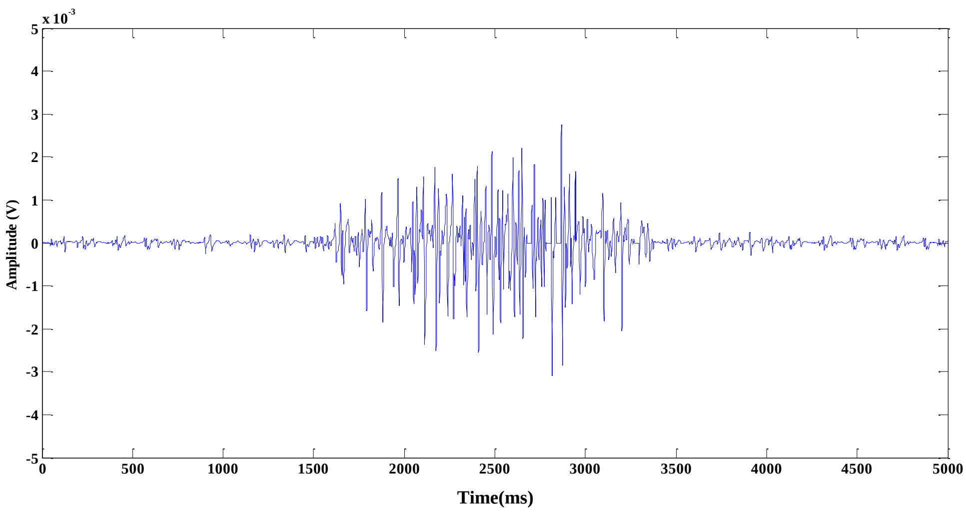


Figure 4.2 The raw EMG signal during muscle contraction.

4.2 Filtered EMG Signal

The raw EMG signal is required to be filter for analysing the signal. Before the signal is filtered, the raw EMG signal has to be rectified into half wave signal as in Figure 4.3. The rectified signal cut off the EMG negative signal value to simplify the analysis of the features. The importance of rectifying the signal is to analyse the raw signal in positive value. The EMG signal is reflected at the x-axis, thus, the rectified process is the important process to obtain the features in absolute value. Thus, amplitude signal in Figure 4.3 shows the rectified signal is on the positive side only.

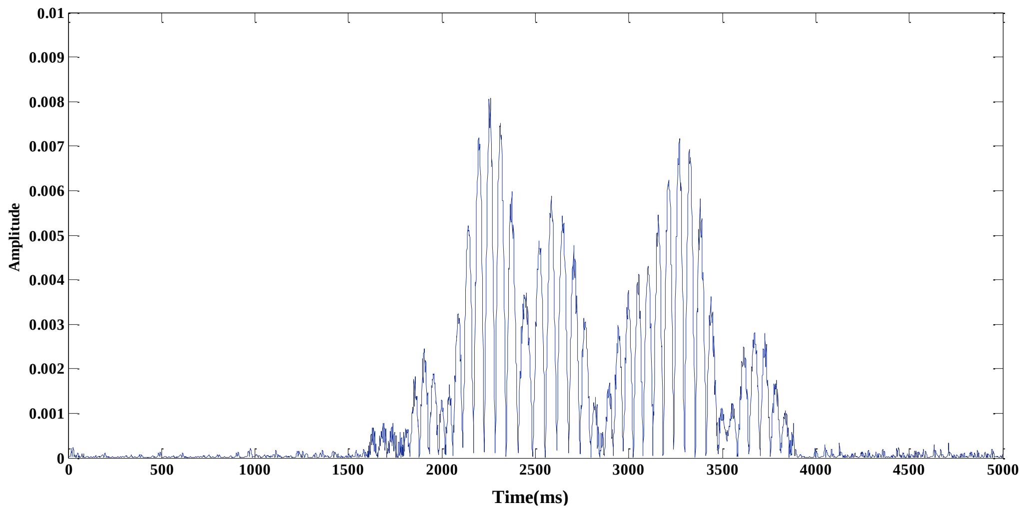


Figure 4.3 The rectified raw EMG signal.

The signal is filtered by using the Butterworth filter. The filtering process is conducted by using the software programming in MATLAB 2013a. The Butterworth filter is set by using 5^{th} order of filter and 10/1000 Hz of low pass frequency. The low pass frequency is determine by using power frequency spectrum, the actual frequency is located at the most useful signal frequency(for this case is 10Hz) other than that are noises. The result of Butterworth filter signals is showed in Figure 4.4.1 to Figure 4.4.3. Each of figures below represents the movement and the result of EMG signal during muscle contraction. From the figures of filtered signal, the EMG signals shows smooth signal with curvy line at the peak amplitude compare to the raw EMG signal which had the spark at the peak of the amplitude. These are affected by the number of order filter and the low pass frequency value. The filtered signals look alike envelope to the raw EMG signal. This pattern of signal shows that the signal is already filter. However, the Figure 4.41 to Figure

4.4.3 only to shows the EMG signal during the muscle contraction for 60, 90 and 120 degree of movement. The raw signal for every signal is rectified and filtered by using the Butterworth filter for features extraction.

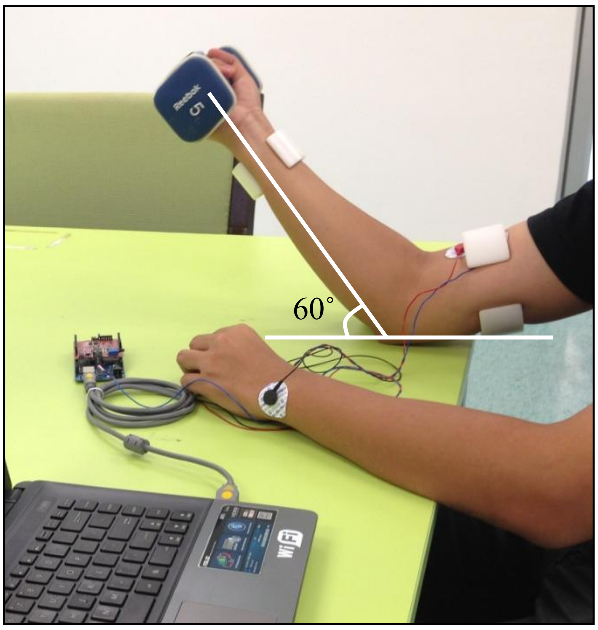


Figure 4.4.1(a) Subject lift up the dumbbell at angle of 60˚.

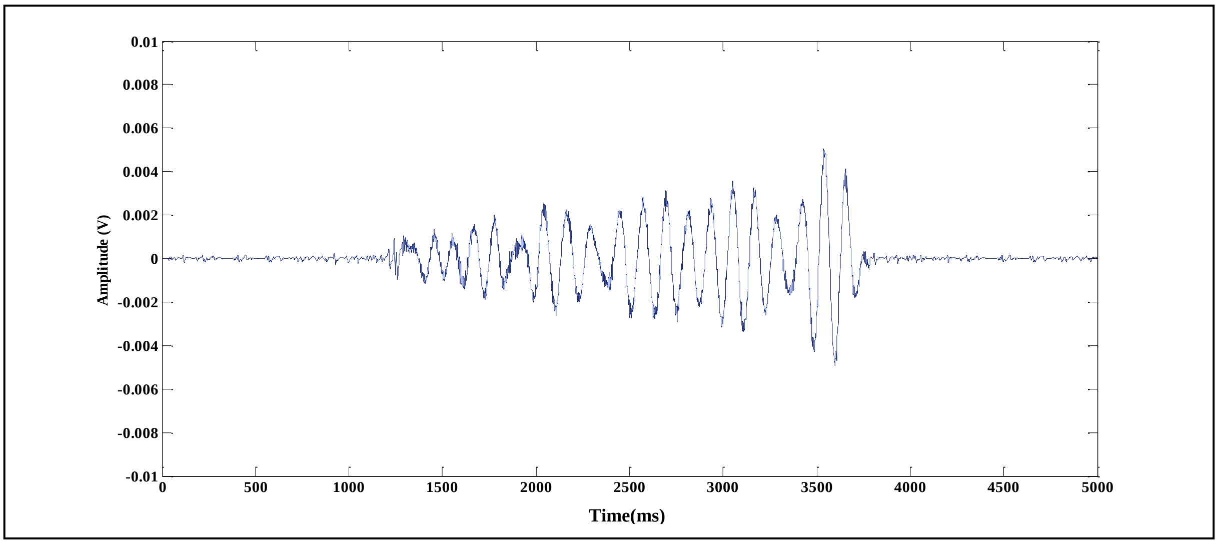


Figure 4.4.1(b) The EMG signal resulted by lifting the dumbbell at angle of 60˚.

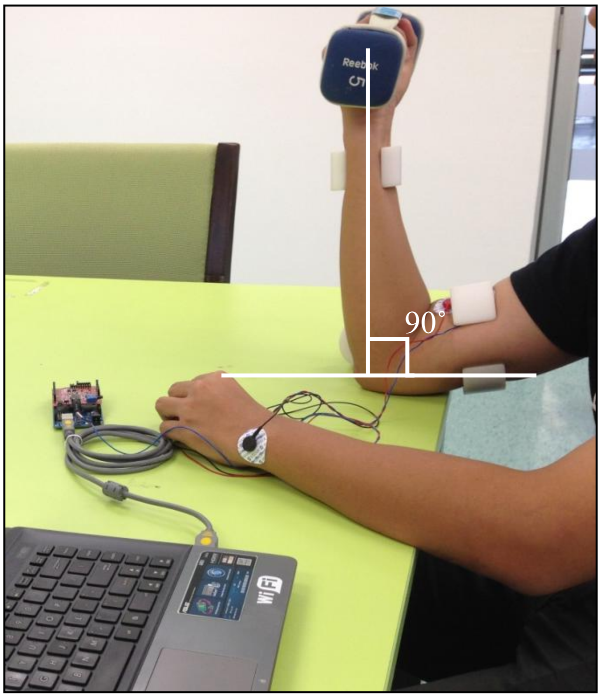


Figure 4.4.2(a) Subject lift up the dumbbell at angle of 90˚.

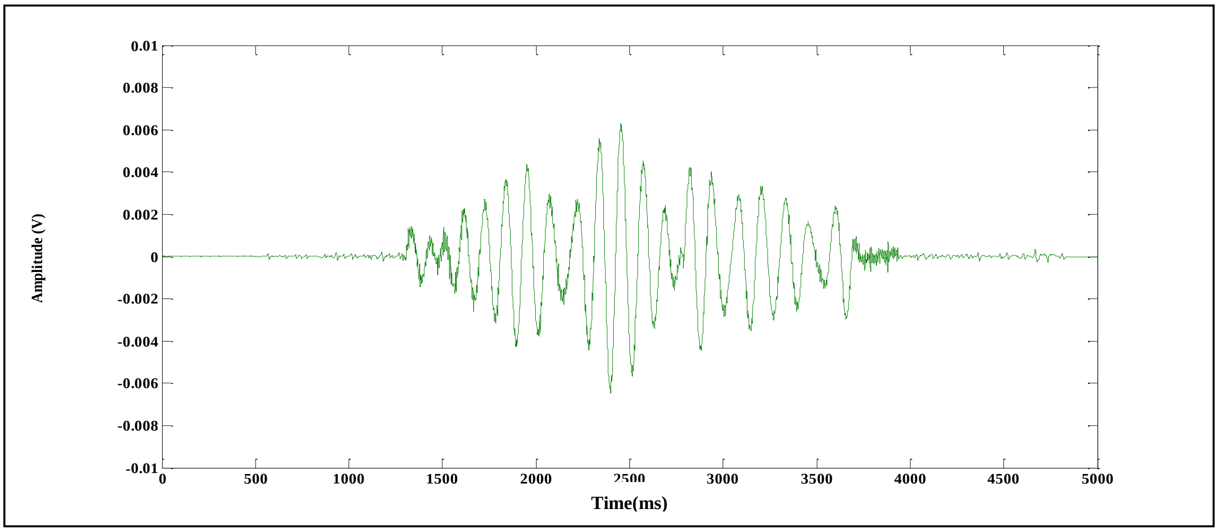


Figure 4.4.2(b) The EMG signal resulted by lifting the dumbbell at angle of 90˚.

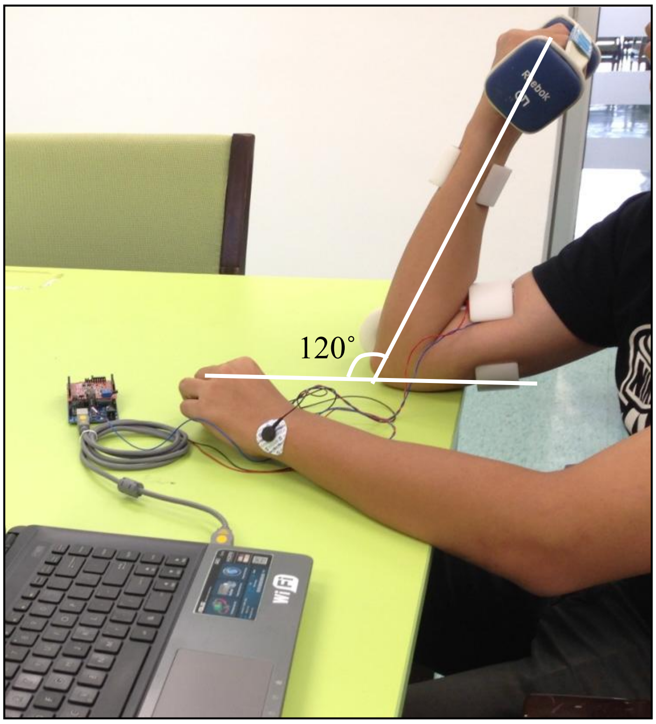


Figure 4.4.3(a) Subject lift up the dumbbell at angle of 120˚.

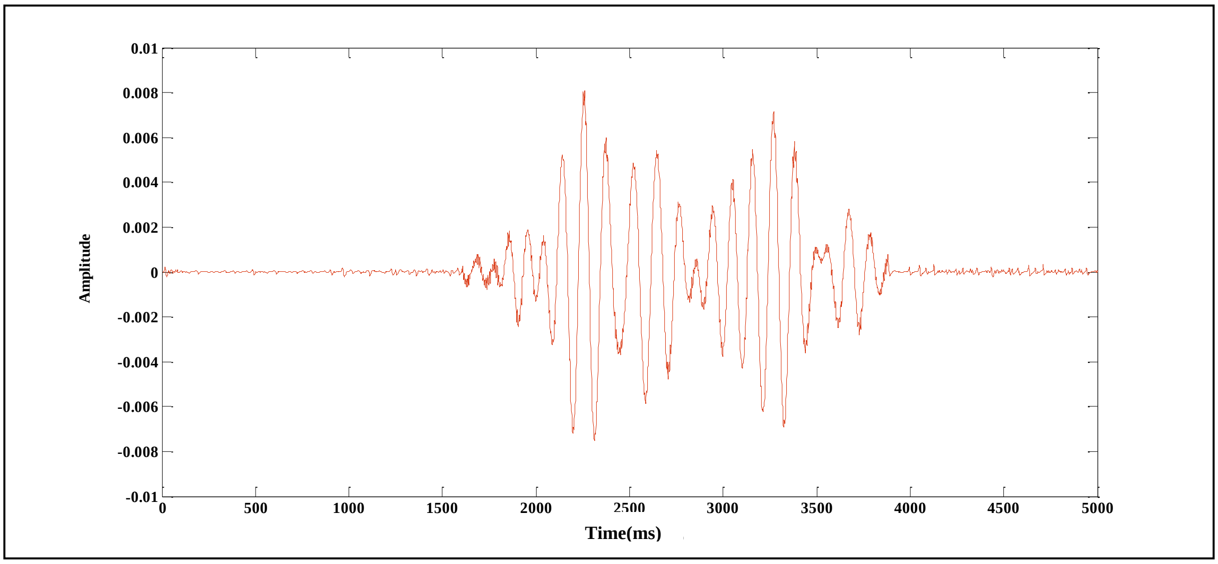


Figure 4.4.3(b) The EMG signal resulted by lifting the dumbbell at angle of 120˚.

The differences of amplitude in Figure 4.4.1 until Figure 4.4.3 showed that the muscle contraction between each angle of movement can be differentiate. The amplitude response for every subject may be differs, as the weights of the body distinguish content of fatty tissue between the skin and the muscles that may decrease the amplitude of the muscles contraction. The fatty tissues that lay under the skin may affect the efficiency of the electrode detection surface. To overcome the fatty tissues obstacle, the electrode is neatly tape to the subject skin by using the skin tape to ensure the detection surface can detect the presence of the muscle activity.

4.3 Features Extraction

The filtered signal goes into features extraction process. The features extraction is set into five types which were RMS, MAV, STD, ZCS and VAR. These features are extracted from each movement of individual EMG signal. The data of the features is accumulated in Table 4.1. The suitable features that may use in classifying the movement are MAV, RMS and STD. ZCS and VAR value are not applicable in classifying the features. ZCS produced the whole number, meanwhile the VAR produced the scientific number that smaller in range of 10^{-6}. The complete result of these features extraction may be view on Appendix B. However, the ZCS and VAR features may be used as it is, in its own class of features. The results are various except the feature is preset.

Table 4.1 Features extraction of EMG signals by subjects.

Subject	Angle	MAV	RMS	STD
S1	60˚	0.001903	0.001981	0.001329
		1.61E-03	0.001777	0.001329
		1.42E-03	1.75E-03	0.001325
	90˚	0.00232	0.0027	0.0022
		0.00231	0.00267	0.00219
		0.00228	0.00254	0.00215
	120˚	0.00318	0.00363	0.00311
		0.00317	0.00365	0.0031
		0.00317	0.00339	3.16E-03
S2	60˚	0.00174	0.00219	1.42E-03
		0.00165	0.00189	1.38E-03
		0.00164	0.00188	1.21E-03
	90˚	0.00244	0.00286	0.00238
		0.00237	0.00285	0.00231
		0.00232	0.00277	0.00228
	120˚	0.00315	3.99E-03	0.00316
		0.00316	3.98E-03	0.00318

		0.00315	0.00384	0.00314
S3	60˚	9.75E-04	0.0019	0.00124
		9.15E-04	0.00162	0.00133
		9.13E-04	1.61E-03	1.10E-03
	90˚	0.002	0.00239	0.00209
		0.00189	0.00231	0.00207
		0.00186	0.00228	0.00205
	120˚	0.00282	0.00318	0.00314
		0.00291	0.00316	0.00307
		2.98E-03	0.00315	0.00302
S4	60˚	0.00161	0.00198	0.00133
		0.00154	0.00185	0.00129
		0.00141	1.73E-03	0.00127
	90˚	0.00233	0.00246	2.44E-03
		0.00231	0.00243	0.00237
		2.23E-03	0.00242	0.0026
	120˚	0.0033	0.00391	0.00317
		0.0032	0.00382	0.00313
		0.00327	0.00378	3.11E-03

4.4 Classification of EMG Signals

Artificial Neural Network can be divided into supervised and unsupervised learning. The learning process of Neural Network requires many branches, layers, and neurons to yield the output. In this study, the coach for learning the network model is the features of the EMG signals. The classifier that cover on this study is Self-Organizing Map(SOM). SOM is learns in unsupervised manner. Data in Table 4.1 are applied in SOM-Toolbox using Matlab to classify the degree of movement. However, to simplify the data input into the 'm.file', the data is calculated to average value for each movement. The simplified table is represented in Table 4.2.

Table 4.2 The average value of angle movement features.

SUBJECT	STD	MAV	RMS	ANGLE
S1	0.001328	0.001645	0.001836	60
S2	0.001337	0.001674	1.99E-03	60
S3	1.22E-03	9.35E-04	0.001709	60
S4	1.30E-03	0.001418	0.001855	60

S5	0.002636	0.002303	0.002178	90
S6	0.002826	0.002377	0.002325	90
S7	2.33E-03	0.00192	0.002072	90
S8	2.44E-03	0.002291	2.47E-03	90
S9	0.003121	0.003174	0.003556	120
S10	0.003158	0.003154	0.003936	120
S11	0.003076	0.002903	0.003164	120
S12	0.003138	0.003255	0.003837	120

Data from Table 4.2 is plotted into scatter graph in Figure 4.5. Sample 1 up to sample 4 be owned by movement of 60˚, sample 5 to sample 8 is belong to movement of 90˚ and sample 9 to sample 12 is fit in movement 120˚. The green, yellow and red outline colour in Figure 4.5 shows that the scatter features is obviously been clustered by its angle of movements' class. Even though the clustered movements is scattered in its class, the objective of this study is achievable. The learning of the features is continued in data classification.

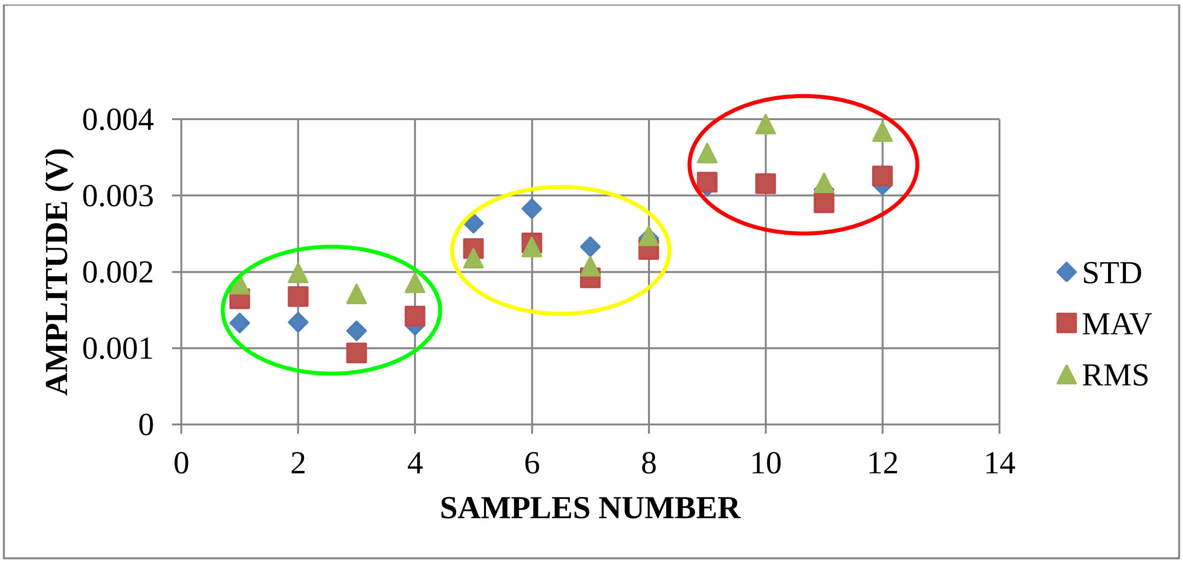


Figure 4.5 The scatter graph of features versus amplitude voltage.

4.5 Self-Organising Map (SOM)

The unsupervised manner is applied in SOM-Toolbox using Matlab software. This toolbox is a powerful tool that may helps to cluster randomized data. The data can be cluster even though the data is not arranged on its class. The more data the merrier clustering process. The data from Table 4.2 is relabelled into predefine ‘T’. Ts are defined as the trials belong to movements for certain angle in Table 4.3. Its’ labelled as predefined T in ‘m.file’ in Matlab for data training. The random data training is compiled in ‘m.file’ and number of neuron is update to observe the clustered data of predefine ‘T’.

Table 4.3 Predefine T for unsupervised learning.

T	DESCRIPTION	SUBJECT
T1, T2, T3	Movements by angle of 60˚	**S1**
T13, T14, T15	Movements by angle of 90˚	
T25, T26, T27	Movements by angle of 120˚	
T4, T5, T6	Movements by angle of 60˚	**S2**
T16, T17, T18	Movements by angle of 90˚	
T28, T29, T30	Movements by angle of 120˚	
T7, T8, T9	Movements by angle of 60˚	**S3**
T19, T20, T21	Movements by angle of 90˚	
T31, T32, T33	Movements by angle of 120˚	
T10, T11, T12	Movements by angle of 60˚	**S4**
T22, T23, T24	Movements by angle of 90˚	
T34, T35, T36	Movements by angle of 120˚	

The data training is started by 100 of neurons. SOM-Toolbox visualized the output as in Figure 4.6(a)(b). Figure 4.6(a) shows the component planes in SOM. The variables in component planes are the features of EMG signal for all subjects. The features are RMS, MAV and STD. The components by each variable shows that the feature is clustered on its own feature class. In MAV feature plane shows that the MAV data is clustered at the top left of the plane. Which means the clustered data in dark blue colour is clustered and the distance among the data is closed. The dark blue colour in MAV plane is surrounded by the light blue, green, yellow and red colour. The colour in the plane shows the distance from the components that had cluster. The red colour is the farthest distance from the clustered data. RMS shows quite similar clustered plane as MAV but the clustered data range is smaller than MAV clustered data. Meanwhile the STD shows the largest clustered area in its plane. Which means STD is the most data that affect the visualization of combination U-Matrix.

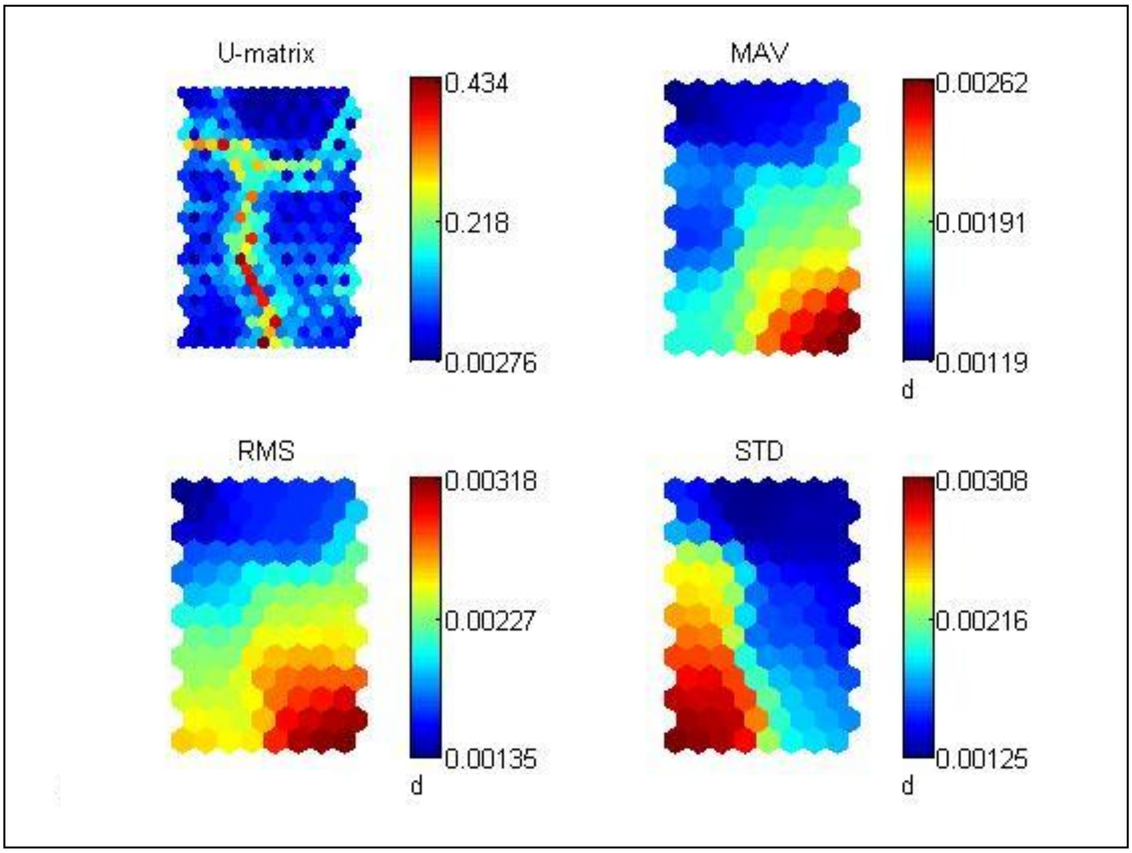


Figure 4.6 (a) The components planes of EMG signals features.

Figure 4.6(b) is U-Matrix visualization. The U-Matrix is visualized by three EMG features, RMS, MAV and STD. U-Matrix shows the predefined 'T' had been clustered by the EMG features. The predefined 'T' is scattered and hardly to obtain the class of angle movements. In Figure 4.6(b) six clustered data in red, yellow and black outline colour. The red line colour is defined as movements by angle of 60˚. It is because the small and large red outline colour is separated by small deviation(light blue colour). The yellow outline colour had about identical area of clustered data, it shows that the clustered data essentially of two type of difference data. The yellow outline clustered data is predicted as movements by angle of 120˚. While the black outline prediction goes to movements by angle of 90˚.

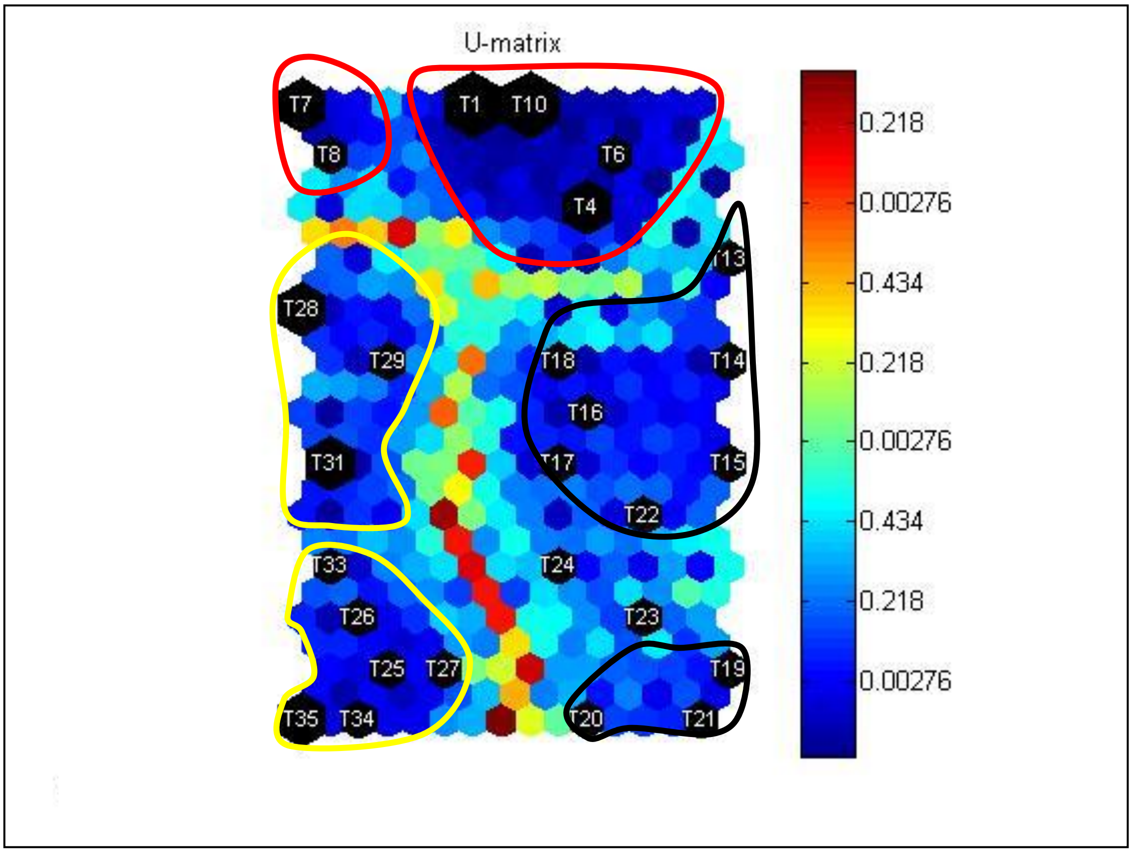


Figure 4.6(b) Visualization of U-Matrix for 100 neurons.

100 numbers of neurons is not sufficient amount to classify the movements. The test of increment number of neurons is carried until the data can be classified. The neurons are increased gradually by 10. The resulted of the test including the training time, quantization error and topographic error is compiled in Table 4.4. The number of neurons is updated in purpose to have the best matching unit of neighbourhood. The best matching unit function as tracking the node that produces the smallest distance. The node requires smaller distance to pull the neighbouring nodes closer to the input vector.

Table 4.4 The training data result.

No. of Neuron	Training Time	Quantization Error	Topographic Error
100	0s	0.026	0.056
110	0s	0.025	0.028
120	0s	0.023	0.028
130	0s	0.022	0.000
140	0s	0.018	0.028
150	1s	0.014	0.028
160	1s	0.015	0.000
170	1s	0.015	0.028
180	1s	0.016	0.028
190	1s	0.013	0.028
200	1s	0.011	0.000
210	1s	0.009	0.000
220	1s	0.009	0.000
230	1s	0.006	0.028
240	1s	0.007	0.000
250	2s	0.007	0.000
260	2s	0.006	0.000
270	2s	0.004	0.000
280	2s	0.004	0.000
290	2s	0.003	0.000
300	2s	0.003	0.000

The result in Table 4.4 is gathered by training the neurons via Matlab with SOM-Toolbox. The neurons training outcome the error and the training time for each increment of neurons. The errors values facilitate to decide the best number of neurons to classify the EMG signals for each movement. Neural Network is recognized by the winner in the neurons. In this experiment, the neurons win at number of 300. 300 neurons amount, resulted none topographic error and the smallest quantization error among the neurons. The training time in this experiment just reached 2 seconds. It is still categorized as rapid learning and applicable for features classification. The 300 neurons are closer to the input vector compared to the 100 neurons.

Figure 4.7(a)(b) shows the result of the SOM classifier. The component planes in Figure 4.7(a) show that STD is the largest area data that can be clustered in this experiment. This means that the STD feature extraction is the reliable feature that classifies the data. This is supported by the Figure 4.8, where the STD value is fall nearly to the range of degree movements. The blue line colour in Figure 4.8 shows that the line is virtually reaching the expected line of degree movements. Meanwhile, the RMS and MAV are quite distant from the expected line of degree movements. The component planes in Figure 4.7(a) already prove that the MAV and RMS features are clustered by minor of dark blue area. The dark blue colour of RMS and MAV shows tiny spot compared to STD dark blue colour spot.

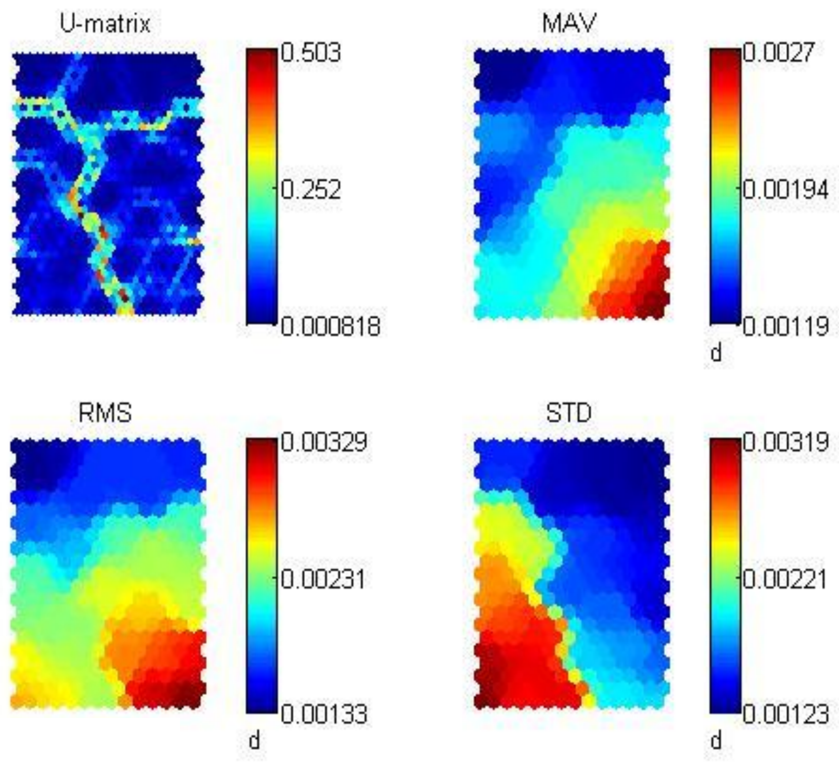


Figure 4.7 (a) The clustered features of EMG signal in 300 amount of neurons.

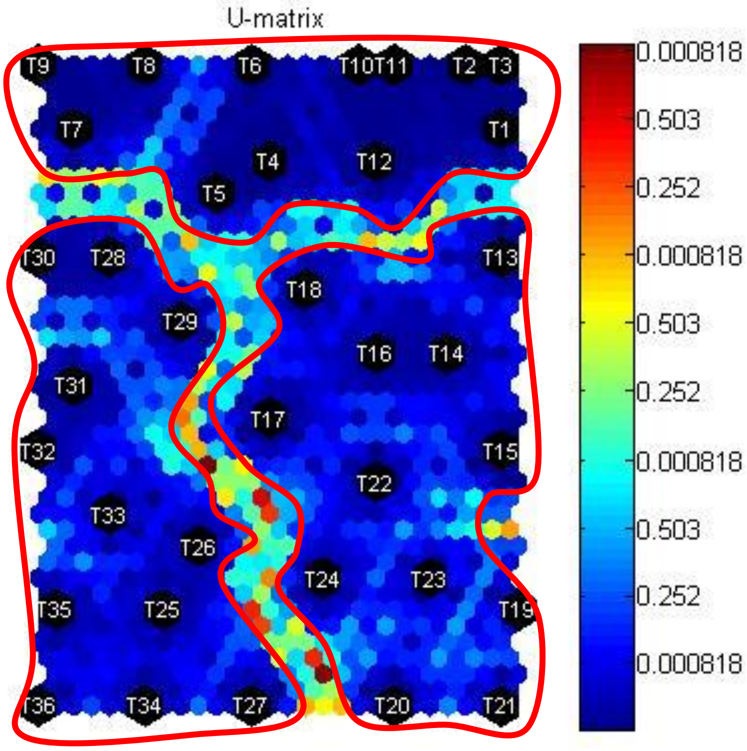


Figure 4.7(b) The visualization of classified angle movements.

Figure 4.8 The features extraction in the range of angle(degree).

Therefore, the EMG signals from the subjects can be classify into the movements by degree of motion. The classification by using one of the Neural Network branches which is Self-Organizing Map(SOM) can be applied to distinguish the movements. As visualized in Figure 4.7(b), predefine ‘T’ are successfully separated into three parts which are angle movements by 60˚, 90˚ and 120˚. By referring to Figure 4.7(b), the predefine ‘T’ in Table 4.3 for T1 to T12 falls into one part which is 60˚, T13 to T24 into 90˚ part and T25 to T36 fulfil the last part which is 120˚.

4.6 Summary

The EMG signal from the subjects is relevant in classification for several degrees of arm movements. The objectives of this study is obtain thorough this chapter. The classification of features extraction only can be applied for three types of time-domain features are Mean Absolute Value(MAV), Root Mean Square(RMS) and Standard Deviation(STD).

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

In this study has further discussed on the noise and the environment that affects the EMG signal during data collection. The surface electrodes contain lot of noise compared to needle insertion procedure, noise from the skin itself and the environment have been discussed in this study for better understanding to get a better quality of EMG signals.

The objectives of this study are to extract the features and to classify the features by using SOM technique. The features that have successfully obtained from the experiment are MAV, STD, RMS, ZCS and VAR. On the other hand, not all the features can be classified into the class of several degrees of movements. The suitable features for classification are MAV, STD and RMS. The features are obtained by signal processing phase. The features of time-domain are extracted by using programming software use in MATLAB software. The arm movements of 60˚, 90˚ and 120˚ are classified into their own class of degrees movements by using SOM-Toolbox for MATLAB. SOM-Toolbox for MATLAB developed by EsaAlhoniemi*et al.* on 1997 is one of the algorithms for Self-Organising Mapping Technique. The technique is depends on the distance between the nodes and updated weights for classification process.

5.2 Recommendations

Throughout completing this study, there are several enhancements that can be made to obtain the optimised result. Signal acquisition might be improve by using high-tech of data acquisition system such as hardware developed by DELSYS and the electrodes are wireless. The wireless electrodes are assisted for minimising the error from causative factor. The wireless also provides single electrode bar, which means the distance by two electrodes is joint into one bar.

Meanwhile, subjects selection can be improved by select at small rangeamong 20 to 22 of BMI standards. The fix standards of BMI may lead to consistent EMG signals. The classification of this movement is important to have the consistent EMG signals by reducing the error movement from degree to another degree. There are several of features can be extracted from the EMG signals. Addition of features in classification maximise the result for unsupervised learning algorithm.

5.3 Future Works

Classified EMG signals from this study can be applied into arm rehabilitation device. The signals that classified into the device consist of 60˚, 90˚ and 120˚ movements, the bilateral movement might be improved by minimising the degree movements and includes the triceps muscles as agonist anatomy for flexion and extension motion.

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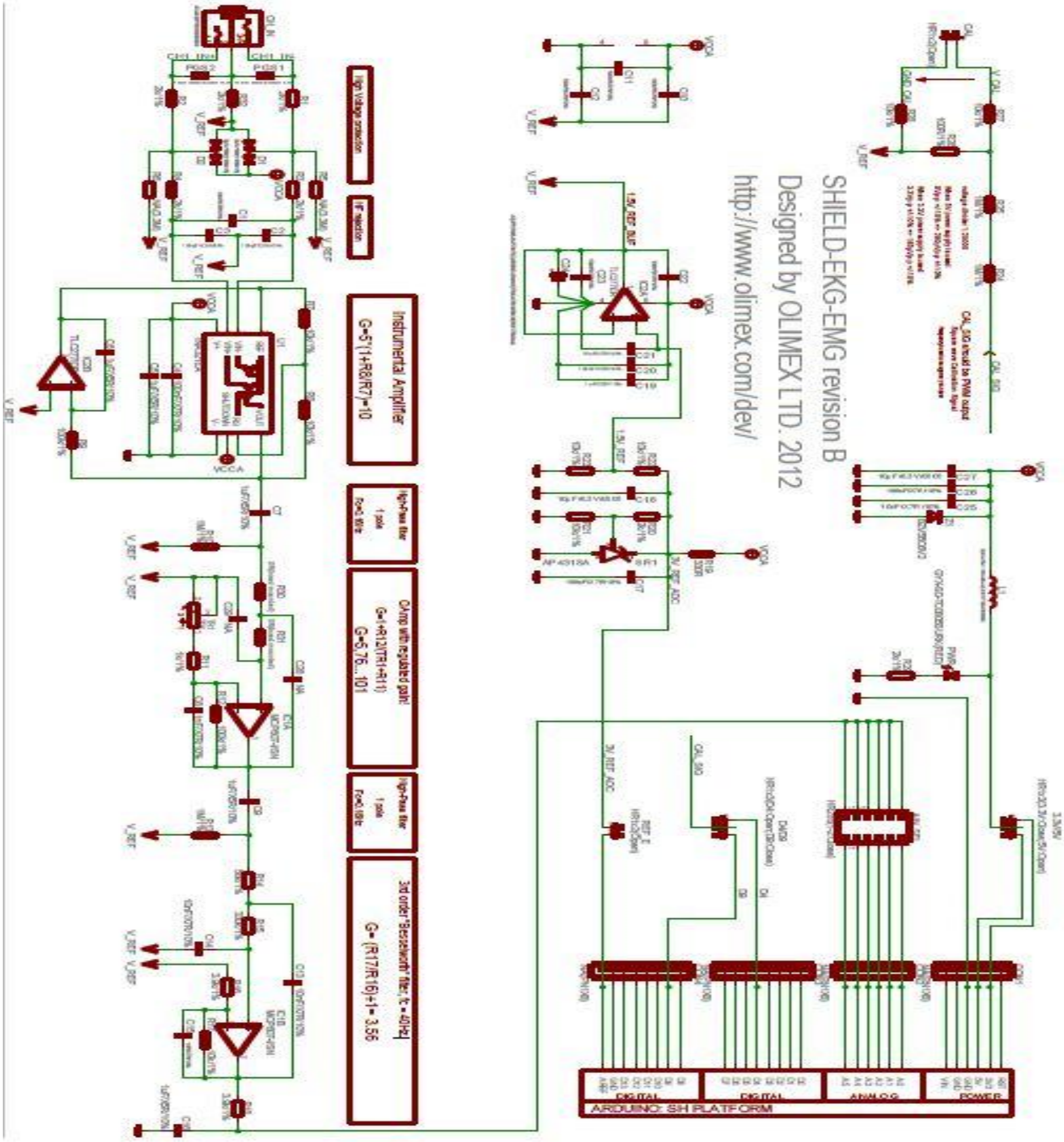
APPENDIX A


SHIELD-EKG-EMG revision B
Designed by OLIMEX LTD. 2012
http://www.olimex.com/dev/

APPENDIX B

Subject	Angle	MAV	RMS	STD	ZCS	VAR
S1	60°	0.001903	0.001981	0.001329	50	1.68E-06
		1.61E-03	0.001777	0.001329	48	1.99E-06
		1.42E-03	1.75E-03	0.001325	44	0.001325
	90°	0.00232	0.0027	0.0022	58	2.66E-06
		0.00231	0.00267	0.00219	43	2.15E-06
		0.00228	0.00254	0.00215	37	2.189E-06
	120°	0.00318	0.00363	0.00311	39	3.13E-06
		0.00317	0.00365	0.0031	41	2.71E-06
		0.00317	0.00339	3.16E-03	51	3.71E-06
S2	60°	0.00174	0.00219	1.42E-03	65	9.50E-07
		0.00165	0.00189	1.38E-03	65	9.75E-06
		0.00164	0.00188	1.21E-03	31	1.76E-06
	90°	0.00244	0.00286	0.00238	81	2.35E-06
		0.00237	0.00285	0.00231	85	2.62E-06
		0.00232	0.00277	0.00228	54	1.62E-06
	120°	0.00315	3.99E-03	0.00316	13	3.56E-06
		0.00316	3.98E-03	0.00318	33	3.93E-06
		0.00315	0.00384	0.00314	45	3.42E-06
S3	60°	9.75E-04	0.0019	0.00124	27	8.34E-07
		9.15E-04	0.00162	0.00133	19	1.22E-06
		9.13E-04	1.61E-03	1.10E-03	19	8.38E-07
	90°	0.002	0.00239	0.00209	23	1.24E-06
		0.00189	0.00231	0.00207	17	1.93E-06
		0.00186	0.00228	0.00205	41	1.75E-06
	120°	0.00282	0.00318	0.00314	31	2.49E-06
		0.00291	0.00316	0.00307	50	2.53E-06
		2.98E-03	0.00315	0.00302	23	2.60E-06
S4	60°	0.00161	0.00198	0.00133	15	1.89E-06
		0.00154	0.00185	0.00129	19	1.46E-06
		0.00141	1.73E-03	0.00127	20	2.00E-06
	90°	0.00233	0.00246	2.44E-03	30	2.21E-06
		0.00231	0.00243	0.00237	25	2.75E-06
		2.23E-03	0.00242	0.0026	27	2.06E-06
	120°	0.0033	0.00391	0.00317	34	3.05E-06
		0.0032	0.00382	0.00313	36	3.16E-06
		0.00327	0.00378	3.11E-03	37	3.01E-06

Features Extraction of EMG Signal using Time Domain Analysis for Arm Rehabilitation Device

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Abstract. Rehabilitation device is used as an exoskeleton for people who had failure of their limb. Arm rehabilitation device may help the rehab program whom suffers from arm disability. The device that is used to facilitate the tasks of the program should improve the electrical activity in the motor unit and minimize the mental effort of the user. Electromyography (EMG) is the techniques to analyze the presence of electrical activity in musculoskeletal systems. The electrical activity in muscles of disable person is failed to contract the muscle for movements. In order to prevent the muscles from paralysis becomes spasticity, the force of movements should minimize the mental efforts. Therefore, the rehabilitation device should analyze the surface EMG signal of normal people that can be implemented to the device. The signal is collected according to procedure of surface electromyography for non-invasive assessment of muscles (SENIAM). The EMG signal is implemented to set the movements’ pattern of the arm rehabilitation device. The filtered EMG signal was extracted for features of Standard Deviation (STD), Mean Absolute Value (MAV) and Root Mean Square (RMS) in time-domain. The extraction of EMG data is important to have the reduced vector in the signal features with less of error. In order to determine the best features for any movements, several trials of extraction methods are used by determining the features with less of errors. The accurate features can be use for future works of rehabilitation control in real-time.

Keywords: Rehabilitation Device, Electromyography, Features Extraction
PACS: 8089

INTRODUCTION

Human support system is endoskeleton. Endoskeleton plays a role as a framework of the body which is bone. Our daily movements are fully depends on the functionality of our complex systems in the body. The disability of one or more systems in our body will reduce our physical movements. The assistive device is a need for rehab as an exoskeleton. The functionality of the rehabilitation device has to smooth as the physical movement of normal human. Nowadays, rehabilitation program are using exoskeleton device in their tasks. The functionality of exoskeleton depends on muscle contraction. Electromyogram studies help to facilitate the effectiveness of the rehabilitation device by analyzing the signal transmitted from the muscle.

The technique of measuring electrical activity that produced from the muscles during rest or contractions known as electromyography (EMG). The electric signal generates from the brain and sends to the muscles via motor neuron. The EMG may detect the dysfunctional of the muscles or failure in signal transmission from nerve to muscle. The failure of sending the electrical signal from the brain requires electrical stimulation from the external source to muscles. Electrodes are used for signal detection of electrical activity in muscles. The study of this electrical activity is important for combination of electromyogram and rehabilitation device.

The rehabilitation device is a tool that used to help the movements for daily life activities of the patients who suffer from the failure of muscle contractions, due to the failure of the muscles contractions the movements is limited. The ability of the patients to do the tasks in the rehabilitation programs need to be measured. The rehabilitation programs have to assure whether the tasks will cause effective or bring harm to the patients [1].

Historically, the rehabilitation tasks have been avoided due to a belief that it would increase spasticity [2]. In this research, the analysis of the data will be focusing on upper limb muscles contraction consisting of biceps muscles only. The experiment is limited to the certain of upper limb movements that use in training. EMG is a division of bio signal; the bio signal analysis is the most complex analysis. Thus, the signal analysis is a complicated process that has to be through many phases of analysis [3].Therefore, the challenge of this study to assure that the signal processing is conducted properly to overcome the environment noise during data collection.

ARM REHABILITATION DEVICE

The arm rehabilitation device is designed by considering two types of muscles that consist in arm, which were; biceps and triceps. These two muscles react against each other; the biceps muscle is the pick-up area for the surface electrode in this study. During flexion motion, the muscles contraction cause the slack in the biceps muscles and tense in triceps muscles and both of these muscles are in rest position when the hand is fully extend which is no muscles having any contraction (refer FIGURE 3).

The purpose to look over the activity of the muscles contraction or electrical activity in the muscles and nerves is to classify the pattern of the movement for two degree of freedom to be applied on the rehabilitation device that have been designed for flexion and extension movement only. Nowadays in medical history, patients who suffering the paralysis or amputate normally are having the nerve injury is not likely to be cured by any kind of treatment though. Indeed, the rehabilitation device is a necessary to ease the patients' movements that have been pattern into the device depending on the degree of freedom (d.o.f) itself.

Disabilities of the paralyses patients have been the motivator to this study in order to help them in their daily routine. The importance of electromyogram on normal and healthy person is very helpful to determine the almost accurate movement of arm rehabilitation device. The parameters resulted by the electromyography will determine the best features to be implement for classification purpose and the parameters plays a major role to set the value in range of the ability normal people may perform for preventing the range is exceed the ability and may bring harm to the user.

This study are focusing on flexion and extension of the elbow firstly because this movements is one of the daily routine movements, secondly from the view of upper limb anatomy, arms consists of biceps brachii and triceps muscles only which were larger, easy for electrode placements right on the belly of the muscles and lastly these movements is the beginning for this research before it can proceed to another higher level degree of freedom that may consider more than two types of muscles such as muscles in the forearm and fingers. The nerve injury that experienced by the paralyses patients that may join the rehab program mostly can feel the presence of the limb but unable or difficult to move it, the existence of this device may ease them. However, for those patients who face the problem from the main supplier of muscles which is from the backbone itself, the rehab device does not help them as they cannot feel the presence of the limb and does not have the determination to move the upper limb as the brain fail to transmit the signal to the nerve through the upper limb.

DATA ACQUISTION IN sEMG

Surface EMG is the technique that had been applied in this study for recording the electrical activity in the muscles by the electrodes. The sEMG provide an easy, safe and non-invasive method that allow the quantification of the muscles' energy. Recording the signal are depends on several criteria that need to be considered before the signal is recorded. According to Zahak Jamal *et al.* [4] on his studies, the electrode placements are an important issue that need to be considered, the placements is depends on the type of the muscles as the muscles at each limb is different. The quality of the sEMG signal that generates from the muscles' energy can be maximizes by placing the electrodes at the belly of the muscles not at or near the tendon and motor unit. If the electrodes is bipolar configuration (FIGURE 1), which have three detecting surfaces, both electrode need to be placed nearly to each other within 1-2cm [4]. These two detecting surfaces are connected to differential amplifier while another one electrode is placed at the reference (bone).

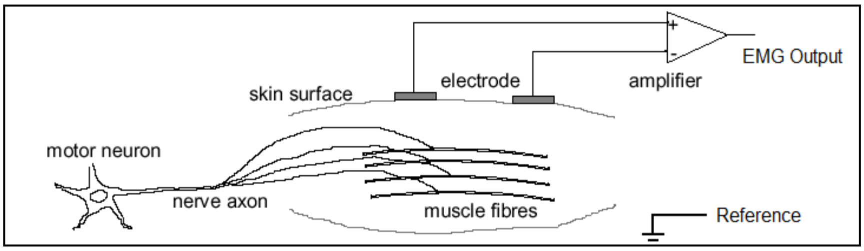


FIGURE 1. Bipolar configuration

The aim for this study to have the EMG signal for analysis purpose by reduce all the unwanted noise from the electrode, hardware and the environment to maximize the quality of the EMG signal. There have a lot of noise factor that can be categorized as follows;

iv) *Causative Factors:* This is the direct affected on signals.

b. *Extrinsic* – The signal get affected by the electrode placement, structure, surface detection, distance between electrode (bipolar configuration), and location of the surface detection on the skin.

c. *Intrinsic* – It may due to physiological, biochemical and anatomical factors.

v) *Intermediate Factors:* This is the phenomena of influencing by one or more causative factors.

vi) *Deterministic Factors:* This is influenced by the intermediate factors.

By reducing all these factor of noises, the quality of EMG signal will be enlarge and the analysis of the information will be less of error and easy to obtain. However, the precautions of handling the hardware and the electrode are needed. Acquisition data play the important role to maximizing the quality of the EMG signal, such as minimizing the distortion in EMG signal, using any filtering tools are not recommended. In terms of signal-to-ratio (SNR) the information that carried in SNR should contain the maximum information of EMG signal [4][5]. Moreover, the quality of EMG signal is affected by the environment, has to set by minimizing the noise factor, this method also known as control environment. The ambient noises sourced by electromagnetic device such as radio transmission, fluorescent lights and power line interference from electrical wires [5][6]. These ambient noise and motion artifact can be reduced by the proper electrode placements, circuit configuration and control environment. The signal recorded in FIGURE 2 shows the appearance of electrical activity in muscles cannot be differentiate by any muscles contraction, because of not following the criteria to reduce the noises and the electrode placements detection surface range.

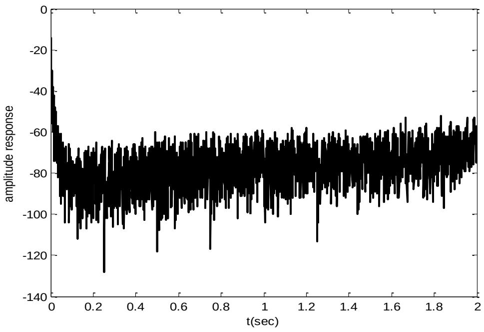


FIGURE 2. The effects of placement the bipolar electrodes not within 1-2cm without environment control (ambient noise)

TIME DOMAIN FEATURES

The goal of this study is to facilitate the future works for designing the rehabilitation devices system. The time domain feature is the most commonly used by the researchers, among them are Angkoon Phinyomark *et al.*[7] and M. Hamedi *et al.*[8]. These researchers implement these features in their future studies in pattern recognition and classifier. One of the advantages of using time domain is it can be implemented in real time. These features can be analyze by using the powerful tool which is MATLAB, as for this study, the analysis is conducted in MATLAB 2013a. There are many of features that related to time domain, below is described more on features in this study:

i) Root mean square

The RMS represents the square root of the average power of the EMG signal for a given period of time. It is known as a time domain variable because the amplitude of the signal is measured as a function of time

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} EMG(i)^2}$$

(1)

ii) Mean absolute value

The MAV is the computer calculated equivalent of the average rectified value (ARV). The MAV is known as a time domain variable because it is measured as a function of time. It represents the area under the EMG signal once it has been rectified, it is defined by the negative voltage values have been made positive. The MAV is used as a measure of the amplitude of the EMG signal like the root mean square (RMS) the RMS is often preferred over the MAV because it provides a measure of the power of the EMG signal while the MAV does not. The mean absolute value is calculated using a moving window. It is calculated for each window of data according to the equation:

$$MAV = \frac{1}{s}\sum_{1}^{s}\left| f(s) \right|$$

(2)

iii) Standard deviation

The STD of a set of data is the square root of the variance, where $\bar{x}$ refers to the mean of the sample. In Figure 7, the STD is pointed in the graph. The STD is often used as the fluctuation for a sample when data is being collected in an experiment. STD represents noise and other interference. It can represent the signal-to-noise ratio (SNR) of the signal which can be determined by dividing the mean by the standard deviation. Good data means would produce a higher value for the SNR. It is quite common features due to the fact that it can be used to find the threshold level of muscle contraction activity [9]. The results taken from data are frequently written as the mean ± STD.

$$STD_{n-1} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

(3)

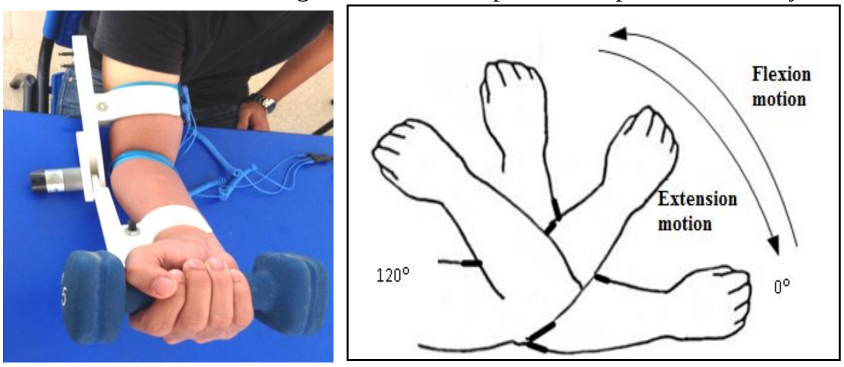
EXPERIMENTAL SETUP

Implementation of arm rehabilitation device based on movement is recorded from the EMG signal of healthy subjects. From the human anatomy studies, different angle movements of upper limb with elbow as the reference is depends on relation of agonist and antagonist. In this study is focusing on the behaviour of biceps muscle as agonist and the triceps as the antagonist respectively. Muscle that involved in this movement is biceps and triceps, however in this study to understand the electrical activity during muscle contraction, the biceps is the only muscle that taking into account. The movements' ranges in between position of arm flexion until arm fully extend.

The environment is in a room with low lighting especially the fluorescent light, any electromagnetic devices is away from the experiment equipment and the environment is in silent room. Then, the experimental is set up with the subject sit on the chair while the hand is on the table. The subject has to complete the task of lift up the dumbbell with 2.268kg of weigh in FIGURE 3(b) for 5 times. Normally, the appearance of EMG signal is chaos and noisy depends on the type of electrodes also the noise factor. To simplify the difference of amplitude response for the motion, the dumbbell is functioned to amplify the amplitude in analyzing the electrical activity during rest and contract. The rehabilitation devices (white in colour on FIGURE 3(a)) helps to keep the position of the elbow joint and the wrist joint in line Mostly, the EMG signal is obtained after several trials of the movements. These movements are specified from angle of 0°(arm in rest position), up to 120°(arm is fully flexion). The experiment will go through several phases as explained in this section [10].

Phase 1: Skin Preparation and Electrode Placements.

Electrode placements are followed by skin preparation, the preparation of skin is ruled by the SENIAM procedure for non-invasive methods. The subject's skin has to be shaved by using small electrical shaver and cleaned with sterile alcohol swabs saturated with 70% Isopropyl Alcohol as shown in FIGURE 4. This step is to be taken for minimizing the noise and to have a good contact with the electrodes of the skin by decreasing the impedance of the skin. The skin has to be clean from any contamination of body oil, body salt, hair and the dead cells. The preparation of skin can be done by wiping the alcohol swab into the area of skin that electrode placement to be applied. The placements of the electrode have to be at the belly of the muscles not in the tendon or motor unit. This ensured the detecting surface intersects most of the same muscle on subject as in FIGURE 5(a) at the biceps brachii, and as a result, an improved superimposed signal is observed. Reference electrode has to be at the bone as the ground, for this experiment it placed at elbow joint.



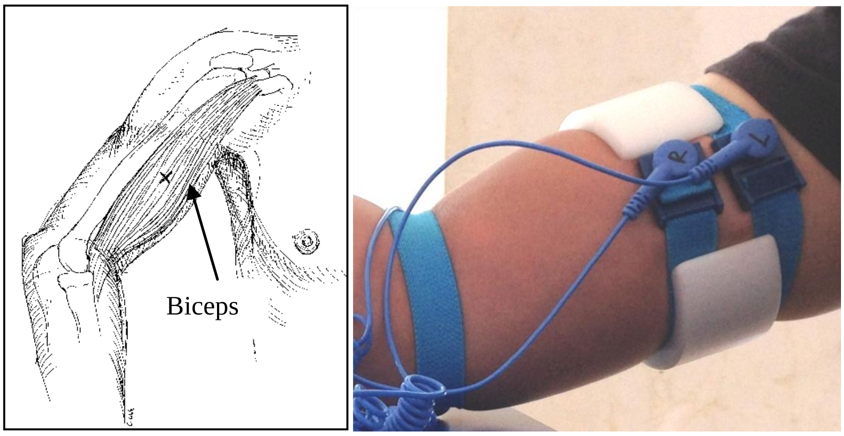
(a) (b)

FIGURE 3. Subject is set-up with arm rehabilitation assistive device for experiment (a). Simulation of subject's to lift up the dumbbell 2.268 kg of weight (b).

FIGURE 4. The alcohol swab that used in this experiment.

Phase 2: sEMG Signal Acquisition

Olimex EKG-EMG-PA provides bipolar electrode which has two detecting surfaces and one reference electrode. These two detecting surface need to be placed in range of only 1-2 cm from each of it at the biceps muscle as showed in FIGURE 5(b). As stated at electrodes, the R label is negative input and the L label is the positive input from the electrical activity in the biceps brachii muscle. These EMG signals will go through into high voltage protection to protect any electrical surge that may bring harm to the user and the hardware. These electrodes are connected to the combination of hardware Olimex EKG-EMG-PA and Arduino Mega. These signals are available for signal conditioning process as the next step to be taken. The electrical diagram for this hardware is showed in FIGURE 6.



(b)

(b)

FIGURE 5. The biceps brachii muscles for electrode positions(a), The electrode placements on subject skin(b)

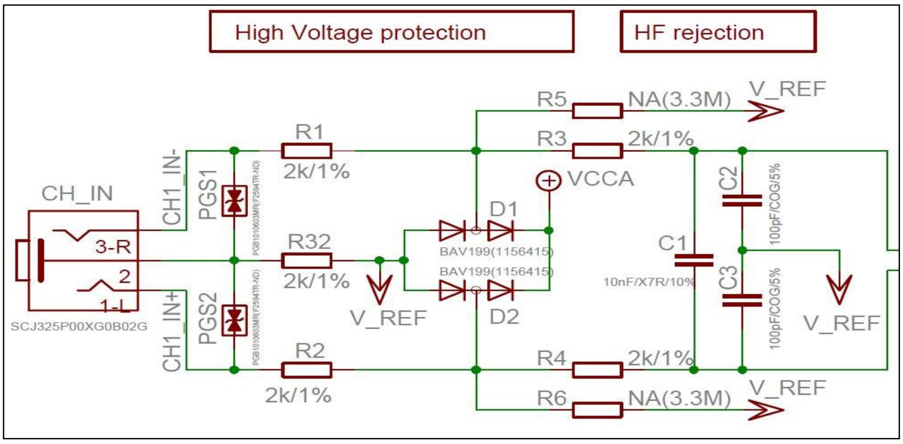


FIGURE 6. The electrical diagram of electrode sensor, high voltage protection and frequency rejection.

Phase 3: Signal Conditioning

The filtering signal is accessed for features extraction. The raw sEMG signal is continued by filtering for removing the noise in purpose to obtain the clean features. Low pass Butterworth's filter is chose for removing the unwanted frequencies of a sEMG signal. The Butterworth's filter preserves the wave shape of any filtered signals across the group delay in the passband. The features from the filtered signal are known as clean features. These clean features are necessary to obtain the differences of the features sEMG signal. This EMG signal evaluated in time domain features. These features are Root-Mean-Square (RMS), Mean Absolute Value (MAV) and Standard Deviation (STD). As for the STD, the results can be obtained from the graph itself, refer to FIGURE 7-8. This statistical information of the features evaluations were run in the MATLAB R2013a. The feature with less of error percentage is chose. The percentage obtained from the several trials of movements by each of features. Then, the average result of each feature will determined the percentage error for each features.

RESULTS AND DISCUSSION

The EMG signals are produced by the subjects during flexion and extension motion by lifting the 2.268kg of dumbbell with their right hand due to the rehabilitation device that designated for right hand. Figure 7 and 8 shows the raw EMG signal from 2 out of 15 subjects. Both of figures show that the amplitude signals is amplified when the arm is in flexion motion and shrinking during extension motion.

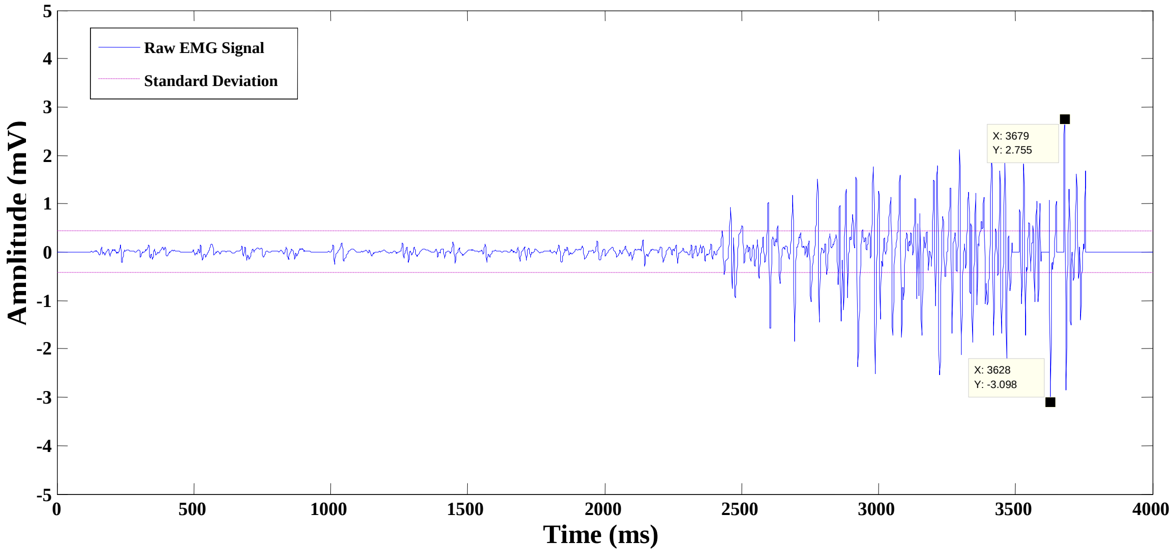


FIGURE 7. Raw sEMG Signal from Subject 1.

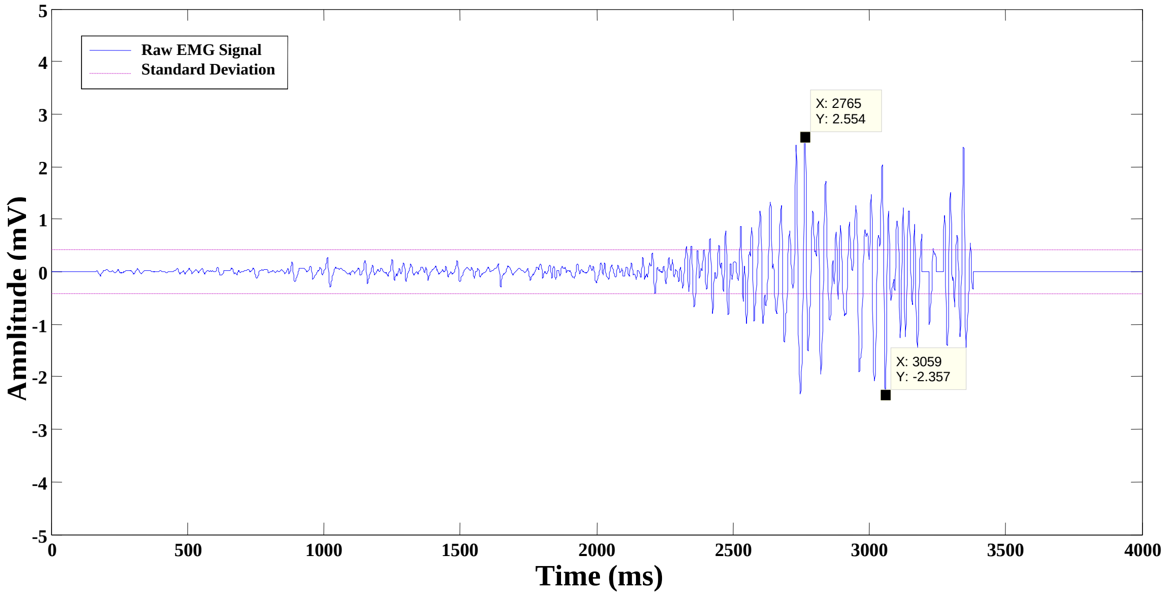
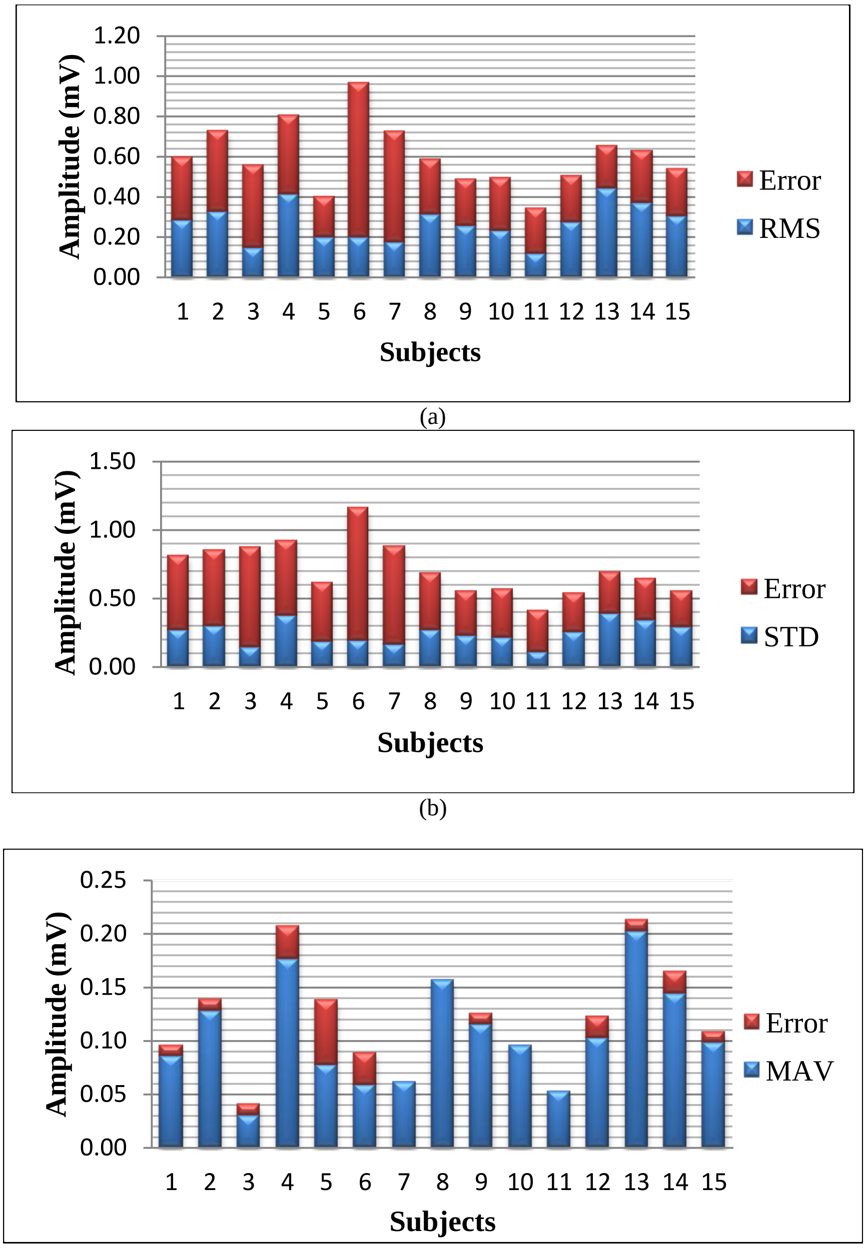


FIGURE 8. Raw sEMG Signal from Subject 2.

EMG is one of the bio signal that makes it complicated to analyze, the significance collecting the raw EMG as many as possible from the normal and healthy subject is to obtain convincing results that can be apply on the analysis for features extraction, next to further on classification. The differences of amplified signal can be observed by pointed at the maximum and minimum value of the EMG signal as shown by the data tip in FIGURE 7 and FIGURE 8. Five trials from every subject are needed to yield the average value for each subject, up to produce the average value from the average feature value. The average features of each subject after completing five trial of flexion and extension motion are plotted in FIGURE 9. The feature in FIGURE 9 is plotted based on the average value of the clean features which is from the filtered EMG signal.



(a)

(b)

(c)

FIGURE 9. RMS features with error percentage (a). STD features with error percentage (b). MAV features with error percentage (c).

However, the noise features are needed to be considers to yield the percentage of error for the features. This evaluation method is used by Angkoon Phinyomark *et al.*[7] in her research to evaluate the quality of the robust of the EMG features. The percentage error is determined by the equation:

$$Percentage\ \ Error = \left| \frac{feature_{clean} - feature_{noise}}{feature_{clean}} \right| x100\%$$

(4)

Where $feature_{clean}$ denotes as the average of sEMG signal after filtering and $feature_{noise}$ denotes as the average of rectified raw sEMG signals. The performance of these features is determined by their percentage of error. The smaller percentage of error gives the better performance of the feature [7]. The percentage error of these features is scheduled in TABLE (1).

TABLE (1). Percentage Error of Time Domain Features.

	RMS	MAV	STD
Percentage of Error	33.0 %	1.47%	46.7%

The percentage error of these features is based on analysis by using Butterwoth's low pass filter shown that, STD is giving the 46.7% of error which is not suitable for future procedure by having huge range of error, while RMS gave 33.0% error smaller compare to STD but not yet to satisfy the analysis that need the smallest percentage of error. Thus, MAV wins the percentage of error with only gave 1.47% of error, which means the MAV feature provides the best performance in future to be applied in pattern recognition or any classifier. However, the percentage of error in this study is limited to flexion and extension motion of biceps brachii muscles. The percentage error of any motion or muscles may be differs.

CONCLUSION

The objectives of this study were to analyze the features in time domain soon to implement it in future works such as pattern recognition or classifier. The importance of this study to obtain the best feature performance by determined the percentage error of the features. The MAV shows the best performance as a feature in time domain. By having the small error percentage the features helps to design the rehabilitation system device with the greater performance of the device control system. The RMS and STD performance might be useful for multi-features on any future study. Therefore the mean absolute value (MAV) shows the better performance for further study on arm rehabilitation device control.

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: .... ii CLASSIFY EMG DATA FOR UPPER LIMB MUSCLE BASED ON DIFFERENT MOVEMENT OF ARM REHABILITATION DEVICE ‘IFFAH MASTURAH BINTI IBRAHIM

15**A report submitted in partial fulfilment of the requirements for the** Degree **of Bachelor** in Electrical **Engineering** (Control, Instrumentation & Automation) **Faculty of** Electrical **Engineering UNIVERSITI** TEKNIKAL **MALAYSIA**

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: .... iv For my beloved Mama and Abah, To my dearest Brothers and Sisters, Hasanuddien, Mohd Hafiz, Muhammad Nor Helmi, Nurul Muallimah, Iffah Amirah. Thanks for all the pray, supports and loves. Your girl loves you. Lots. v ACKNOWLEDGEMENT Alhamdulillah, Thanks and Praise to Allah S.W.T;

19**I take this opportunity to express my profound gratitude and deep regards to my guide** supervisor **Mr.**

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7**The blessing, help and guidance given by him time to time shall carry me a long way in the journey of life on which I am about to embark. I**

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29**I would like to express my** thanks **to my** beloved **parents for** blessed me in **their** prayer **and**

being my good listener to all the complaints in the difficulties. I will not be able go through all the obstacles without the blessed. Special thanks to my beloved brother Muhammad Noor Helmi for his guidance in human anatomy, your medical field do help me a lot to understand this project. Last but not least, to my siblings, brothers and sisters your courage, support and pray brought me here to complete this thesis successfully. vi ABSTRACT Rehabilitation device is used as an exoskeleton for people who experience limb failure. Arm rehabilitation device may ease the rehabilitation programme for those who suffer arm dysfunctional. The device used to facilitate the tasks of the program should improve the electrical activity in the motor unit by minimising the mental effort of the user. Electromyography (EMG) is the techniques to analyse the presence of electrical activity in musculoskeletal systems. The electrical activity in muscles of disable person are failed to contract the muscle for movements. To prevent the muscles from paralysis becomes spasticity or flaccid the force of movements has to minimise the mental efforts. To minimise the used of cerebral strength, analysis on EMG signals from normal people are conducted before it can be implement in the device. The signals are collect according to procedure of

3**surface electromyography for non-invasive assessment of muscles (SENIAM). The**

implementation of EMG signals is to set the movements' pattern of the arm rehabilitation device. The filtered signal further the process by extracting the features as follows; Standard Deviation(STD),

32**Mean Absolute Value(MAV), Root Mean Square(RMS),** Zero Crossing(ZCS) **and Variance(VAR).**

The extraction of EMG data is to have the reduced vector in the signal features for minimising the signals error than can be implement in classifier. The classification of time-domain features only can be applied for three types of

10**time-domain features are Mean Absolute Value(MAV), Root Mean Square(RMS)**

and Standard Deviation(STD). The arm movements of 60˚, 90˚ and 120˚ are classified into their own class of degrees movements by using SOM-Toolbox for MATLAB are visualized in U- Matrix form. vii ABSTRAK Alat bantu pemulihan digunakan sebagai rangka luar bagi membantu individu yang mengalami kegagalan fungsi anggota tubuh badan. Alat bantu pemulihan tangan mampu memudahkan individu yang mengalami kegagalan anggota tangan menjalani program dipusat pemulihan. Alat bantu yang digunakan bagi memudahkan aktiviti di dalam program tersebut perlu meningkatkan aktiviti elektrik di dalam unit motor dengan mengurangkan penggunaan mental pengguna. Electromyography(EMG) merupakan kaedah untuk menganalisa kehadiran aktiviti elektrik di dalam sistem otot manusia. Aktiviti elektrik dalam tubuh pesakit tidak mampu untuk mengecutkan otot. Bagi mengatasi otot tersebut dari menjadi kaku atau lembik, daya tujahan untuk menggerakkan alat bantu tidak boleh melebihi kemampuan mental. Bagi mengurangkan penggunaan kekuatan mental, analisis isyarat EMG dari individu yang normal perlu dijalankan sebelum digunakan pada alat bantu pemulihan. Isyarat-isyarat tersebut dikumpulkan melalui kaedah penilaian otot menggunakan permukaan electromyography bukan invasif (SENIAM). Isyarat EMG ini digunakan bagi menetapkan jenis pergerakan terhadap alat bantu pemulihan. Isyarat signal yang ditapis seterusnya di proses bagi mengekstrak ciri-ciri seperti berikut; Sisihan Piawai(STD), Nilai Min Mutlak(MAV), Punca Min Kuasa Dua(RMS), Lintasan Zero(ZCS) and Varian(VAR). Ekstraksi dari data EMG ini bertujuan untuk mengurangkan vektor dalam ciri-ciri isyarat bagi mengurangkan ralat dalam isyarat untuk digunakan dalam pengelas. Pengelasan dalam domain masa hanya boleh digunakan terhadap ciri-ciri Nilai Min Mutlak(MAV), Punca Min Kuasa Dua(RMS), dan Sisihan Piawai(STD). Pengelasan. Pergerakan lengan pada sudut 60˚, 90˚ dan 120˚ dikelaskan mengikut peringkat kelas pergerakan menggunakan SOM-Toolbox untuk MATLAB diperlihatkan dalam bentuk U-Matrix. viii

9**TABLE OF CONTENTS CHAPTER** TITLE **PAGE** ACKNOWLEDGEMENT

46**CHAPTER 1 INTRODUCTION 1.1 Background** Human support system **is** known as **an**

endoskeleton. Endoskeleton plays a role as a framework of the body which is bone. Our daily movements are fully depends on the functionality of our complex systems in the body. The disability one or more of the systems in our body will reduce our physical movements. Exoskeleton device is known as rehabilitation device to facilitate disable person. The functionality of the rehabilitation device has to smooth as the physical movement of normal human. People who have temporary physical disability have the chances to recover. The rehabilitation programs provide the suitable plan for conducting the nerve and stimulate the muscles. Nowadays, rehabilitation program are using rehabilitation devices in their tasks. The functionality of devices depends on muscle contraction. Electromyogram studies help to facilitate the effectiveness of the rehabilitation device. The technique of measuring electrical activity that produced by muscles during rest or contractions known as electromyography (EMG). The electrical signal generates from the brain and sends to the muscles via motor neuron. The EMG could detect the dysfunctional of the muscles or failure in signals transmission from nerves to muscles. The failure of sending the electrical signal from the brain to the conducting nerves requires electrical stimulation from the external source to muscles. Electrodes are used for signal detection of electrical activity in muscles. The study of this electrical activity is important for combination of electromyogram into the rehabilitation device. 1.2 Motivation Nowadays, increment number of accidents' victim who suffer the failure of the upper limb, demands for the affordable arm rehabilitation devices. Rehabilitation centre will cost the patients a lot amount of money to precede the training course. Besides that, the patients who can survive for unsupervised course are preferable to possess their own rehabilitation device. The unsupervised rehabilitation will facilitate the user to use with convenient. In order to help the needy, the studies on rehabilitation device are carried out. Electromyography is a technique that has been commonly applied in the electromyogram studies into the rehabilitation device. Nowadays the development of exoskeleton for human performance is trending in this country. The government provides a lot of platform and provision of funds to share the findings and future development in the applied mathematics and engineering fields as well as to encourage collaborations between mathematical research and engineering applications. In attempt to welcoming of this move, the idea and research works of the rehabilitation device have to focus on these EMG signals processing for a smooth performance of the device. The study is carried out to understand the importance of the rehabilitation device and the development of the rehabilitation device to facilitate the user. Thus, the electromyogram studies including the extract features and the classification of the EMG signal is a goal of this study. 1.3 Problem Statement The rehabilitation device is a tool that used to help movements in daily life activities of the patients who experienced the failure of muscle contractions. Due to failure of muscles contractions the movements is limited. The ability of the patients to do the tasks in the rehabilitation programs need to be measured. The rehabilitation programs have to ensure either the tasks is effective or harmful to the patients. Historically, the rehabilitation tasks have been avoided due to a belief that it would increase spasticity. [3] However, the spasticity is one type of failure in muscle contraction. In this study, the focus is on the patients who suffer the paralysis either flaccid or spasticity. In this study, the analysis of the data will be focusing on upper limb consisting of biceps brachii muscles only. The experiment is limited to several degrees of upper limb movements that use in the training. EMG is divisions of bio signal analysis. The bio signal analysis is the most complex analysis. Thus, the signal analysis is a complicated process. The EMG signals must be reliable to include in the signal processing process. Therefore, the challenge of this study to ensure that signal processing is conducted properly towards reducing the environment noise during collecting data. The reliable signals is continued to extract the features that will use in movement classification. The study is succeeded when the EMG signals can be classify into the movements than soon will use in rehabilitation device and may not harm the user. 1.4

36**Objectives The objectives of this research are to** extract **the** time domain features **of**

biceps brachii muscles based on different degree of arm movements using MATLAB and SIMULINK software. Subsequently, the extracted features are to cluster into several degrees of arm movements using Self-Organising Map technique. 1.5

47**Scope of Research** In achieving **the** objectives **of this study,** the experiment has **to**

be conducted within the scope of study. The EMG signals are collected from the healthy subjects based on BMI standards without any medical history within 20 to 30 years old. The EMG signals is acquired from the muscles at the upper limb which is biceps brachii. The muscles biceps is taking into consideration for this experiment due to arm feed forward stretching movements that include the contraction of biceps muscles. The feed forward stretching movements' are set up with angle of 60˚, 90˚ and 120˚ by estimation. The studies of muscles contraction of normal and healthy subjects are important for better understanding before it can be applied to abnormal subject. The data is collected by using surface electrodes which is non-invasive method. The collected data are used for signal processing to carry out the extraction of signal features to be classified. The analysis of the EMG signals are conducted in powerful tool which are MATLAB 2013a, SIMULINK and SOM- Toolbox developed by Esa Alhoniemi et al. The features are classified by using Self- Organising Map technique. 1.6 Contribution of Research After completing this research, the studies may contributes in rehabilitation field involves; extracted features in time-domain of the EMG signal of upper limb for several degrees of movement and the classified movements by using Self-Organising Map technique. 1.7 Outlines of the Report This research comprises of five chapters. Chapter 1, the background and the idea of this research is proposed for better understanding. This chapter consists of the objectives and the scope of this research. Chapter 2, general reviews of the idea that related to this study. This chapter also include the flow of strategies that used in this research. Methodology has been briefly explained in Chapter 3; the study will begin with the experimental setup. Preparing the subject and collecting the data due to the angle degree of movements. The results of the raw EMG signals, features extraction and classifier are presented in Chapter 4. Finally, the conclusion of this study, experiment, recommendations towards the future works is covered in Chapter

375. **CHAPTER 2 LITERATURE REVIEW This chapter reviews** related **to** this **research**

title. This review is referred from several research papers, books and journals that much related to engineering, muscle anatomy, signal processing and software. 2.1 Introduction Hand consists of arm, forearm, wrist and fingers for physical movement. Arm is located at shoulder joint, while forearm is located at elbow joint. A physical arm movement is less complex compare to forearm, wrist and fingers motion. This is because when it refers to musculoskeletal, the largest muscles involved with the motion are biceps and triceps only. However, when the musculoskeletal system is failed on the arm it will disable the motion of the forearm and fingers. Nowadays, people who suffer from stroke(hemiplegic), flaccid and paralysis they have lost the limb function. [9] As the failure of upper limb, they still can feel the presence of the arm because it still there but cannot move it. Thus, their intention to move the arm is generated from their brain. The brain transmits the signal and this signal called electrical activity is send via neurons. This electrical activity is known as myoelectric signal. The signal that generates from the muscle contraction can be recorded by electromyography. This technique shows the muscles are active and able to do the physical movements.[4] 2.2 Arm Rehabilitation Device Rehabilitation Engineering is a field for engineer and designer to share the idea and come out with the solution that may ease the disabled person to live their daily life such a normal people. The development of the rehabilitation device is improved gradually. The brilliant ideas and work pieces from these engineer and technologist helps to achieve the multifunctional rehabilitation device. The efforts by them bring a lot of enhancement in rehab's world. Nowadays, spill over rehab devices in marketplace helps the disable person to make a choice from the cheapest to the most expensive device that suits their finances. The devices rank always put the cheapest devices with the less function or motion while the expensive devices with multifunctional or more degree of motion. Therefore, the rehabilitation devices contribute into the entrepreneur technologies and establish the competency by implementing the devices. Furthermore, to fulfil the demands from the user, engineer and designer should create the device to facilitate their movement and user-friendly. Currently, the superficial device is the best design to expand for the purpose of unsupervised modes. By referring to the United States Patent for Arm Rehabilitation and Testing Device documents by Reddy et al., to invent the rehabilitation device, the design should provide: i. a portable and extremely convenient device. ii. a device that may use to measure the degree of recovery. iii. an adjustable size or length of individual arms. iv. a desired speed and force depending on patient's deficiencies.[23] The mechanism of rehabilitation device is automatic without any force from the user and comfortable. This mechanism helps the disable person to train their muscle for rehabilitation in supervised or unsupervised modes. There are some beliefs that the rehabilitation device may harm the user.[3] Depending on the muscles either flaccid which is no muscle tone or spastic that has too much muscle tone. Flaccid patient needs the rehabilitation device to increase the muscle tone, while spastic patient may need the device to reduce the muscle tone. However, the spastic patient is the case where the technologist had to consider the force and speed in the device to preclude the spasm in the muscles. Therefore, as an engineer the invention of a new thing have to follow the etiquette and the rule for the effectiveness and the user convenience. Courtesy: google.com Figure 2.1 Example some of the arm rehabilitation device. Arm Holder Wrist Holder Figure 2.2 The arm rehabilitation device that used in this research. 2.3 Signal Processing The output of the system commonly is defined by the input. The output is the main achievement of the system. However, the input is always raw signals that need to be process into several plants until it can produce the desired output. EMG signal is one type of bio signal that contains lot of noise from many factors. The noise may come from the skin at the electrode placement, type of electrode that may use for data collecting and also the environment. There are various type of size and pattern of electrodes(Figure 2.3), depends on the muscle area would like to detect and the thickness of the skin layer. The EMG noise signal can be reduced by choosing the gelled electrode which were Silver – Silver Chloride(Ag-AgCl) as the substance. Ag-AgCl introduces less electrical noise into the measurements. However, these noise should be eliminate to have a better signal for analysing purpose, the noise can be eliminate by many factors such as control environment, electrode placements and signal acquisition circuitry and configuration.[7][13] As for the features extraction there were various types in terms of

4**frequency domain, time frequency domain and time scale domain.**

These types are chose based on the purpose of the analysis of the signal. In signal conditioning for time domain analysis, there is some features that can be applied. These features are described briefly as follows: i) Root-Mean-Square (RMS) RMS is the

3**square root of the mean over time of the square of the vertical distance of the graph from the rest state.** It much **related to the constant force and non-fatiguing contraction of the muscle. In most cases, it is similar to standard deviation method.**

[3] RMS ? N ?i?1EMG(i)2 1 N ii)

14**Mean Absolute Value(** MAV) **Mean absolute value is**

4**calculated by taking the average of the absolute value of EMG signal. Since it represents the simple way to detect muscle contraction levels, it becomes a popular feature for myoelectric controlled applications.**

[3] ∑|( )| iii) Standard Deviation(STD)

6**Standard deviation is a measure of the dispersion of a set of data** sample **from its mean. The more spread apart the data, the higher the deviation. Standard deviation is calculated as the square root of variance.**

√ ∑( )2.4 Maximisation of EMG Signal Signal is condition that always affected by the factors that make it unstable and non-linear. As EMG signal, the non-linear of the signal mostly came from the noise factor. There have a lot of noise factor that can be categorized as follows; i)

18**Causative Factors: This is the direct affect on signals.**

a. Extrinsic – The signal get affected by the electrode placement, structure, surface detection, distance between electrode(bipolar configuration), and location of the surface detection on the skin. b. Intrinsic – It may due to physiological, biochemical and anatomical factors. ii) iii) Intermediate Factors: This is the phenomena of influencing by one or more causative

18**factors. Deterministic Factors:** This is **influenced by** the **intermediate factors.** Figure 2.3 **The**

various type of wet electrodes that may used to detect the EMG signal. By minimizing all these factor of noises, the quality of EMG signal will be much better and the analysis of the information will be less of error and easy to obtained. However, the precautions of handling the hardware and the electrode are needed. Figure 2.3 shows the several of electrodes that may use in collecting the EMG signals. This various type of electrodes depends on the size, radius and shape that might be use on skin surface. The shape and the size are depending on the area of muscles to detect and the thickness of the skin. If the skin is thick and the area of belly muscle is large, larger area of electrodes might be use for a better signals detection. Acquisition data play the important role to maximizing the quality of the EMG signal, such as minimizing the distortion in EMG signal, using any filtering tools are not recommended. In terms of signal-to- ratio(SNR) the information that carried in SNR should contain the maximum information of EMG signal [6][17]. Moreover, the quality of EMG signal is affected by the environment, also known as control environment. The environment has to set with minimizing the noise factor. The ambient noise sourced by electromagnetic devices such as radio transmission devices, fluorescent lights and power line interference from electrical wires.[17][10] These ambient noise and motion artifact can be reduced by the proper electrode placements, circuit configuration and control environment. The flow of signal processing in this study based on the Figure 2.4. The placements and type of electrodes are important to ensure the electrical activity in muscles can be detected. The raw EMG signal from the electrodes goes into phase of signal and data acquisition for minimising the signal error. The raw EMG signal is need to reduce the vector to come out with extraction of signal features. Finally, the signal features can be classified into the classifier. Electrodes Raw Signal & Features Signal (sensor) Data Raw Signal Acquistion Signal Extraction Reduced Vector Classification Figure 2.4 Flow of Signal Processing 2

38**.5 Self Organizing Map (SOM)** The **Artificial Neural Network(ANN)** analysis **is**

one of the computer science's branch. The ANN's are significant in problem solving such as pattern recognition and classification. ANN analysis is a dominant tool

1**to analyze data** and **to interpret the results of the analysis,**

followed by sketching the conclusions on a structure of analyzed data. Self- organizing map(SOM) is well known as one type of neural network model that were commonly used for visualizing the data and to cluster the data. SOM was introduced by T. Kohonen in 1982, his exploration into this model to preserve the topology of multidimensional data. SOM is learns as unsupervised manner,

43**which means no human intervention is needed** throughout **the learning.**

The SOM is a bundle of nodes, attached to

1**one another via a rectangular or hexagonal topology** in Figure 2.5. Figure 2.5 Rectangle Topology (Two-Dimensional SOM).[19] The learning

1**starts from the components of the vectors** Mij **initialized at random. If n-dimensional vectors**

X1, X2,..., Xm

2**are needed to map, the components of these vectors x1, x2,** ..., xn **are passed to the network as the inputs, where m is the number of the vectors, n is the number of components of the vectors.** At each **learning**

step, an input vector Xp ϵ {X1, X2, ..., Xm }

2**is passed to the neural network. The vector** Xp **is compared with all** the **neurons** Mij. Regularly **the Euclidean distance** || Xp – Mij || **between** the **input vector** Xp **and each neuron** Mij is **calculated. The vector (neuron) Mc with the** least **Euclidean distance to** Xp **is** elected **as a winner.**

[19][22] Training the SOM network after carrying out the learning step is to evaluate the quality of the learning. Two types of errors which are; topographic error, Ete and quantization error, Eqe

1**are calculated. The quantization error** Eqe **shows how well neurons of the trained network adapt to the input vectors. Quantization error** (1) **is the average distance between the data vectors** Xp **and their neuron-winners** Mc **(p).**

[19] ∑ ǁ ( )ǁ (1) Meanwhile the topographic error Ete

1**shows how well the trained network keeps the topography of the data analyzed. The topographic error** (2) **is calculated by the formula:**

∑ ( ) (2) The distance of the neighbouring neurons can be visualized by using the visualization technique so-called

22**unified distance matrix (U-matrix). U-matrix** shows **the** distance of **neighbouring neurons and the** number **of** neighbours. **The**

SOM is visualized by u-matrix as presented in Figure 2. 6. Figure 2.6 U-Matrix representations in SOM Figure 2.7 The features' distance in their own class of features. The U-matrix elements in SOM is coloured by different colour to differentiate the distance of the neurons neighbour. The dark blue colour represents the clustered neurons while the red colour represents the most long distance between the neurons.[24] The numbering bar colour next to the U-matrix in Figure 2.6 denotes the distance between the U-matrix elements. The SOM algorithm is applied using SOM-Toolbox created by Esa Alhoniemi et al. using MATLAB software. Pavel Stefanoviˇ et al. investigation in his study proved that SOM-Toolbox had most advantages of possibilities such as: i.

1**Amount of data items and** dimensions. ii. **Represent class names of all**

1**neuron winners in the same cell of map.** iii. **Easy data file preparation.** iv. Represents **distance between** neurons **in a map.** v. **Can be used some** neighbouring **function and any learning rate.** vi. **Can be used different learning step (epochs or iterations). SOM-Toolbox**

has a lack of losing the possibility for

1**represent proportion of different classes of neuron winners in the cell of a map.**

The new system of SOM is the only model has this possibility, which previously improved. 2.6 Related Research Work The movements of arm rehabilitation devices are limited to several motions. Development of rehabilitation device covers unilateral, bilateral and up to multilateral motion. The multilateral motion gives the advantages to the rehabilitation device and the user to perform the task without difficulty. However, the beginning of the superior and multilateral rehabilitation device is began from the electrical activity detection in muscles. The technique proposed by M.B.I Reaz et al.(2006) shows that EMG signal carries valuable information. Technique of detection, decomposition is highlighted in this research. Use of right technique for detection brings a lot of valuable information that might be use for signal processing and classification. Knowing the factor of the noise and the obstacles for minimising the error during detection and maximising the signals will help for a better analysis of EMG signals. The technique discussed by Sachin Sarma et al.(2012) shows various technique for features extraction used

14**to extract** the **features from the** recorded **EMG** signals. **The**

features are in forms of

14**time-domain and frequency domain.** Both **of**

these domains have been used for classification of EMG pattern recognition. The time-domain features will be extracted in this study to be applied in the classifier is given by this reference. Meanwhile, the recognition technique that will lead to classification is discussed by Guanglin Li et al.(2010). From his studies, pattern recognition for controlling the multifunctional rehabilitation device

26**requires surface EMG signals to provide accurate**

26**information for classification of intended movements.**

The accuracy of information in the signals is valued by the percentage accuracy of sampling rate. The sampling rate below 1 kHz is possible for accurate classification by 11 types of motions. Software library developed by Esa Alhoniemi et al.(1997) for MATLAB is used for signal classification. The software library is known as SOM-Toolbox used by researcher to classify the several of data into the classifier. Comparative study for Self-Organising Map classifier conducted by Pavel Stefanovic et al. (2011) shows that the SOM-Toolbox provides 6 out of 7 possibilities of unsupervised learning in the algorithm. The SOM- Toolbox loses the possibility to

1**represent proportion of different classes of neuron winners in the same cell of a map.**

The software library of SOM-Toolbox is used in Matlab for this study. 2.7 Research Strategies Theoretical studies of development of arm rehabilitation device and the drawbacks Determine the movements that related to arm and musculoskeletal that involved Functionality studies of Olimex shield and the two types of electrodes. Selecting the healthy subjects and collecting the data of raw EMG signal. Software (MATLAB and Simulink) familiarization used for analysing the data. Filter and rectify the raw EMG signal Extracting and analyse the features of the EMGs signal The best features are choose to be classify by using SOM Conclusion Figure 2.8 The work flow of this research. The strategies of this research are drafted in Figure 2.8. The research is begun by studying the theoretical of arm rehabilitation device and the drawbacks of the device that will be preclude on this study. Though, the movement of the arm is limited to several degree of motion that could be pattern into the device. Thus, the functionality of the hardware and the software is familiarized before the experiment is begun. The hardware and software are used in analysing the EMG signals for extracting the features and classification the EMG signal. The features are important to determine the classification of the several degree movements. CHAPTER 3 METHODOLOGY Methodology is the most important structure that needs to be firm as for understanding purpose. In this chapter the whole step from collecting the data, analysis, summary and output will emphasise in detail. 3.1 Introduction Implementation of arm rehabilitation device based on different angle movement is recorded from the EMG signal of healthy subjects. From the human anatomy studies, different angle movements of upper limb are depends on relation of agonist and antagonist. In this study is focusing on the behaviour of biceps muscle as agonist. Muscle that only involved in this study is biceps brachii. 3.2 Procedure and Experimental Setup The experiment's environment is in a room with low lighting especially the fluorescent light, any electromagnetic devices is away from the experiment equipment and the environment is in soundless room. Then, the experimental is set up with the subject sit on the chair while the hand is on the table. The subject has to complete the task of lift up the dumbbell with 2.27kgs of weigh in Figure 3.1 for 10 times. Mostly, the EMG signal is obtained after several trials of the movements. Normally, the appearance of EMG signal is chaos and noisy depends on the type of electrodes also the noise factor. To simplify the difference of amplitude response's motion, the dumbbell is functioned to amplify the amplitude in analyzing the electrical activity during rest and contract. The rehabilitation devices(white in colour on Figure 3.1(a).) helps to keep the position of the elbow joint and the wrist joint in line without being affected by the weight of the dumbbell during lift up motion. These movements are specified from angle of 0°(arm in rest position), up to 120°(arm is fully flexion). The experiment will go through several phases as explained in the next section. (a) (b) Figure 3.1 Subject is set-up with arm rehabilitation assistive device for experiment (a). Simulation of subject has to lift up the dumbbell 2.27 kgs of weight (b). i. Phase 1: Skin Preparation and Electrode Placements. The placement of the electrode is followed after skin preparation. The preparation of the skin is needed before placing the electrodes. The subject's skin has to shave using small electrical shaver and cleaned with sterile alcohol swabs saturated with 70% Isopropyl Alcohol as shown in Figure 3.2(a). This step is to be taken for minimising the noise and

16to have a good contact with the electrodes of the skin. The skin

has to be clean from any contamination of body oil, body salt, hair and the dead cells. The preparation of skin can be done by wipe the alcohol swab into the area of skin that electrode placement to be applied. The placements of the electrode have to be at the belly of the muscles not in the tendon or motor unit. Electrode leads and gelled electrode (Figure 3.2(b)) is used to collect the data. The combination of Arduino Mega and the OLIMEX shield, simplified the hardware. As the EMG signals are too sensitive towards magnetic devices, the neatness of the hardware is needed. The neatness ensured the electrode leads and the detecting surface intersects most of the same muscle on subject as in Figure 3.3 at biceps, and as a result, an improved superimposed signal is observed. Reference electrode has to be at the

16body where no muscles exist as the ground signal,

for this experiment it placed at wrist on the unaffected hand(refer Figure 3.3(b)). (a) (b) Figure 3.2 The alcohol swab(a) and the gelled electrode(b) that used in this experiment. ii. Phase 2: sEMG Signal Acquisition Biceps Biceps (a) (b) Figure 3.3 The biceps brachii muscles for electrode positions(a), The electrode placements on subject skin(b) Gelled electrode has two leads detecting surfaces and one lead as reference electrode. These two detecting surface need to be placed in range of less than 1-2 cm from each of it at the biceps muscle as pointed in Figure 3.3(b). The gelled electrode for the blue lead and red lead are placed at the biceps skin for detection purpose, meanwhile the gelled electrode with black lead is placed at area with no muscles exist and unaffected hand.[7] The grounded electrode hand is placed at the leg to have a better grounding purpose. From Figure 3.4 these EMG signals will go through into high voltage protection to protect any electrical surge that may bring harm to the user and the hardware. These signals are available for signal conditioning process as the next step to be taken. The circuit that be used in this experiment is provided by the OLIMEX shield. The signals via the OLIMEX shield through the analogue circuit are very weak the voltage is around 10μV, full of noise and contain primarily 60Hz of frequency. The signals are next need to be filter and rectify, reducing the noise and amplifying the signals for analysis purpose. After the signal is filtered and amplified the signal is sent to the digital board and yet ready to display into the MATLAB software. The full circuit diagram of OLIMEX shield can be viewed in Appendix A. Source: olimex Figure 3.4 The electrical diagram of electrode sensor, high voltage protection and frequency rejection. iii. Phase 3: Signal Conditioning The signals from the board are gathered in the SIMULINK software(refer Figure 3.5). Signals from the OLIMEX shield need to be filtered by using the peak notch filter and the high pass filter. Peak notch filter is used for filtering the interference from the line AC and radio frequency from the devices frequency nearby. Meanwhile, the high pass filter is used for placed the baseline of EMG signals display in the scope(SIMULINK) at the zero line, also known as DC offset. Block diagram for collecting the EMG signal is showed in Figure 3.5. The disadvantage by using these two types of filter will affect the originality of EMG signal, might be some information will be removed during passing the filters. This project are using low-end product which is inexpensive, truly helpful in understanding the basic study of EMG signal. The raw EMG signals is next to filter by using Butterworth filter. The Butterworth filter is set to 5th order and 10/1000 Hz frequency. The filtered signal is accessed for features extraction. This EMG signal evaluated in time domain features. The analysis of this study soon to be applied in real-time application. Thus, the time-domain suits this study for better future work. These features are

49Root-Mean- Square(RMS), Mean Absolute Value(MAV), Standard Deviation(STD), Variances(VAR), and Zero Crossing(ZCS). This statistical information of the features evaluations were run in the MATLAB R2013a. The signals that gathered from the SIMULINK is next to be apply for features extraction. The features are extracted using MATLAB 2013a programming. Features extraction by the subjects is gathered in Appendix B. Figure 3.5 Block diagram in SIMULINK software for collecting the EMG signals. iv. Phase 4: Signal Classification Subsequently, the EMG features is analysed for classification process. The features are to be chose either it suits in classification process or not. The classification process is conducted by using unsupervised artificial

55**neural network technique,** which is **Self- Organizing Map(SOM). The**

SOM is simulated using MATLAB software to classify the angle movement of the subjects. This is to

45**achieve the objective of** this **study** which **is to** classify **the**

extracted features of EMG signal base on the angle movement. The classification signal can be further analyse for arm rehabilitation device implementation. The SOM-Toolbox need the user to organize the data(features) in column form to be analysed. The user also needs to set up the number of neuron to be use in the analysis. This number of neuron is important to determine the training time, size of map, and the error. Then, the data were called to run the analysis. From the analysis, the SOM-Toolbox gave the number of two types of error which mention in Chapter 2, quantization error and topographic error. The analysis by the SOM is recorded. The recorded analysis is next to be proved by the features either the pattern is recognized by the features or unrecognized and yet this study cannot be proved. 3.3 Experiment Work Flow The experiment started by selecting subjects with BMI standards, healthy and without any medical history. The subjects are doing the experiment with voluntary and willing to do the tasks given. The subjects' skin is prepared for electrode placements. The gelled

21**electrode is placed at the biceps brachii**

muscle for detecting the electrical activity in the musculoskeletal system. The

21**EMG signal from the biceps brachii is** observed to see **the**

contraction during flexion and extension movements. The signals from the subjects are collected and compiled into the table for signal conditioning process. The feature extracted from the conditioning process is evaluated either the features falls into the same range of value or not. The suitable features used for classification process by using SOM-Toolbox. The number of neuron is updated until the features are classified into their class of movements. The work flow of this experiment can be view in Figure 3.6. Skin preparation & Placement of electrodes sEMG signal detection by using gelled electrode Signal acquisition - Observe the EMG signal behaviour during muscle contraction sEMG signal conditioning Features Extraction NO Suitable Feature YES Applied to the SOM clustering algorithm Update number of neuron Features are NO separated? YES Features of angle movement is classified Figure 3.6 Flow of the experiment 3.3 Summary Methods to apply from initialization of this research until the reduced vector of EMG data have been thoroughly explained in this chapter. The purpose of the features extraction of the EMG signals is to classify the pattern of the arm movement by degree of angle. This is important for future works of arm rehabilitation device application. The methodology is based on the literature review from other researchers who suggested the precaution to take before and during the experiment is conducted. Finally, this chapter help to achieve the objectives of this research.

42**CHAPTER 4 RESULTS**& DISCUSSION **This chapter** describes **the results** and discussion **of the**

research finding. The signals are collected from hardware which is, ArduinoMega256 and OLIMEX shield. Hardware is connected to electrodes and the recorded EMG signal is shown in MATLAB 2013a. Further analysis on the signal conditioning, time domain feature extraction and classification is also conducted in MATLAB software. 4.1 Raw EMG Signals EMG signals from the Arduino and OLIMEX is displayed in software MATLAB 2013a. The raw EMG signals from the hardware circuit board had through the phase of filtering and amplifying. The signal is contain lot of noise, not at the zero of y-axis and less sensitive to the movement of muscle. From the study, the experiment is conducted in the room with lot of fluorescent light, magnetic devices(i.e, handphone, tablet and line AC power) and the room is not good at grounding purpose. Moreover, the placement and the type of electrode leads are not good at detecting the muscle contraction. The result in Figure 4.1 obtained by using dry electrodes has some disadvantages. The EMG signals has a higher inherent noise level and do not have the long-term stability because of the changes in dielectric properties are the disadvantages of using the dry type of surface electrodes. Thus, the utilization of dry electrodes is wary and requires particular care of electrodes. Arm movements from 90deg to 150deg 0 -20 -40 amplitude response -60 -80 -100 -120 -140 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 t(sec) Figure 4.1 The raw EMG signal affected by the placement of bipolar electrodes not within 1-2cm and without environment control (ambient noise). Thus, the study is proceeded to improve the quality of the EMG signal. The raw EMG signal in Figure 4.2 is obtained by improvement of the methodology for data collection. The signal is obtain from the additional of two types of filter in SIMULINK block as stated in Chapter 3 in Figure 3.4. These filters are needed for signal dc offset and to reduce the noise from the AC power line. The importance to filter the noise and to set the signal at dc offset is to maximize the raw EMG signals. The muscle contraction is easy to observe when the EMG signal has less of noise and maximized. The amplitude of raw EMG signal is easy to observe during the muscle contraction. The amplitude is increasing gradually in Figure 4.2. 5 x 10-3 4 3 2 Amplitude (V) 1 0 -1 -2 -3 -4 -5 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 SamTpimleeN(ummsb)er Figure 4.2 The raw EMG signal during muscle contraction. 4.2 Filtered EMG Signal The raw EMG signal is required to be filter for analysing the signal. Before the signal is filtered, the raw EMG signal has to be rectified into half wave signal as in Figure 4.3. The rectified signal cut off the EMG negative signal value to simplify the analysis of the features. The importance of rectifying the signal is to analyse the raw signal in positive value. The EMG signal is reflected at the x-axis, thus, the rectified process is the important process to obtain the features in absolute value. Thus, amplitude signal in Figure 4.3 shows the rectified signal is on the positive side only. 0.01 0.009 0.008 0.007 0.006 Amplitude 0.005 0.004 0.003 0.002 0.001 0 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 SaTmipmleen(mumsb)er Figure 4.3 The rectified raw EMG signal. The signal is filtered by using the Butterworth filter. The filtering process is conducted by using the software programming in MATLAB 2013a. The Butterworth filter is set by using 5th order of filter and 10/1000 Hz of low pass frequency. The low pass frequency is determine by using power frequency spectrum, the actual frequency is located at the most useful signal frequency(for this case is 10Hz) other than that are noises. The result of Butterworth filter signals is showed in Figure 4.4.1 to Figure 4.4.3. Each of figures below represents the movement and the result of EMG signal during muscle contraction. From the figures of filtered signal, the EMG signals shows smooth signal with curvy line at the peak amplitude compare to the raw EMG signal which had the spark at the peak of the amplitude. These are affected by the number of order filter and the low pass frequency value. The filtered signals look alike envelope to the raw EMG signal. This pattern of signal shows that the signal is already filter. However, the Figure 4.41 to Figure 4.4.3 only to shows the EMG signal during the muscle contraction for 60, 90 and 120 degree of movement. The raw signal for every signal is rectified and filtered by using the Butterworth filter for features extraction. 60˚ Figure 4.4.1(a) Subject lift up the dumbbell at angle of 60˚. 0.01 0.008 0.006 0.004

Amplitude (V) 0.002 0 -0.002 -0.004 -0.006 -0.008 -0.01 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 SaTmipmleeN(mumsb)er Figure 4.4.1(b) The EMG signal resulted by lifting the dumbbell at angle of 60˚. 90˚ Figure 4.4.2(a) Subject lift up the dumbbell at angle of 90˚. 0.01 0.008 0.006 0.004 Amplitude (V) 0.002 0 -0.002 -0.004 -0.006 -0.008 -0.01 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 STamimpleeN(ummbse)r Figure 4.4.2(b) The EMG signal resulted by lifting the dumbbell at angle of 90˚. 120˚ Figure 4.4.3(a) Subject lift up the dumbbell at angle of 120˚. 0.01 0.008 0.006 0.004 Amplitude 0.002 0 -0.002 -0.004 -0.006 -0.008 -0.01 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 STamimplee(mnusm)ber Figure 4.4.3(b) The EMG signal resulted by lifting the dumbbell at angle of 120˚. The differences of amplitude in Figure 4.4.1 until Figure 4.4.3 showed that the muscle contraction between each angle of movement can be differentiate. The amplitude response for every subject may be differs, as the weights of the body distinguish content of fatty tissue between the skin and the muscles that may decrease the amplitude of the muscles contraction. The fatty tissues that lay under the skin may affect the efficiency of the electrode detection surface. To overcome the fatty tissues obstacle, the electrode is neatly tape to the subject skin by using the skin tape to ensure the detection surface can detect the presence of the muscle activity. 4.3 Features Extraction The filtered signal goes into features extraction process. The features extraction is set into five types which were RMS, MAV, STD, ZCS and VAR. These features are extracted from each movement of individual EMG signal. The data of the features is accumulated in Table 4.1. The suitable features that may use in classifying the movement are MAV, RMS and STD. ZCS and VAR value are not applicable in classifying the features. ZCS produced the whole number, meanwhile the VAR produced the scientific number that smaller in range of 10-6. The complete result of these features extraction may be view on Appendix B. However, the ZCS and VAR features may be used as it is, in its own class of features. The results are various except the feature is preset. Table 4.1 Features extraction of EMG signals by subjects. Subject Angle MAV RMS STD 60˚ 0.001903 1.61E-03 1.42E-03 0.001981 0.001777 1.75E-03 0.001329 0.001329 0.001325 S1 90˚ 0.00232 0.00231 0.00228 0.0027 0.00267 0.00254 0.0022 0.00219 0.00215 120˚ 0.00318 0.00317 0.00317 0.00363 0.00365 0.00339 0.00311 0.0031 3.16E-03 60˚ 0.00174 0.00165 0.00164 0.00219 0.00189 0.00188 1

52**.42E-03 1.38E-03 1.21E-03**

S2 90˚ 0.00244 0.00237 0.00232 0.00286 0.00285 0.00277 0.00238 0.00231 0.00228 120˚ 0.00315 0.00316 3.99E-03 3.98E-03 0.00316 0.00318 0.00315 0.00384 0.00314 60˚ 9

50**.75E-04 9.15E-04 9.13E-04**

0.0019 0.00162 1.61E-03 0.00124 0.00133 1.10E-03 S3 90˚ 0.002 0.00189 0.00186 0.00239 0.00231 0.00228 0.00209 0.00207 0.00205 120˚ 0.00282 0.00291 2.98E-03 0.00318 0.00316 0.00315 0.00314 0.00307 0.00302 60˚ 0.00161 0.00154 0.00141 0.00198 0.00185 1.73E-03 0.00133 0.00129 0.00127 S4 90˚ 0.00233 0.00231 2.23E-03 0.00246 0.00243 0.00242 2.44E-03 0.00237 0.0026 120˚ 0.0033 0.0032 0.00327 0.00391 0.00382 0.00378 0.00317 0.00313 3.11E-03 4.4 Classification of EMG Signals Artificial Neural Network can be divided into supervised and unsupervised learning. The learning process of Neural Network requires many branches, layers, and neurons to yield the output. In this study, the coach for learning the network model is the features of the EMG signals. The classifier that cover on this study is Self-Organizing Map(SOM). SOM is learns in unsupervised manner. Data in Table 4.1 are applied in SOM-Toolbox using Matlab to classify the degree of movement. However, to simplify the data input into the 'm.file', the data is calculated to average value for each movement. The simplified table is represented in Table 4.2. Table 4.2 The average value of angle movement features. SUBJECT STD MAV RMS ANGLE S1 0.001328 0.001645 0.001836 60 S2 0.001337 0.001674 1.99E-03 60 S3 1.22E-03 9.35E-04 0.001709 60 S4 1.30E-03 0.001418 0.001855 60 S5 0.002636 0.002303 0.002178 90 S6 0.002826 0.002377 0.002325

90 S7 2.33E-03 0.00192 0.002072 90 S8 2.44E-03 0.002291 2.47E-03 90 S9 0.003121 0.003174 0.003556 120 S10 0.003158 0.003154 0.003936 120 S11 0.003076 0.002903 0.003164 120 S12 0.003138 0.003255 0.003837 120 Data from Table 4.2 is plotted into scatter graph in Figure 4.5. Sample 1 up to sample 4 be owned by movement of 60˚, sample 5 to sample 8 is belong to movement of 90˚ and sample 9 to sample 12 is fit in movement 120˚. The green, yellow and red outline colour in Figure 4.5 shows that the scatter features is obviously been clustered by its angle of movements' class. Even though the clustered movements is scattered in its class, the objective of this study is achievable. The learning of the features is continued in data classification. 0.004 AMPLITUDE (V) 0.003 0.002 STD 0.001 MAV 0 RMS 0 2 4 6 8 10 SAMPLES NUMBER 12 14 Figure 4.5 The scatter graph of features versus amplitude voltage. 4.5 Self-Organising Map (SOM) The unsupervised manner is applied in SOM-Toolbox using Matlab software. This toolbox is a powerful tool that may helps to cluster randomized data. The data can be cluster even though the data is not arranged on its class. The more data the merrier clustering process. The data from Table 4.2 is relabelled into predefine 'T'. Ts are defined as the trials belong to movements for certain angle in Table 4.3. Its' labelled as predefined T in 'm.file' in Matlab for data training. The random data training is compiled in 'm.file' and number of neuron is update to observe the clustered data of predefine 'T'. Table 4.3 Predefine T for unsupervised learning. T DESCRIPTION SUBJECT T1, T2, T3 Movements by angle of 60˚ T13, T14, T15 Movements by angle of 90˚ S1 T25, T26, T27 Movements by angle of 120˚ T4, T5, T6 Movements by angle of 60˚ T16, T17, T18 Movements by angle of 90˚ S2 T28, T29, T30 Movements by angle of 120˚ T7, T8, T9 Movements by angle of 60˚ T19, T20, T21 Movements by angle of 90˚ S3 T31, T32, T33 Movements by angle of 120˚ T10, T11, T12 Movements by angle of 60˚ T22, T23, T24 Movements by angle of 90˚ S4 T34, T35, T36 Movements by angle of 120˚ The data training is started by 100 of neurons. SOM-Toolbox visualized the output as in Figure 4.6(a)(b). Figure 4.6(a) shows the component planes in SOM. The variables in component planes are the features of EMG signal for all subjects. The features are RMS, MAV and STD. The components by each variable shows that the feature is clustered on its own feature class. In MAV feature plane shows that the MAV data is clustered at the top left of the plane. Which means the clustered data in dark blue colour is clustered and the distance among the data is closed. The dark blue colour in MAV plane is surrounded by the light blue, green, yellow and red colour. The colour in the plane shows the distance from the components that had cluster. The red colour is the farthest distance from the clustered data. RMS shows quite similar clustered plane as MAV but the clustered data range is smaller than MAV clustered data. Meanwhile the STD shows the largest clustered area in its plane. Which means STD is the most data that affect the visualization of combination U-Matrix. Figure 4.6 (a) The components planes of EMG signals features. Figure 4.6(b) is U-Matrix visualization. The U-Matrix is visualized by three EMG features, RMS, MAV and STD. U-Matrix shows the predefined 'T' had been clustered by the EMG features. The predefined 'T' is scattered and hardly to obtain the class of angle movements. In Figure 4.6(b) six clustered data in red, yellow and black outline colour. The red line colour is defined as movements by angle of 60˚. It is because the small and large red outline colour is separated by small deviation(light blue colour). The yellow outline colour had about identical area of clustered data, it shows that the clustered data essentially of two type of difference data. The yellow outline clustered data is predicted as movements by angle of 120˚. While the black outline prediction goes to movements by angle of 90˚. Figure 4.6(b) Visualization of U-Matrix for 100 neurons. 100 numbers of neurons is not sufficient amount to classify the movements. The test of increment number of neurons is carried until the data can be classified. The neurons are increased gradually by 10. The resulted of the test including the training time, quantization error and topographic error is compiled in Table 4.4. The number of neurons is updated in purpose to have the best matching unit of neighbourhood. The best matching unit function as tracking the node that produces the smallest distance. The node requires smaller distance to pull the neighbouring nodes closer to the input vector. Table 4.4 The training data result. No. of Neuron Training Time Quantization Error Topographic Error 100 0s 0.026 0.056 110 0s 0.025 0.028 120 0s 0.023 0.028 130 0s 0.022 0.000 140 0s 0.018 0.028 150 1s 0.014 0.028 160 1s 0.015 0.000 170 1s 0.015 0.028 180 1s 0.016 0.028 190 1s 0.013 0.028 200 1s 0.011 0.000 210 1s 0.009 0.000 220 1s 0.009 0.000 230 1s 0.006 0.028 240 1s 0.007 0.000 250 2s 0.007 0.000 260 2s 0.006 0.000 270 2s 0.004 0.000 280 2s 0.004 0.000 290 2s 0.003 0.000 300 2s 0.003 0.000 The result in Table 4.4 is gathered by training the neurons via Matlab with SOM-

Toolbox. The neurons training outcome the error and the training time for each increment of neurons. The errors values facilitate to decide the best number of neurons to classify the EMG signals for each movement. Neural Network is recognized by the winner in the neurons. In this experiment, the neurons win at number of 300. 300 neurons amount, resulted none topographic error and the smallest quantization error among the neurons. The training time in this experiment just reached 2 seconds. It is still categorized as rapid learning and applicable for features classification. The 300 neurons are closer to the input vector compared to the 100 neurons. Figure 4.7(a)(b) shows the result of the SOM classifier. The component planes in Figure 4.7(a) show that STD is the largest area data that can be clustered in this experiment. This means that the STD feature extraction is the reliable feature that classifies the data. This is supported by the Figure 4.8, where the STD value is fall nearly to the range of degree movements. The blue line colour in Figure 4.8 shows that the line is virtually reaching the expected line of degree movements. Meanwhile, the RMS and MAV are quite distant from the expected line of degree movements. The component planes in Figure 4.7(a) already prove that the MAV and RMS features are clustered by minor of dark blue area. The dark blue colour of RMS and MAV shows tiny spot compared to STD dark blue colour spot. Figure 4.7 (a) The clustered features of EMG signal in 300 amount of neurons. Figure 4.7(b) The visualization of classified angle movements. 0.004 150 AMPLITUDE (V) 0.003 120 ANGLE (DEGREE) 90 0.002 60 0.001 0 30 0

30**S1 S2 S3 S4 S1 S2 S3 S4 S1 S2 S3 S4**

SUBJECTS STD MAV RMS Figure 4.8 The features extraction in the range of angle(degree). Therefore, the EMG signals from the subjects can be classify into the movements by degree of motion. The classification by using one of the Neural Network branches which is

54**Self-Organizing Map(** SOM) **can be applied to** distinguish **the**

movements. As visualized in Figure 4.7(b), predefine 'T' are successfully separated into three parts which are angle movements by 60˚, 90˚ and 120˚. By referring to Figure 4.7(b), the predefine 'T' in Table 4.3 for T1 to T12 falls into one part which is 60˚, T13 to T24 into 90˚ part and T25 to T36 fulfil the last part which is 120˚. 4.6 Summary The EMG signal from the subjects is relevant in classification for several degrees of arm movements. The objectives of this study is obtain thorough this chapter. The classification of features extraction only can be applied for three types of

10**time-domain features are Mean Absolute Value(MAV), Root Mean Square(RMS)**

and Standard Deviation(STD).

11**CHAPTER 5 CONCLUSION & RECOMMENDATIONS 5.1 Conclusion** In **this study has**

further discussed on the noise and the environment that affects the EMG signal during data collection. The surface electrodes contain lot of noise compared to needle insertion procedure, noise from the skin itself and the environment have been discussed in this study for better understanding to get a better quality of EMG signals. The objectives of this study are to extract the features and to classify the features by using SOM technique. The features that have successfully obtained from the experiment are MAV, STD, RMS, ZCS and VAR. On the other hand, not all the features can be classified into the class of several degrees of movements. The suitable features for classification are MAV, STD and RMS. The features are obtained by signal processing phase. The features of time-domain are extracted by using programming software use in MATLAB software. The arm movements of 60˚, 90˚ and 120˚ are classified into their own class of degrees movements by using SOM-Toolbox for MATLAB.

48**SOM-Toolbox for MATLAB developed by** Esa Alhoniemi **et al.**

on 1997 is one of the algorithms for Self-Organising Mapping Technique. The technique is depends on the distance between the nodes and updated weights for classification process. 5.2 Recommendations Throughout completing this study, there are several enhancements that can be made to obtain the optimised result. Signal acquisition might be improve by using high-tech of data acquisition system such as hardware developed by DELSYS and the electrodes are wireless. The wireless electrodes are assisted for minimising the error from causative factor. The wireless also provides single electrode bar, which means the distance by two electrodes is joint into one bar. Meanwhile, subjects selection can be improved by select at small range among 20 to 22 of BMI standards. The fix standards of BMI may lead to consistent EMG signals. The classification of this movement is important to have the consistent EMG signals by reducing the error movement from degree to another degree. There are several of features can be extracted from the EMG signals. Addition of features in classification maximise the result for unsupervised learning algorithm. 5.3 Future Works Classified EMG signals from this study can be applied into arm rehabilitation device. The signals that classified into the device consist of 60˚, 90˚ and 120˚ movements, the bilateral movement might be improved by minimising the degree movements and includes the triceps muscles as agonist anatomy for flexion and extension motion. REFERENCES [1] M. R. Ahsan, "Electromygraphy (EMG) Signal based Hand Gesture Recognition using Artificial Neural Network (ANN),"

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APPENDIX B Subject Angle MAV RMS STD ZCS VAR 0.001903 0.001981 0.001329 50 1.68E-06 60˚ 1.61E-03 0.001777 0.001329 48 1.99E-06 1.42E-03 1.75E-03 0.001325 44 0.001325 0.00232 0.0027 0.0022 58 2.66E-06 S1 90˚ 0.00231 0.00267 0.00219 43 2.15E-06 0.00228 0.00254 0.00215 37 2.189E-06 0.00318 0.00363 0.00311 39 3.13E-06 120˚ 0.00317 0.00365 0.0031 41 2.71E-06 0.00317 0.00339 3.16E-03 51 3.71E-06 0.00174 0.00219 1.42E-03 65 9.50E-07 60˚ 0.00165 0.00189 1.38E-03 65 9.75E-06 0.00164 0.00188 1.21E-03 31 1.76E-06 0.00244 0.00286 0.00238 81 2.35E-06 S2 90˚ 0.00237 0.00285 0.00231 85 2.62E-06 0.00232 0.00277 0.00228 54 1.62E-06 0.00315 3.99E-03 0.00316 13 3.56E-06 120˚ 0.00316 3.98E-03 0.00318 33 3.93E-06 0.00315 0.00384 0.00314 45 3.42E-06 9.75E-04 0.0019 0.00124 27 8.34E-07 60˚ 9.15E-04 0.00162 0.00133 19 1.22E-06 9.13E-04 1.61E-03 1.10E-03 19 8.38E-07 0.002 0.00239 0.00209 23 1.24E-06 S3 90˚ 0.00189 0.00231 0.00207 17 1.93E-06 0.00186 0.00228 0.00205 41 1.75E-06 0.00282 0.00318 0.00314 31 2.49E-06 120˚ 0.00291 0.00316 0.00307 50 2.53E-06 2.98E-03 0.00315 0.00302 23 2.60E-06 0.00161 0.00198 0.00133 15 1.89E-06 60˚ 0.00154 0.00185 0.00129 19 1.46E-06 0.00141 1.73E-03 0.00127 20 2.00E-06 0.00233 0.00246 2.44E-03 30 2.21E-06 S4 90˚ 0.00231 0.00243 0.00237 25 2.75E-06 2.23E-03 0.00242 0.0026 27 2.06E-06 0.0033 0.00391 0.00317 34 3.05E-06 120˚ 0.0032 0.00382 0.00313 36 3.16E-06 0.00327 0.00378 3.11E-03 37 3.01E-06 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46