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FINAL YEAR PROJECT REPORT

EMG CLASSIFICATION BASED ON FEATURES REDUCTION USING FUZZY C-MEANS CLUSTERING TECHNIQUE

PREPARED BY:

NURUL ILLIYYANA EMIRA BT JUSOH

BACHELOR OF ELECTRICAL ENGINEERING

(CONTROL, INSTRUMENTATION AND AUTOMATION)

"I hereby declare that I have read through this report entitle "*EMG Classification Based On Features Reduction using Fuzzy C-Means Clustering Technique* " and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)".

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Date : ………………………………………………

EMG CLASSIFICATION BASED ON FEATURES REDUCTION USING FUZZY C-MEANS CLUSTERING TECHNIQUE

NURUL ILLIYYANA EMIRA BINTI JUSOH

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

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ABSTRACT

This paper illustrates the features reduction technique for Electromyography (EMG) classification by using Fuzzy C-Means Clustering (FCM) technique. There are two types of EMG study which are diagnosis EMG and Kinesiological EMG. The diagnosis EMG is study about the characteristics of the motor unit action potential for duration and amplitude while for the Kinesiological EMG is about the movement analysis of the muscle activity. This work will focus more on Kinesiological EMG that used two types of electrode which are surface electrode and fine wire. The EMG signal is a measure of electrical current during the contraction of the muscle. EMG classification is not an easy task due to the signal contains a lot of uncertainties that leads to a high dimensional feature vector. The objective of this work is to extract the time domain features from the EMG signal and to perform the features reduction technique before classifying the EMG signal based on different pattern using FCM. In this work, five subjects that use right hand as dominant and without previous illness record are selected. Then, the subjects will be asked to perform 5 different patterns which are lateral, tripod, tip, power and extension. The EMG signal is collected at the forearm muscle. It is expected that FCM could perform EMG feature reduction to classify the upper limb muscle based on the different pattern.

ABSTRAK

Kertas kerja ini menggambarkan teknik-teknik pengurangan klasifikasi dalam Electromyography (EMG) dengan menggunakan teknik Fuzzy Kelompok C-purata (FCM). Kertas kerja ini menggambarkan EMG mempunyai dua jenis kajian iaitu EMG diagnosis dan EMG Kinesiological. Kertas kerja ini menggambarkan EMG diagnosis ialah kajian tentang ciri-ciri potensi tindakan unit motor untuk jangka masa dan amplitud manakala bagi Kinesiological EMG adalah mengenai analisis pergerakan aktiviti otot. Kertas kerja ini akan memberi tumpuan kepada Kinesionological EMG yang menggunakan dua jenis elektrod iaitu elektrod permukaan dan wayar halus. Kertas kerja ini akan mengukur arus elektrik semasa berlakunya pergerakan pada otot. Kertas kerja ini menggambarkan klasifikasi EMG itu bukan satu tugas yang mudah kerana isyarat yang mengandungi banyak ketidaktentuan yang membawa kepada dimensi wayar vektor ciri yang tinggi. Objektif kajian ini adalah untuk mendapatkan ciri-ciri domain masa dari isyarat EMG dan melaksanakan teknik ciri pengurangan sebelum mengklasifikasikan isyarat EMG berdasarkan pola yang berbeza dengan menggunakan FCM. Dalam karya ini, lima orang individu yang menggunakan tangan kanan sebagai dominan dan tanpa rekod penyakit sebelum ini yang dipilih sebagai bahan uji kaji. Kemudian, subjek akan diminta untuk melaksanakan 5 corak yang berbeza iaitu lateral, tripod, tip, kuasa dan sambungan. Isyarat EMG akan diukur pada bahagian otot lengan. Ia dijangka bahawa FCM boleh melakukan EMG pengurangan ciri untuk mengklasifikasikan otot lengan atas berdasarkan corak yang berbeza.

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CHAPTER 1

INTRODUCTION

This chapter will give a brief explanation about the project background, problem statement, objectives and the scopes of this thesis. Then, the objective was set to get the goal of this project. Lastly, project scopes will ensure the limitations will always be on the track.

1.1 Background

Research on EMG classification is essential in the field of medical research and human technology interaction. It required a strong foundation of the neuromuscular system, impact of the tools used during signal acquisition in order to collect meaningful data and signal processing technique. One of the commonly application related to this study is prosthetic device

Fuzzy logic has been applied to many fields in the control system. The idea of fuzzy logic is from Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s. Fuzzy logic is based on degree of truth whether 1 or 0. The EMG is commonly used in various fields to investigate the muscular activities. During the contraction of the muscle, it will produce the EMG signal and the electrical activities are detected [3]. The control of prosthesis and other assistive equipment is one of the most important applications of EMG signal classification [2]. It will record the electrical activity from the skeletal muscle and evaluates the data [3]. According from the theory of Peter Konrad [4], there have two types of electrode which are surface (non-invasive) and intramuscular (invasive) electrode to measure the EMG signal. The advantage when using the intramuscular (invasive) electrode is the signal from the muscle that is show more accurate. The active electrode it has built-in the amplifier and filter that will increase the noise while doing the experiment [6]. Then, for the passive electrode [7], there have no built-in the amplifier and filter but this electrode has the electrode gel. While, the surface of non-invasive electrode is the surface just only to apply on the skin and not inserted to the skin. So, the signal show is less accurate compared to the signal when using the invasive electrode.

To detect the muscle activities, the traditional EMG uses a fine needle while the surface EMG is using the surface electrode [5]. The main point of the EMG is to optimise the signal to ratio of noise [10]. The noises that exist while performing the experiment the raw EMG signal Electromyography can be divided into two types which are ambient noise and transducer noise. The ambient noise is the noise that produces from the computers and power line [10]. The performance of signal classification in time domain features are chosen compared to frequency domain and time- frequency domain because low noise environments and their lower computational complexity [8]. The time domain also has the disadvantages that are the data will assumed in stationary state for the non-stationary properties of the electromyography (EMG) signal that the raw EMG signal not in time domain of the featured of the extraction [9] [11].

1.2 Problem Statement

There are several problems based on the Electromyography (EMG) classification based on features reduction using fuzzy c-means clustering technique. First of all, EMG classification is not an easy task due to the signal contains a lot of uncertainties that leads to a high dimensional feature vector because it controlled by the nervous system and depends on the movement of the upper limb muscle. Based on the result of the EMG signal is the important way to detect the condition of the nerves or muscle.

This project is to classify the EMG signal based of the upper limb muscle for different pattern movement of muscle based on features reduction using fuzzy c-means clustering techniques. The signal has different EMG signal for each section. From the input signal that detect at the electrode, this project would be able to display output signal for each section on the MATLAB. Usually, EMG machine that are used is very expensive, but in this project, the EMG Data Acquisition used to acquire the signal is the cheaper one due to cost savings.

1.3 Objectives

The objectives as shown below:

i. To extract the time domain features from the EMG signal.
ii. To perform the features reduction technique
iii. To classify the EMG signal based on different pattern using Fuzzy C-Means (FCM).

1.4 Scope of Research

The scopes of this research are:

i. Data acquisation device for Electromyography signal used is NI myRIO and muscle V3 as a preamplifier.
ii. LabVIEW myRIO toolkit is for data display and recorder
iii. The feature extracted signal using the time domain which are root mean square (RMS), mean absolute value (MAV), standard deviation (STD) and variance (VAR).
iv. The muscle that is concentrated on forearm muscle only.
v. The criteria of target subject are male or female that is used right hand as a dominant and without previous illness record.
vi. Investigate for the five different of pattern.
vii. There are 5 subjects based on criteria in Table 1.1:

Table 1.1: The Criteria of Target Subject

Specifications	Male or female that are used a right hand as dominant
Weight	50kg to 60kg
Pattern that applied to the muscles	Lateral, Tripod, Tip, Power and Extension
Health condition	Normal

1.5 Motivation and Significance

For the motivation and significance in this research, the motivation is to classify the Electromyography (EMG) signal. The signal is come from the human muscle. Then, the signal must be classify into several type of pattern. The EMG signal must be extract into time domain features which are Root Mean Square (RMS), Mean Absolute Value (MAV), Standard Deviation (STD) and Variance (VAR).

The technique used in the research is Fuzzy C-Means Clustering Technique (FCM). The technique used to classify the signal for every pattern.

1.6 Report Outline

In this report will go through into 5 chapters:

Chapter 1:
In this chapter, discuss about the project background which is explain about the project. Then, the problem statement of this project and the scope of the research also will be discussed.

Chapter 2:
In this chapter, reviews of the previous researches project that are related with this project will be discussed. The information will be become additional source for the project in to be able more successful. To have a brief understanding of the researches related to the project, a few literature reviews had been done. This chapter will describe the related to the literature reviews.

Chapter 3:
The chapter 3, the explanations about the flow chart of the project from the beginning to the end of the project. For this chapter, it will explain the principles of the methods and techniques that are using by the previous researcher. The selected techniques must be chosen to approach the objective of this project. The data will be record from the experimental setup. Then, the Gantt chart also discuss in this chapter.

Chapter 4:

In this part, the discussion of the project and the result will show. The analysis of the result also discussed in this chapter.

Chapter 5:

Finally, the last chapter is about the conclusion of this research and recommendation is discuss.

CHAPTER 2

LITERATURE REVIEW

2.1 Electromyography (EMG)

There are many types of technique to detect the muscle. The electromyography (EMG) are commonly used in various fields to investigate the muscular activities [2].EMG signal is a biomedical signal that measures electrical activities from the skeletal muscles. It can be measured during the contraction of the muscle exhibiting neuromuscular activities. During the contraction of the muscle, it will produce the EMG signal and the electrical activities will detect [3]. The control of prosthesis or other assistive equipment is the most important application to applying the different pattern of EMG signal [2]. It will record the electrical activity from the skeletal muscle and evaluates the data [3]. The disadvantage of the EMG is when to recorded the data because the surface of the electromyography is usually more susceptible to artifact that is intramuscular EMG. The electric current of the EMG signal can be measured by the electrode [3]. According from the theory of Peter Konrad [4], there have two types of electrode which are surface (non-invasive) and intramuscular (invasive) electrode to measure the EMG signal. The intramuscular electrode needed a needle or fine-wire electrode that must be inserted into the skin that will make the electrode to be invasive to the skin [2]. The advantage when using the intramuscular (invasive) electrode is the signal from the muscle that is show more accurate. While, the surface of non-invasive electrode is the surface just only to apply on the skin and not inserted to the skin. So, the signal show is not accurate compared to the signal when using the invasive electrode. To detect the muscle activities, the traditional EMG uses a fine needle while the surface EMG is using the surface electrode [5]. When the electrode is placed, the one of the factor that affects the raw signal of EMG is the noises that are present. Therefore, when to do the experiment, make sure the surrounding in the less noise that will affect the data. The main point of the EMG is to optimise the signal to ratio of noise [10].

2.2 Noise in Electromyography

The noises that exist while performing the experiment the raw EMG signal Electromyography can be divided into two types which are ambient noise and transducer noise. The ambient noise is the noise that produces from the computers and power line [10]. Then, the transducer noise is from the ionic to an electronic. The types of noise in transducer are D/C and A/C voltage Potential [10]. The noise that is caused by differences in the impedance between the skin and the electrode is D/C (Direct Current) Voltage Potential. For the noise that is generated by fluctuations in impedance between the conductive the skin and transducer is A/C (Alternating Current) Voltage Potential. The effective ways to overcome the noise between the conductive transducer and the skin is use the silver/silver chloride (Ag-AgCl) electrode that are consists a thin layer of silver chloride material and silver metal surface plated.

2.3 The Electrode

They are two types of electrode are commonly use which are passive and active electrodes. The active electrode it has built-in the amplifier and filter that will increase the noise while doing the experiment [6]. Then, for the passive electrode [7], there have no built-in the amplifier and filter but this electrode has the electrode gel. In the study carried out by P. Laferriere et al [2], to obtain the EMG signals on the skin‟s surface, the electrode needs to use electrode gel because that has some problems of the surface of the electrode, silver/silver chloride (Ag/AgCl) electrode that cause the skin irritation and allergies. The electrode gel is provide the electrolytic gel that that can overcome the problem because that can react as a chemical which is interface between the skin and the metallic part of the electrode [10]. The dimension of electrode for EMG in the direction of the fibres that suggested is 10mm diameter [10]. The advantages when using the surface electrode is it is easy to apply while the contraction of the muscle and user friendly [7].

Figure 2.1: Disposable Ag/AgCl electrodes and the active surface electrode

2.4 The Location of the electrode

The surface electrode is placed at the forearm muscle. The experiment is using one input channel and three of the electrode. The three of electrode are two positive electrode and one ground electrode. The reference electrode which is the ground electrode that will locate at the bone and the other two electrodes must be near in 1cm only that is shown in figure 2.2. For the step of the experiment, firstly the subject‟s skin surface must be cleaned on forearm muscle. It is to reduce the skin impedance. Then, the skin in impedance will be measured. When the skin gets a light red colour, it shows good skin impedance condition [2]. Table 2.1 below shows the impedance ranges that are recommended.

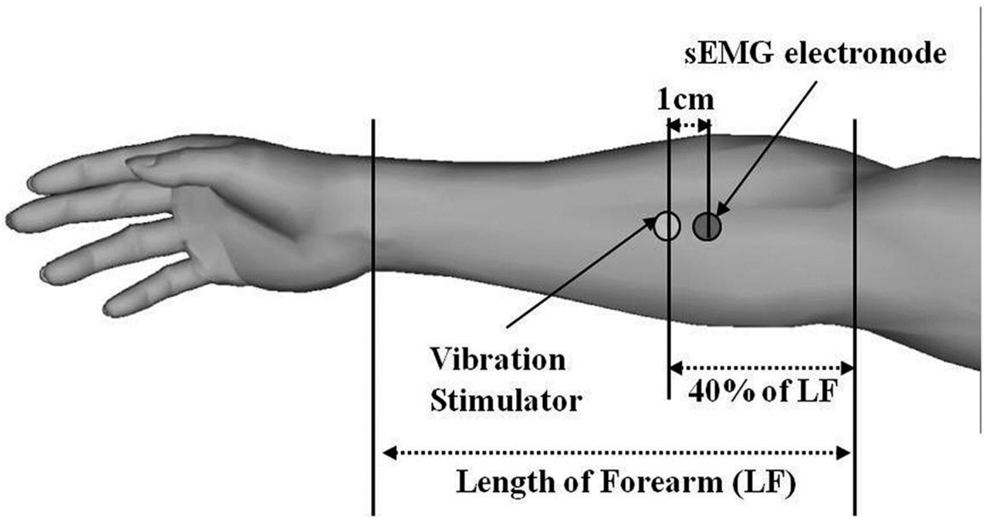


Figure 2.2: The Location of the Electrode in 1cm

Table 2.1: The Condition of the Skin Impedance

Impedance Range(KOhm)	Recommendation
1-5	Very good
5-10	Good
10-30	Acceptable
30-50	Less good
>50	Should be avoid

2.5 The Signal Features Extraction of Electromyography (EMG)

In this project, there are three features extraction technique that have been considered. The signal features extractions of Electromyography (EMG) are time domain, frequency domain and time-frequency domain. The extracted features of the EMG signals in time domain is the less percentage error for the ideal feature. The EMG signal can be extracted to time domain because the objective of this project is to evaluate the better features of the extraction. Based on the features of the extraction, the EMG signals in time domain can be implement in signal classification [2]. The time domain features are used in signal classification because it is easy and have quick implementation. The features are calculated based on raw EMG time series, so it does not need any transformation. The time domain features assume the data as a stationary signal. The performance of signal classification in time domain features are chosen compared to frequency domain and time-frequency domain because low noise environments and their lower computational complexity [8]. The root mean square, (RMS) and mean absolute value, (MAV) also can be used with standard deviation (MAV) to get a useful time domain features. The time domain also has the disadvantages that are the data will assumed in stationary state for the non-stationary properties of the electromyography (EMG) signal that the raw EMG signal not in time domain of the featured of the extraction [9].

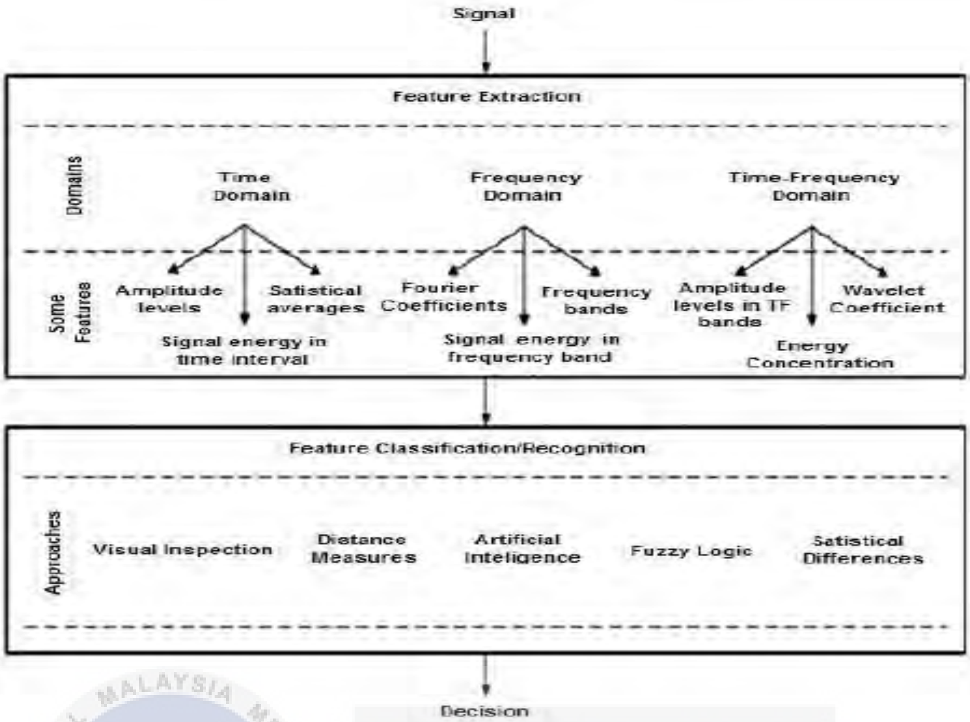


Figure 2.3: Signal Processing For Pattern Classification in Typical Application

2.6 Fuzzy C-Means features reduction clustering technique

From the thesis [11], it says that compared to Neural Network, the fuzzy logic system give more consistent classification results. Besides that, fuzzy logic also has incentive to over-training. The accuracy rate EMG classification is given below:

Table 2.2: The Typical EMG Classification Accuracy Rate

The Typical EMG Classification Accuracy Rate	
Method	Accuracy Rate
Neural Network	84%
Fuzzy Logic System	85%

In biomedical, fuzzy logic system can be used for EMG signal classification [11]. To emulate human decision making more closely, fuzzy logic is more preferable than ANN [11]. In this thesis, the fuzzy C- Means Clustering (FCM) is used. To identify the grouping from the large data is the objective of clustering to make the data briefly. This method as an improvement on earlier clusters methods.FCM shows the clustering technique of the group data points into a specific number of data point in the dataset in a different clusters. When the data point that too close to the centre of the cluster it will have a high degree of membership function while the data point that is far away from the centre of the cluster will have a low membership function. Fuzzy Logic Toolbox command line function fcm performs FCM clustering starts with an initial guess for the cluster centers, which are intended to mark the mean location of each cluster. The initial guess for these cluster centers is most likely incorrect. Then, fcm assigns every data point a membership grade for each cluster. By iteratively updating the cluster centers and the membership grades for each data point, fcm iteratively moves the cluster centers to the right location within a data set. This iteration is based on minimizing an objective function that represents the distance from any given data point to a cluster center weighted by that data point's membership grade. The information by fcm to help to create the fuzzy inference system by creating the membership functions to represent the fuzzy classification for each cluster.

2.7 Review of Previous Related Works

Based on “Techniques of EMG signal analysis: detection, processing, classification and applications” paper [1], by M.B. I. Reaz, M. S. Hussain and F. Mohd-Yasin, it discuss about to illustrate the various methodologies and algorithms for EMG signal analysis to provide efficient and effective ways of understanding the signal and its nature. This paper provides a hardware implementation. The paper is focus on application of prosthetic grasp recognition, interaction of human control and prosthetic hand control. The EMG signal is the signal that measures the electric current when muscle is in contraction condition. The EMG signal in human muscle is a complicated because it has a lot of noise. The signal comes through the different muscle with different signal. The signal is control by the nerve system that is dependent on the properties of muscle. The clinical diagnosis and biomedical applications is the main part and the reason for EMG signal analysis to analyze the data. In the research, there are using two types of electrode. There are invasive electrode and non-invasive electrode. The invasive electrode is by using needle in electrode that are inserted in the muscle while non-invasive is the skin surface electrode that only work on skin surface of human body. There are many electrical noises that are affecting the data of EMG signal. There are inherent noise in electronics equipment, ambient noise, motion artefact and inherent instability of signal. There are some artificial intelligent techniques that are used for processing the EMG signal in the paper. The valuable information regarding the nerve system is carrying by EMG signal. The objective of this paper is to brief the information about the EMG and reveal the various methods to analyze the signal. There are discussing about the advantage and disadvantage about their technique for detection, decomposition, classification and process.

Based on "Features Extraction of Electromyography Signals in Time Domain in Biceps Brachii Muscle" paper [2], by Wan MohdBukhari Wan Daud, Abu BakarYahya, Chong Shin Horng, MohamadFaniSulaima and RubitaSudirman, it says about to evaluate the features extraction of the time domain from the electromyography (EMG) signal. To select the ideal features is important in analyze the EMG signal. There was conducting the experiment to surface EMG for non-invasive assessment of muscle. To get the features, the data that recorded must be analyzed in time domain. From the paper, there are using three featuresbased o statistical features. Then, the features were evaluates to get the percentage of error for each feature. For determine the ideal feature, the feature that ishaving less percentage error is the best feature. To implements in signal classification, by extracted features of the EMG signals in time domain. This can be integrated to design a signal classification based on features extraction. The biomedical signal that measures electrical currents which is EMG signal is generated by skeletal muscle when the muscle in contraction neuromuscular activities. The biosignals of non-invasive measurement is important due to their abilities for the critical biomedical application. The surface EMG is the electrode that does not involve tools that break the skinand enter the human body. There are many application of EMG signal. For example, the application used to control the prosthesis or other assistive equipment. There are various types of electrode that being used to measure EMG signals which are surface electrode and needle electrode. The recommendation by the surface electromyography for the Non-Invasive Assessment for Muscle (SENIAM) project is use the surface electrode. There is having several stages for features extraction due to implements. It detects muscle contraction. There are Maximum Amplitude (MAX), Standard Deviation (STD) and Root Mean Square (RMS). In the research, the EMG data was measured during lifting their hand without load and with a dumbbell for 3kg and 5 kg. The amplitudes are directly proportional to the load. That means, the higher the loads, the higher the EMG signal. The ideal feature can be obtain by calculate the percentage error for each feature.

Based on "A Practical Introduction to Kinesiological Electromyography" paper [4], by Peter Konrad, the research is about Electromyography (EMG). EMG means technique to develop record and analyze the myoelectric signals. The EMG also known as the study of muscle function through the inquiry of the electrical signal the muscles emanate. The EMG signal is widely used for applied research, sport training, interaction of human body and rehabilitation. There are many benefits of EMG. For example, the EMG allows to directly looking into the muscle. Besides that, it can helps in decision making before and after surgery. Then, it can allow the analysis to improve sport activities for human sport. Next, the EMG also helps patients to train their muscle in biomedical system. It will detect the muscle response in ergonomic studies to improve the knowledge about it. The „raw" EMG signal is unfiltered signal that are detected at the muscle. The factors that influence the EMG signal. There are tissue characteristics, external noise and electrode and amplifiers. The procedure for skin preparation is removing the hair. This is important to improve the adhesion of the electrodes of sweaty skin types. Second procedure is cleaning the skin. The reference electrode must be paste at joints or boney area. When the skin preparation is complete, the skin impedance must be test. The impedance ranges that are recommended are 1 to 5 (KOhm). The impedance range greater than 50 that should be avoids and requires cleaning for the second time.

Based on "Wavelet Signal Processing of Human Muscle Electromyography Signals" paper [5], by Amur Hamed Mohammed Almanji, the thesis is about to identify action of human muscle action through EMG signal. There are several muscles that involve in this research. There are carried out from the experiments on triceps, biceps and flexor digitorum superficialis (FDS) muscles. From this paper, the result shows have futuristic engineering implications in biomedical engineering and bio robotic applications. The future work includes compromising two wavelets that have different properties on both frequency domains and time. There are the complex Shannon wavelet and the Meyer wavelet. The Shannon wavelet is having very good frequency resolution and it have slow decay in time domain. The Meyer wavelet is having the good frequency resolution and a faster decay in time domain compare than Shannon wavelet. There is having comparison of surface and indwelling EMG. The factors that include in comparison are electrode type, position, pick up zone, cross talk, muscle type and usage. The electrode type for surface is flat disk while the indwelling is needle or fine wire. The position of surface to take the data is only place it over selected muscle skin while indwelling is inserted into selected muscle. Then, for the pick-up zone of surface is large while the pick-up zone for indwelling is smaller than a surface. After that, the surface crosstalk is significant while the indwelling cross-talk is not significant. Next, the muscle type for surface is superficial muscles while indwelling muscle type is profound muscles. Besides, the usage for surface is reprehensive of muscle activities while the indwelling is good for motor unit studies. The wavelet theories have a weakness which is the central frequency is dependent on the mother wavelet. It will solve by rearrange the frequency of pseudo equation to analyze the signal within the desired range of frequency.

Based on "Important Factors in Surface EMG Measurement" paper [10] by Dr. Scott Day, the thesis is about the signal of EMG is can be measured by applying the electrode whether surface electrode or needle electrode. The frequency domain and time and amplitude of EMG signal will affect when the several factors involve. The factors that are affected are the timing and intensity of muscle contraction, the electrode distance from the active muscle area, the amplifier and electrode properties and the quality of contact between the skin and the electrode. Usually, the factor that is affected mostly in the experiment is the timing and intensity of muscle contraction. To overcome this problem are using the same amplifier and electrode and also make sure the quality of contact between the skin and electrode is consistent. The main point for this paper is minimize the noise while maximize the amplitude. There have two types of noises which are ambient noise and transducer noise. The ambient noise is the noise that is generated by electromagnetic devices while the transducer noise is generated at the electrode and skin junction. In transducer noise also divide into two types of noise sources. There are D/C (Direct Current) Voltage Potential and A/C (Alternating Current) Voltage Potential. The noise that is caused by differences in the impedance between the skin and the electrode is D/C (Direct Current) Voltage Potential. For the noise that is generated by fluctuations in impedance between the conductive the skin and transducer is A/C (Alternating Current) Voltage Potential. The effective ways to overcome the noise between the conductive transducer and the skin is use the electrode Ag-AgCl that are consists a thin layer of silver chloride material and silver metal surface plated.

2.8 The Table of Summarize For Literature Review

Table 2.3: The Table Of Summarize For Literature Review

Author	Description	Reference
M.B. I. Reaz, M. S. Hussain and F. Mohd-Yasin	The paper discuss about to illustrate the various methodologies and algorithms for EMG signal analysis to provide efficient and effective ways of understanding the signal and its nature. This paper provides a hardware implementation. The paper is focus on application of prosthetic grasp recognition, interaction of human control and prosthetic hand control. The EMG signal is the signal that measures the electric current when muscle is in contraction condition. The EMG signal in human muscle is a complicated because it has a lot of noise. The signal comes through the different muscle with different signal. The signal is control by the nerve system that is dependent on the properties of muscle. The clinical diagnosis and biomedical applications is the main part and the reason for EMG signal analysis to analyze the data. In the research, there are using two types of electrode. There are invasive electrode and non-invasive electrode. The invasive electrode is by using needle in electrode that are inserted in the muscle while non-invasive is the skin surface electrode that only work on skin surface of human body. There are many electrical noises that are affecting the data of EMG signal. There are inherent noise in electronics equipment, ambient noise,	[1]

	motion artifact and inherent instability of signal. There are some artificial intelligent techniques that are used for processing the EMG signal in the paper. The valuable information regarding the nerve system is carrying by EMG signal. The objective of this paper is to brief the information about the EMG and reveal the various methods to analyze the signal. There are discussing about the advantage and disadvantage about their technique for detection, decomposition, classification and process.	
Wan MohdBukhari Wan Daud, Abu BakarYahya, Chong Shin Horng, MohamadFaniSulaima and RubitaSudirman	The paper is about to evaluate the features extraction of the time domain from the electromyography (EMG) signal. To select the ideal features is important in analyze the EMG signal. There was conducting the experiment to surface EMG for non-invasive assessment of muscle. To get the features, the data that recorded must be analyzed in time domain. From the paper, there are using three features based o statistical features. Then, the features were evaluates to get the percentage of error for each feature. For determine the ideal feature, the feature that is having less percentage error is the best feature. To implements in signal classification, by extracted features of the EMG signals in time domain. This can be integrated to design a signal classification based on features extraction. The biomedical signal that measures electrical currents which is EMG signal is generated by skeletal muscle when the muscle in contraction neuromuscular activities. The biosignals of non-invasive measurement is important due to their abilities for the critical biomedical application. The surface EMG is the electrode that does not involve	[2]

	tools that break the skin and enter the human body. There are many application of EMG signal. For example, the application used to control the prosthesis or other assistive equipment. There are various types of electrode that being used to measure EMG signals which are surface electrode and needle electrode. The recommendation by the surface electromyography for the Non-Invasive Assessment for Muscle (SENIAM) project is use the surface electrode. There is having several stages for features extraction due to implements. It detects muscle contraction. There are Maximum Amplitude (MAX), Standard Deviation (STD) and Root Mean Square (RMS). In the research, the EMG data was measured during lifting their hand without load and with a dumbbell for 3kg and 5 kg. The amplitudes are directly proportional to the load. That means, the higher the loads, the higher the EMG signal. The ideal feature can be obtain by calculate the percentage error for each feature.	
Peter Konrad	The research is about Electromyography (EMG). EMG means technique to develop record and analyze the myoelectric signals. The EMG also known as the study of muscle function through the inquiry of the electrical signal the muscles emanate. The EMG signal is widely used for applied research, sport training, interaction of human body and rehabilitation. There are many benefits of EMG. For example, the EMG allows to directly looking into the muscle. Besides that, it can helps in decision making before and after surgery. Then, it can allow the analysis to improve sport activities for human sport. Next, the EMG also helps patients to train	[4]

	their muscle in biomedical system. It will detect the muscle response in ergonomic studies to improve the knowledge about it. The „raw" EMG signal is unfiltered signal that are detected at the muscle. The factors that influence the EMG signal. There are tissue characteristics, external noise and electrode and amplifiers. The procedure for skin preparation is removing the hair. This is important to improve the adhesion of the electrodes of sweaty skin types. Second procedure is cleaning the skin. The reference electrode must be paste at joints or boney area. When the skin preparation is complete, the skin impedance must be test. The impedance ranges that are recommended are 1 to 5 (KOhm). The impedance range greater than 50 that should be avoids and requires cleaning for the second time.	
Amur Hamed Mohammed Almanji	The thesis is about to identify action of human muscle action through EMG signal. There are several muscles that involve in this research. There are carried out from the experiments on triceps, biceps and flexor digitorum superficialis (FDS) muscles. From this paper, the result shows have futuristic engineering implications in biomedical engineering and bio robotic applications. The future work includes compromising two wavelets that have different properties on both frequency domains and time. There are the complex Shannon wavelet and the Meyer wavelet. The Shannon wavelet is having very good frequency resolution and it have slow decay in time domain. The Meyer wavelet is having the good frequency resolution and a faster decay in time domain compare than Shannon wavelet. There are having comparison of surface and indwelling	[5]

	EMG. The factors that include in comparison are electrode type, position, pick up zone, cross talk, muscle type and usage. The electrode type for surface is flat disk while the indwelling is needle or fine wire. The position of surface to take the data is only place it over selected muscle skin while indwelling is inserted into selected muscle. Then, for the pick-up zone of surface is large while the pick-up zone for indwelling is smaller than a surface. After that, the surface crosstalk is significant while the indwelling cross-talk is not significant. Next, the muscle type for surface is superficial muscles while indwelling muscle type is profound muscles. Besides, the usage for surface is reprehensive of muscle activities while the indwelling is good for motor unit studies. The wavelet theories have a weakness which is the central frequency is dependent on the mother wavelet. It will solve by rearrange the frequency of pseudo equation to analyze the signal within the desired range of frequency.	
Dr. Scott Day	The thesis is about the signal of EMG is can be measured by applying the electrode whether surface electrode or needle electrode. The frequency domain and time and amplitude of EMG signal will affect when the several factors involve. The factors that are affected are the timing and intensity of muscle contraction, the electrode distance from the active muscle area, the amplifier and electrode properties and the quality of contact between the skin and the electrode. Usually, the factor that is affected mostly in the experiment is the timing and intensity of muscle contraction. To overcome this problem are	[10]

	using the same amplifier and electrode and also make sure the quality of contact between the skin and electrode is consistent. The main point for this paper is minimize the noise while maximize the amplitude. There have two types of noises which are ambient noise and transducer noise. The ambient noise is the noise that is generated by electromagnetic devices while the transducer noise is generated at the electrode and skin junction. In transducer noise also divide into two types of noise sources. There are D/C (Direct Current) Voltage Potential and A/C (Alternating Current) Voltage Potential. The noise that is caused by differences in the impedance between the skin and the electrode is D/C (Direct Current) Voltage Potential. For the noise that is generated by fluctuations in impedance between the conductive the skin and transducer is A/C (Alternating Current) Voltage Potential. The effective ways to overcome the noise between the conductive transducer and the skin is use the electrode Ag-AgCl that are consists a thin layer of silver chloride material and silver metal surface plated.	

2.9 Summary and Discussion of the Review

EMG is the EMG signal is that are measures the electrical activities in the muscle. The signal are form when the muscle in contraction condition. There electrode have two types of electrodes. The types of electrodes are invasive electrode and non-invasive electrode The invasive electrode is by using needle in electrode that are inserted in the muscle while non-invasive is the skin surface electrode that only work on skin surface of human body. There are many electrical noises that are affecting the data of EMG signal. There are inherent noise in electronics equipment, ambient noise, motion artifact and inherent instability of signal. The raw EMG signal is collected. The raw EMG signal is the signal that is unfiltered the noise.

Then, the procedure for skin preparation is removing the hair. This is important to improve the adhesion of the electrodes of sweaty skin types. Second procedure is cleaning the skin. The reference electrode must be paste at joints or boney area. When the skin preparation is complete, the skin impedance must be test. The impedance ranges that are recommended are 1 to 5 (Kohm). The impedance range greater than 50 that should be avoids and requires cleaning for the second time.

The features are selected. To select the ideal features is important in analyze the EMG signal. To get the features, the data that recorded must be analyzed. Then, the features were evaluates to get the percentage of error for each feature. For determine the ideal feature, the feature that is having less percentage error is the best feature.

Lastly, while get the best features, implement the classification for the features.

CHAPTER 3

METHODOLOGY

In this chapter is the most important part to complete this research. This is the flow chart of the research of EMG classification based on features reduction using fuzzy c-means clustering technique. The operation of the EMG signal has been discussed that have to achieve the objective.

3.1 Experimental Protocol

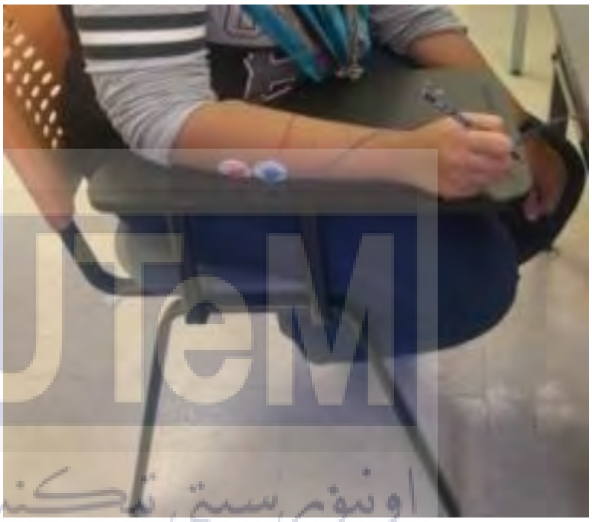
This protocol consists of two main parts which are subject criteria and experimental guideline. The protocol is to make sure that the experiments will be always on the tracks.

3.2 Subject Criteria

The subject comprises of male and female that have right hand as a dominant with average weight of 50kg to 60kg. The healthy conditions of the subjects are also important to ensure the signal is not disturbed by external factor. The subjects must have no medical history because to avoid an accident happen to the subject during taking the data. Then, the other specification of sample can refer to Table 1.1.

3.3 Experimental Guideline

The experimental guideline is the guideline that will ensure the experiment is correct or not. In this experiment, there were 5 subjects involved and each subject was asked to perform 5 types of pattern which are lateral, tripod, tip, power and extension as shown in Figure 1(a),(b),(c),(d) and (e). The data were collected from the subjects for 5 seconds. For the first pattern which is lateral that is holding the key. For the second pattern, it is tripod that is holding the pencil. For the third pattern, it is tip which is holding the button. The second last of the pattern is power which is holding the cylinder and the last one is the pattern of extension which is holding the card. The entire subject must do this respectively. For the computer time and the real time are not same. However, to avoid the difference in time, the stop watch is use to set the time during the experiment to the subject.

1(a) 1(b)


1(c) **1(d)**

1(e)

Figure 3.1: Pattern movement for each subject, (a) Lateral, (b) Tripod, (c) Tip, (d) Power and (e) Extension

3.4 Data Acquisition Setup

In this research, the experimental setup needs to be standard during data acquisition to ensure consistency of the result. NI myRIO is used as data acquisition and Muscle V3 as preamplifier as shown in Figure 3.2. Muscle V3 already amplified and filtered the raw EMG signal. Therefore, further signal conditioning is not required. NI myRIO is interfaced with the LabVIEW myRIO toolkit for data display and recorder as shown in Figure 3.3.The EMG signal variation during muscle contraction can be observed from the LabVIEW simulation. From the observation of the EMG signal in the form of size and shape of the wave, an appropriate data will be collected for further analysis.

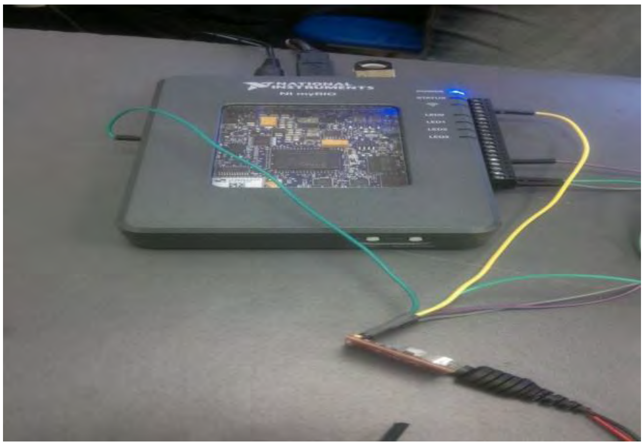


Figure3.2: NI myRIO & Muscle V3

Figure 3.3: LabVIEW as display and data recorder

3.5 The Procedure

Before the experiment, provide the survey and procedure to the subject. The survey and procedure that provided is referring to the appendix.

3.5.1 The Electrode

There are consists two types of electrode which are surface (non-invasive) and intramuscular (invasive) electrode that to measure the EMG signal. The surface electrode was non-invasive because that electrode can only be applied on the skin and would not insert in the skin as intramuscular electrode. In this experiment, the surface (non-invasive) is more preferable because it will not harm the subject. The figure 3.4 shows the surface of the electrode that is used for the subject in this research. Then, figure 3.5 shows the intramuscular electrode that is invasive electrode that applied in the skin. In this experiment, the invasive electrode is not used.

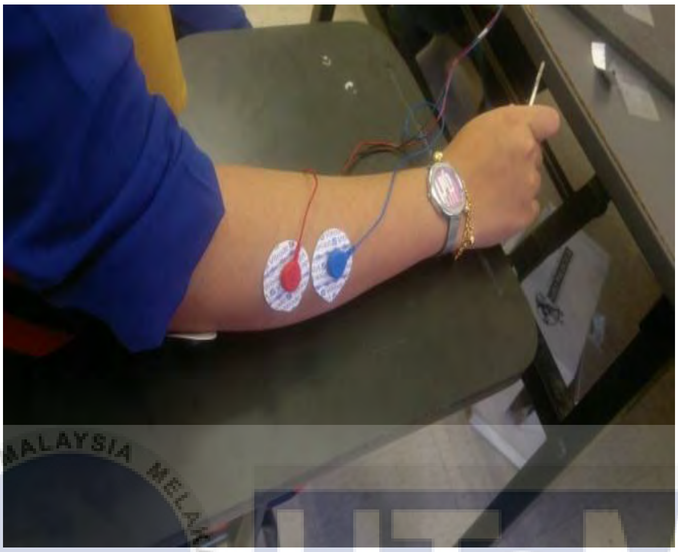


Figure 3.4: The surface of the electrodes

Figure 3.5: The intramuscular electrode

3.5.2 Skin Preparation

Besides, the preparation of the skin is crucial to reduce the skin impedance. Before pasting of the electrode, the skin must be clean and dry. Therefore, an alcohol swab is applied to the skin to clean the location of the electrode. The alcohol swab that is applied is shown in figure 3.6. For the sweaty skin types and hairy, the electric shaves is used to remove the hair. After removing the skin hair, the surface was clean up with wet tissue until it dry.

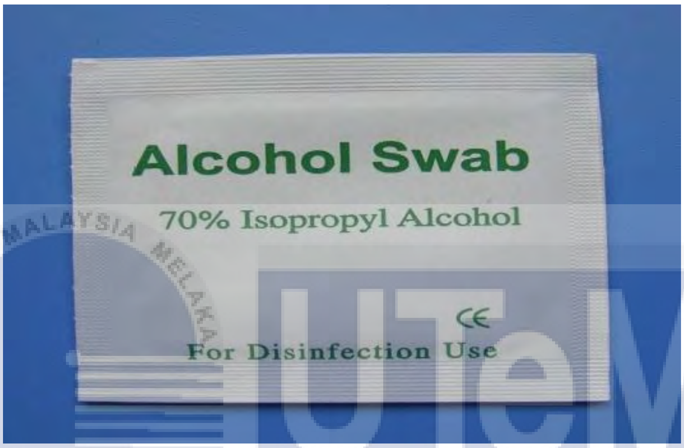


Figure 3.6: The Alcohol Swab

3.5.3 The Placement of Electrode

The electrode was placed at forearm muscle due to limitation of number of channel used in Muscle V3 equipment. The electrode is the sensor that detects the raw EMG signal during the data acquisition. The reference electrode which is the ground electrode is place at the bone [13]. The other two electrodes is place 1cm distance from each other at forearm muscle as shown in Figure 3.7:

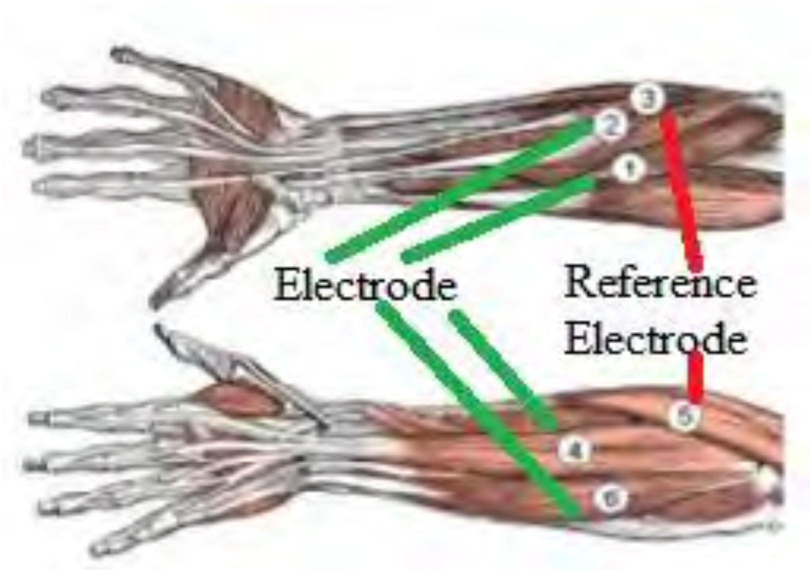


Figure 3.7: The Forearm muscle sites at which the EMG sensors were positioned

3.5.4 Time Domain Features Extraction

This research focused on four types of time domain features which are Root Mean Square (RMS), Mean Absolute Value (MAV), Standard Deviation (STD) and Variance (VAR). The descriptions of each feature are as follow:-

Root mean square (RMS) is model as amplitude modulated Gaussian random process which is related to the constant force and non-fatiguing contraction[12]. It can be define as:

$$\text{RMS} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} {X_n}^2} \quad (1)$$

Mean absolute value (MAV) feature isequivalent to average rectified value (ARV). It can be calculated using the moving average of fullwave rectified EMG. It is an easy way for detection of muscle contraction levels and it is a popular feature used in myoelectric control application[12]. It is represent as:

$$\text{MAV} = \frac{1}{N}\sum_{n=1}^{N}|X_n| \qquad (2)$$

Standard deviation features is generallyrepresent the confidence interval in statistical data of sEMG signal. A low standard deviation indicate that the data points tend to be very close to mean and vice versa if a high standard deviationvalue[12].It can be define as:

$$\text{STD} = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N} X_n{}^2} \qquad (3)$$

Variance is the average of the squared differences from the mean. It can be define as:

$$\text{VAR} = \frac{1}{N-1}\sum_{n=1}^{N} X_n{}^2 \qquad (4)$$

Analysis of variance or ANOVA test is a procedure for assigning sample variance to different source and deciding whether the variation arises within or among different population groups (person). In this experiment, the alpha value sets to be 0.05 [12]. If the p-value is less than 0.05, the test is valid. To proves that the validation of the features, ANOVA test is performed in Matlab.

3.5.5 Classification Method

This research is focus on the fuzzy logic system to classify the features of EMG signal. Based on the previous research, the fuzzy logic system is the best classifier of the upper limb muscle. There are two types of the fuzzy logic system which is Mamdani and Sugeno. The best type of the fuzzy logic system is Mamdani types. It is because this type based on the human-like manner. In this thesis, the fuzzy C- Means Clustering (FCM) is used. To identify the grouping from the large data is the objective of clustering to make the data briefly. This method as an improvement on earlier clusters methods. FCM shows the clustering technique of the group data points into a specific number of data point in the dataset in a different clusters. When the data point that too close to the centre of the cluster it will have a high degree of membership function while the data point that is far away from the centre of the cluster will have a low membership function. Fuzzy Logic Toolbox command line function fcm performs FCM clustering starts with an initial guess for the cluster centers, which are intended to mark the mean location of each cluster. The initial guess for these cluster centers is most likely incorrect. Then, fcm assigns every data point a membership grade for each cluster. By iteratively updating the cluster centers and the membership grades for each data point, fcm iteratively moves the cluster centers to the right location within a data set. This iteration is based on minimizing an objective function that represents the distance from any given data point to a cluster center weighted by that data point‟s membership grade. The information by fcm to help to create the fuzzy inference system by creating the membership functions to represent the fuzzy classification for each cluster.

3.6 Experimental Procedure

3.6.1 Flow of the Experimental Procedure for Single Task

This experimental procedure was important to ensure the process of collecting the raw EMG data from the samples to have the same configuration to ensure the validity of the data. Therefore, the flow chart below will show the flow of the experimental procedure for the task as set by experimental protocol.

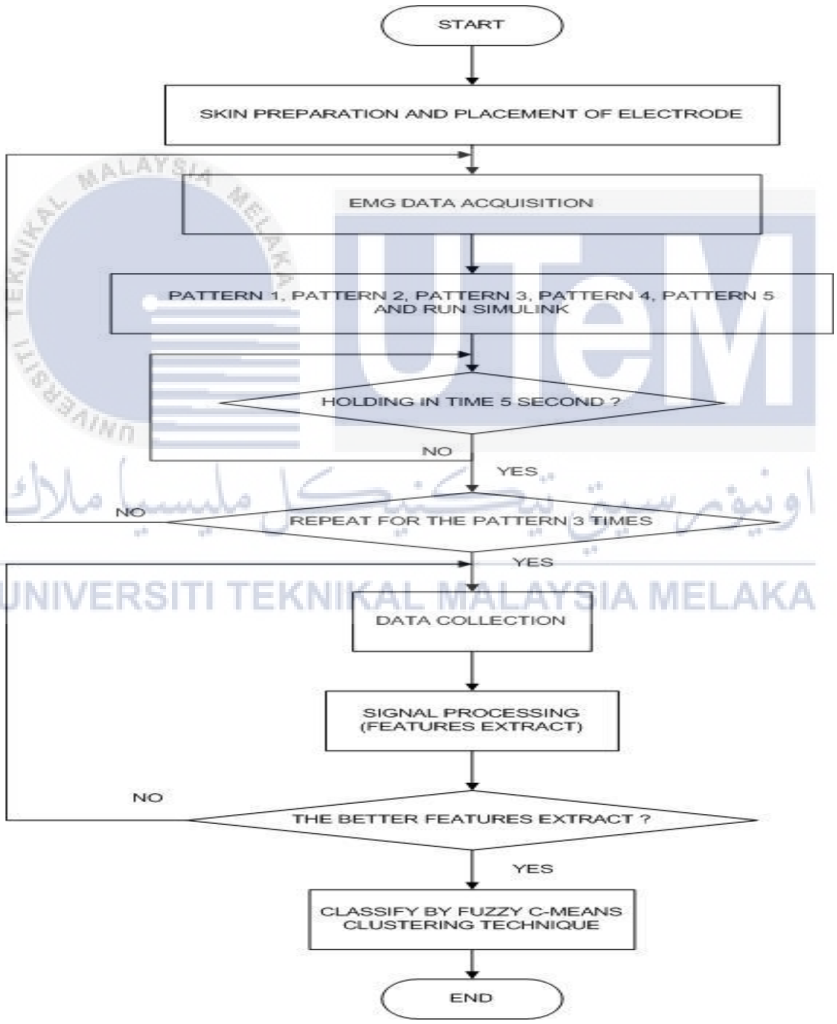


Figure 3.8: Flow Chart of the Experiment

3.7 Gantt Chart

The Gantt chart in table 3.1 is to show the activity of the project from the month of September 2014 to Jun 2015. The final year project 2 (FYP 2) is continue the studies of the final year project 1 (FYP 1).

Table 3.1: Gantt chart

FYP 1					**FYP 2**					
ACTIVITY	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAC**	**APRIL**	**MEI**	**JUN**
Understand project										
Literature review										
Seminar journal preparation										
Experimental Setup										
Select a participant & design a methodology										
Progress report writing & FYP 1 presentation										
Collecting Data for EMG signal										

Feature Extraction of EMG signals										
Evaluation of extracted feature										
Final report writing										
Prepare for Presentation project FYP 2										

3.8 Summary

Table 3.2 shows that the summary of the project of what have done in FYP 1 and FYP 2. For the phase 1 is the process finds the literature review. Then, for the phase 1 is collect the data that are using software. Last phase is the phase 3, classify EMG signal based on features reduction using fuzzy c-means clustering technique

Table 3.2: Summary of the Project

	PROCESS STEP	EXPECTATION
FYP 1	Phase 1 (Literature Review)	Research related project
FYP 1	Phase 2 (The data)	Software phase Select the Feature extraction
PYP 2	Phase 3	Classify EMG signal based on features reduction using fuzzy c-means clustering technique

3.9 Key Miles Stones

Key miles stones that shown in table 3.3, shows the detail of the project have run. From the deal with the supervisor and confirmation about the project title that want to select until the presentation of the project.

Table 3.3: Key miles stones

TASK	DATE
Deal with supervisor and confirmation project title	8/9/2014 – 24/9/2014
Collect the data raw EMG signal	23/10/2014 – 31/10/2014
Seminar and presentation project proposal	27/11/2014
Collect the final of EMG signal	28/2/2015 – 10/3/2015
Extract the features of EMG signal	11/3/2015 – 14/4/2015
Classify the EMG signal by using Fuzzy C-Means Clustering Techniques.	15/4/2015 – 28/5/2015
Due date for sent full report	1/6/2015
Presentation of project	9/6/2015

CHAPTER 4

ANALYSIS AND DISCUSSION

4.1 Analysis Of Variance or ANOVA Test

Analysis of variance or ANOVA test is a procedure that are used before proceed to the next step which is classification method. In this experiment, the alpha value sets to be 0.05. If the p-value is less than 0.05, the test is valid. Based on the result, the p-value is 0.00152 which is less than 0.05 for 5 common features of EMG signal. Therefore, when the p-value is less than 0.05, the process can be consider success. For the table 1, that shows the ANOVA table value of 0.00152. Then, Figure 4.1 shows the variation of each group of features when the p-value is 0.00152.Table 4.2 shows the features extraction data for each pattern.

Table 4.1: ANOVA Table

ANOVA Table

Source	SS	df	MS	F	Prob>F
Columns	0.07507	3	0.02502	45.68	4.53608e-08
Error	0.00876	16	0.00055		
Total	0.08383	19			

α= 0.00152

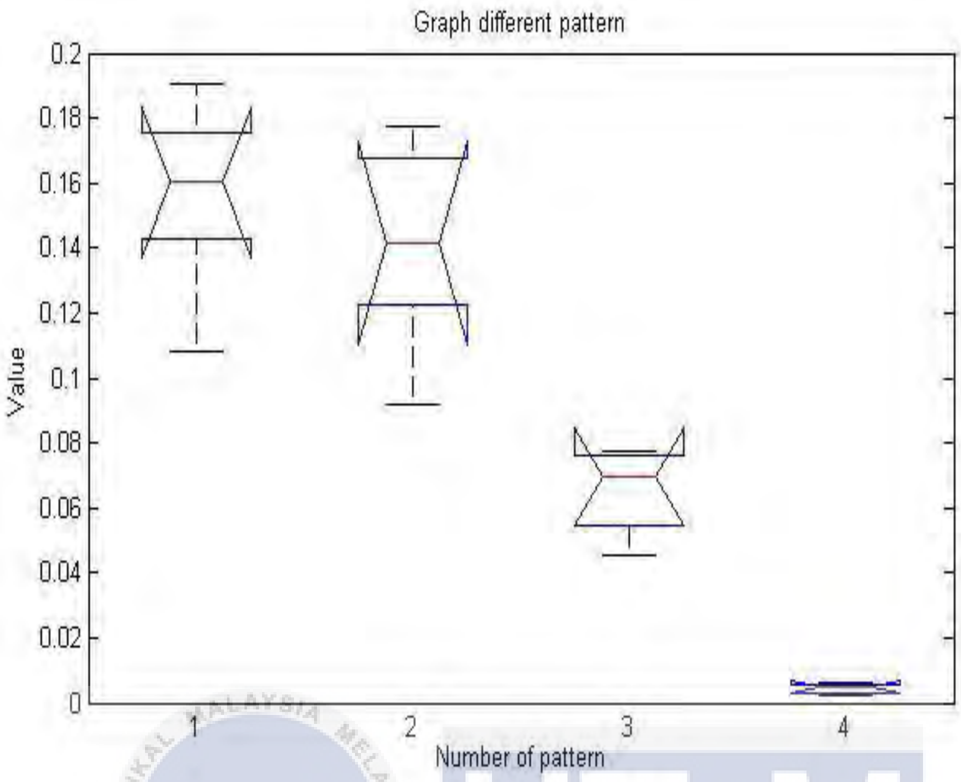


Figure 4.1: Graph ANOVA when p-value 0.00152

Table 4.2: The data features extraction for each pattern.

	RMS	MAV	STD	VAR
Lateral	0.16-0.18	0.16-0.18	0.04-0.05	0.002-0.003
Tripod	0.10-0.12	0.08-0.10	0.05-0.06	0.003-0.004
Tip	0.14-0.16	0.10-0.12	0.00-0.01	0.006-0.007
Power	0.16-0.18	0.14-0.16	0.07-0.08	0.005-0.006
Extension	0.18-0.20	0.16-0.18	0.06-0.07	0.004-0.005

4.2 EMG Classification Using FCM

This section discusses the experimental results of the EMG classification using FCM. There are five different patterns conducted by the subjects which are lateral, tripod, tip, power and extension. The scatter plots of the features using FCM for each pattern are depicted in Figure 4.2. Each colour of point represents the type of features for five different patterns. All the point representing the features should not intersect each other. If the points are intersect, so the data cannot be chosen directly without eliminate one of the data. Based on the observation from the result, the features for each pattern shows that the value of RMS and MAV could be discriminate easily compared to the STD and VAR. It is due to the difference between the features values for each pattern has an acceptable range that enables them to be easily classified. Further analysis has been done to prove that the FCM capable to reduce the features that is inappropriate to recognize the pattern. Figure 4.3 to 4.6 shows the plotting of each feature values versus pattern.

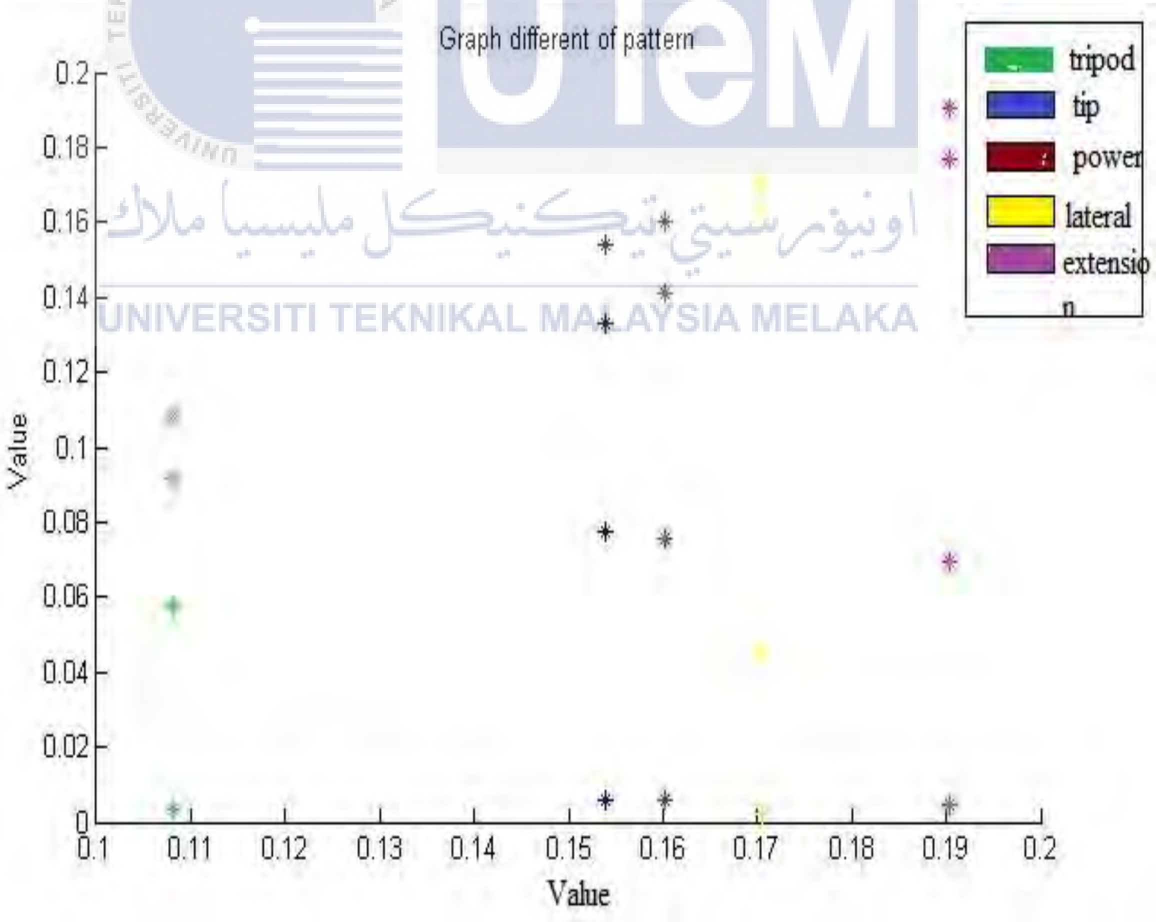


Figure 4.2: Scatter plot of FCM clustering

From the scatter plot of the features, there have the colours that are represents the different of patterns. The green colour is indicates the tripod pattern. Then, for the blue colour is represents the tip pattern. The red colour indicates the tip pattern. The second last of the yellow colour that indicates the power pattern. Lastly, the purple colour represents the extension pattern. The column from the above is the features of RMS, MAV STD and VAR that respectively.

4.3 The Analysis to Prove the FCM Can Reduce the Features That Can be classify the pattern

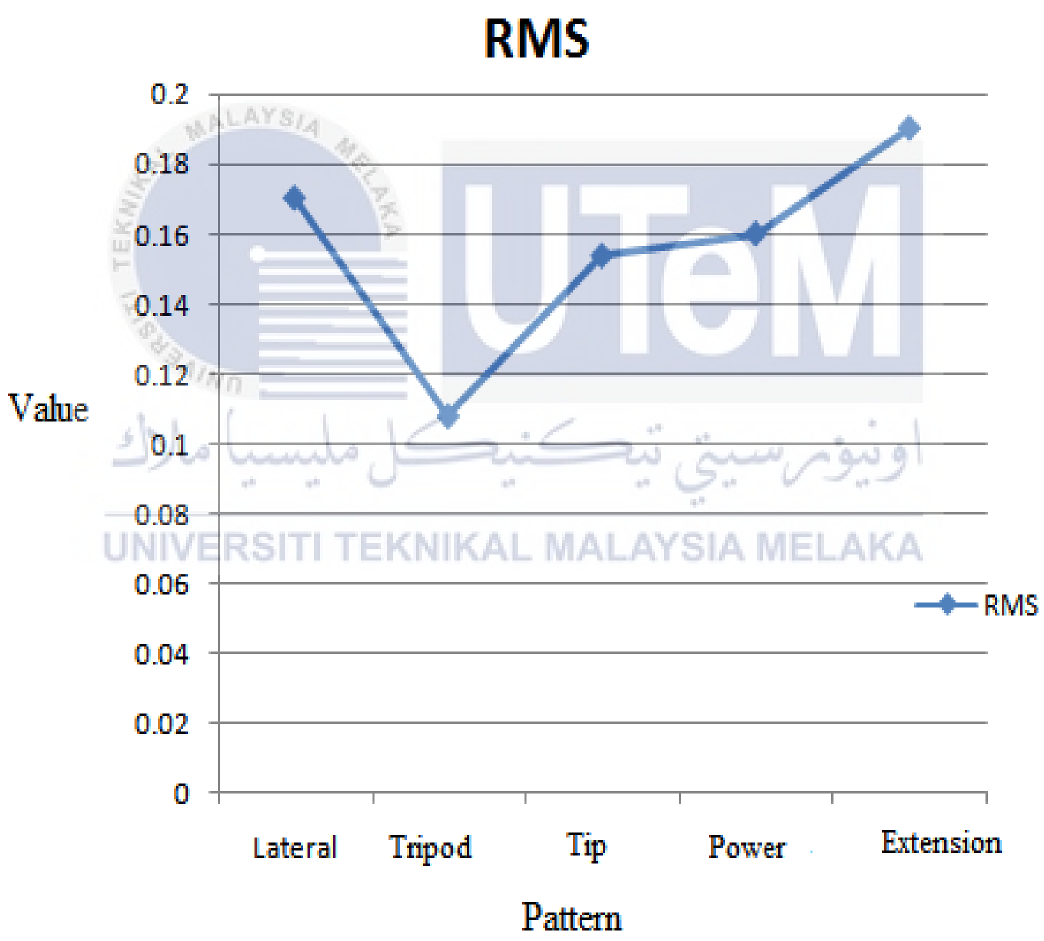


Figure 4.3: Graph RMS against pattern

Figure 4.3 show the graph of the RMS value against the five different of pattern. The extension has the highest value which is 0.1903 compared to the other pattern. Then, the tripod has the lowest value of RMS feature which is 0.1081. The different value between lateral and tripod is 0.0623. Second, the different of value between tripod and tip is 0.0458. Third, different between the pattern tip and pattern power is 0.0063. Lastly, the difference between pattern power and extension is 0.0301. So, it is mean that the graph has different range between each pattern. The entire pattern has the range value is more than 0.01 between each pattern. It is considered an acceptable range because it could discriminate the pattern clearly. If the data is too closed, it will difficult task to implement in recognise for all the patterns. All the patterns have different value of RMS. It is because each of the patterns has their own range value.

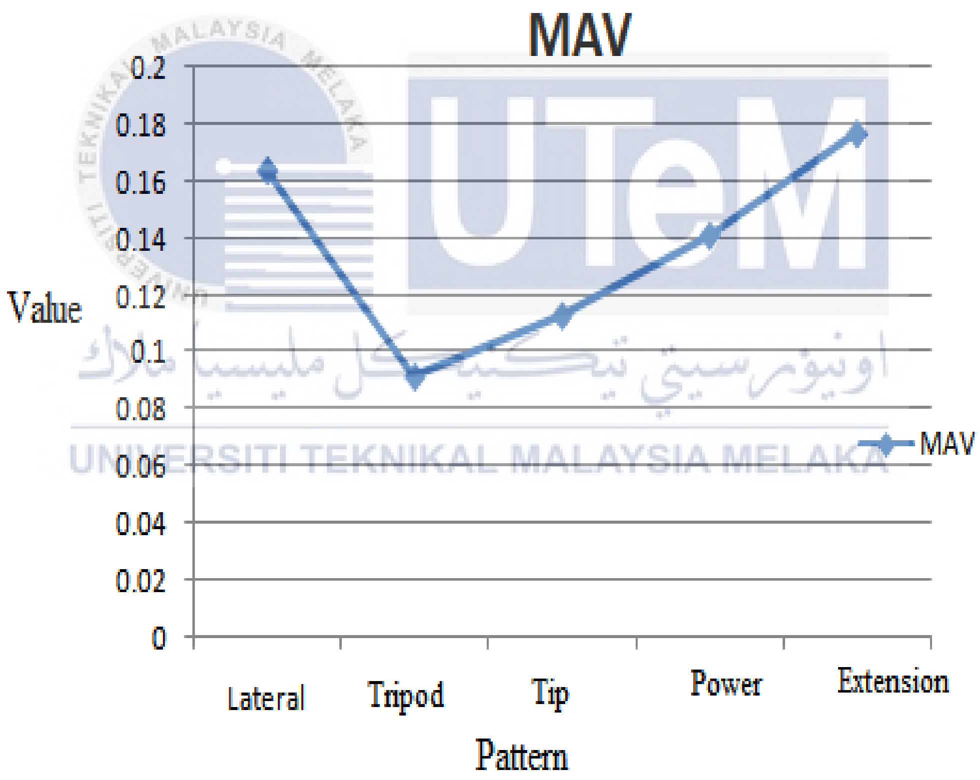


Figure 4.4: Graph MAV against pattern

Based on Figure 4.4, the highest value in this graph is the pattern of extension which is holding the card. The value for the pattern of extension is 0.1771. While, for the lowest value of MAV is tripod which is the subject holding the pencil. The value for the lowest MAV is 0.0916. All the patterns have different value of MAV features. Firstly, the different value between the pattern lateral and tripod is 0.0726. Second, the different between pattern tripod and pattern tip is 0.0415. Third, the different value is 0.0082 for the pattern tip and power. Lastly, the different value between pattern power and extension is 0.0358. MAV feature also has difference range between each pattern that is more than 0.01. When the tolerance of the range is acceptable between pattern, it is easier to classify all the patterns.

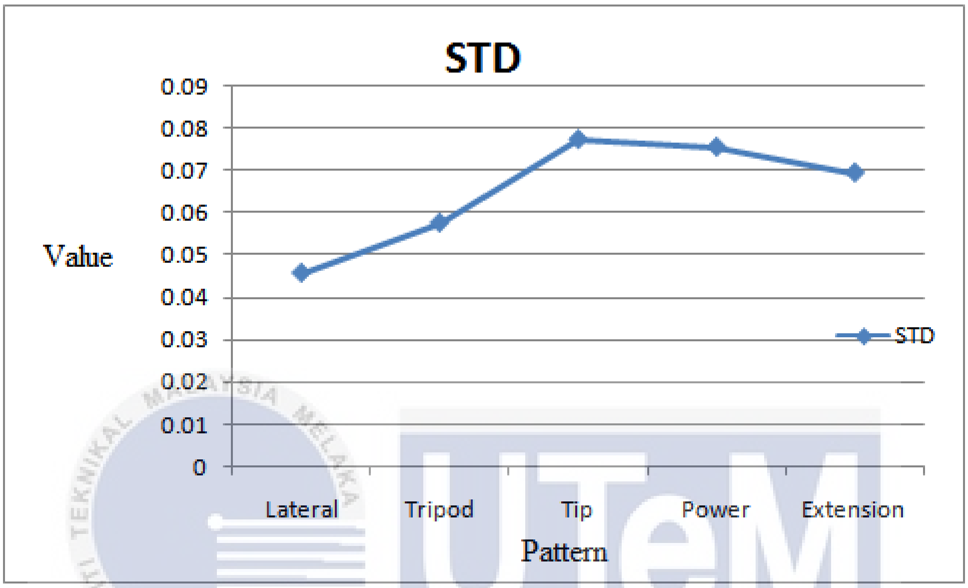


Figure 4.5: Graph STD against pattern.

However, refer to Figure 4.5, the highest value in this graph is the pattern of tip which is holding the button. The value for the pattern of tip is 0.0774. While, for the lowest value of STD is lateral which is the subject holding the key. The value for the lowest STD is 0.0457. Firstly, the different value between the pattern lateral and tripod is 0.0119. Second, the different between pattern tripod and pattern tip is 0.0198. Third, the different value is 0.0018 for the pattern tip and power. Lastly, the different value between pattern power and extension is 0.0061. The STD feature has difference range between pattern for tip and power that is less than 0.005 which is 0.0018. This range is too small that might cause the difficulty to distinguish both patterns. Thus, this feature is not suitable to recognise all the patterns.

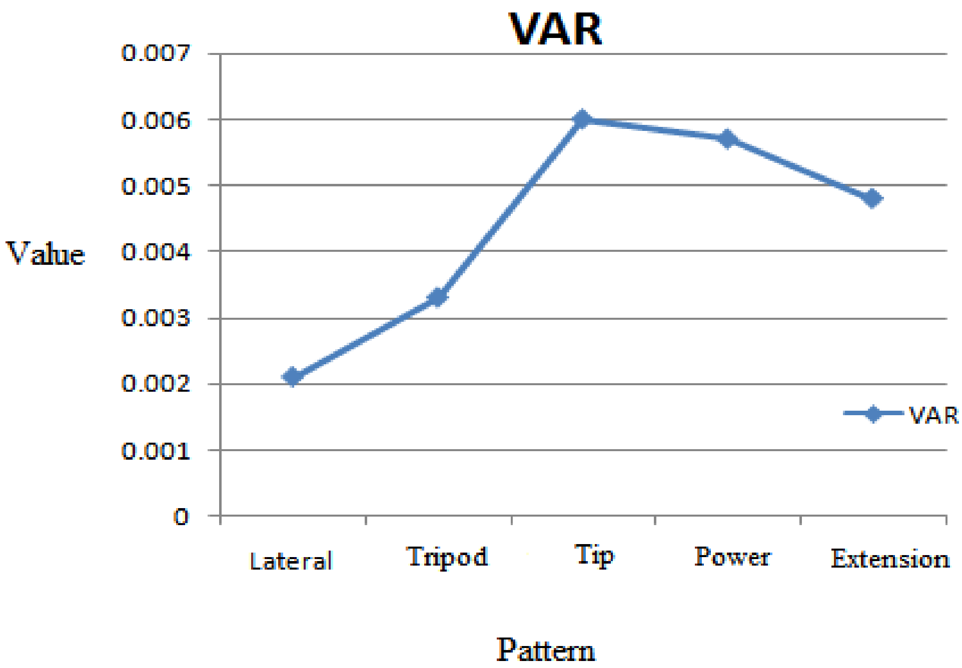


Figure 4.6: Graph VAR against pattern

Figure 4.6 show the graph of VAR feature. From the graph, the highest value is tip pattern which is the value 0.0060 while for the lowest range is the pattern for lateral which is 0.0021. The VAR feature has difference range between pattern for tip and power that is less than 0.0005. For the pattern tip the value is around 0.006 while for the pattern power, the value is 0.0057. The different range between these patterns is 0.0003. Thus, this feature is very difficult to use to classify the range of the pattern. Hence, the most suitable features that can be utilized to classify all the patterns are RMS and MAV. Whereas the STD and VAR are not suitable features for this pattern recognition experiment.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion and Recommendation

As conclusion, FCM clustering technique is capable to reduce the features to be implemented for classification. The experiment results show that the STD and VAR features are not suitable to recognize the entire pattern due to lack of discrimination between them. The difference between the patterns is too narrow. Whereas RMS and MAV features are more suitable features to recognise the entire pattern. This is because the differences between the patterns are considerably reasonable to distinguish between the patterns. It will be difficult task to implement in real time control implementation if the features have low discrimination ability. Therefore, these analyses prove that the FCM is capable to reduce the features that are inappropriate to discriminate the pattern.

The recommendation to reduce the noise signal in muscle contraction is used the EMG signals detection with the powerful and advance methodologies. This is very important requirement in biomedical engineering. Then, discover the problem is the one method that can conduct to improve the other method.

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APPENDICES A

THE SURVEY FOR THE SUBJECT

SECTION A (SUBJECT BACKGROUND)

NAME	
IC – NUMBER	
AGE	
SEX	
WEIGHT	
HEIGHT	
MEDICAL HISTORY	
FACULTY/FIELD	

SECTION B (ELECTROMYORAPHY (EMG) SIGNAL KNOWLEDGE)

		strongly don"t know	A little	uncertain/ moderate	know	strongly know
1.	How much do you understand about EMG signal?	☐	☐	☐	☐	☐
2.	Do you know the factor(s) that why the EMG is important?	☐	☐	☐	☐	☐
3.	Do you understand the fact the eight (8) of ten (10) in Malaysia do not know the ability doing the activities?	☐	☐	☐	☐	☐
4.	Do you know that it will affect our daily activities in general?	☐	☐	☐	☐	☐

APPENDICES B

FACULTY OF ELECTRICAL ENGINEERING
2014/2015

RESEARCH METHODOLOGY

EXPERIMENT ACQUISTION DATA FOR ELECTROMYOGRAPHY SIGNAL CLASSIFICATION FOR DIFFERENT OF PATTERNS

TASK	NAME	SIGNATURE	DATE
PREPARED BY	NURUL ILLIYYANA EMIRA BT.JUSOH		

TITLE:
EMG CLASSIFICATION BASED ON FEATURES REDUCTION USING FUZZY C-MEANS CLUSTERING TECHNIQUE

OBJECTIVES:

At the end of this experiment, student should be able;

1. To collect the raw data of EMG signal in term of time domain features.
2. To recognize the behaviour of EMG signal.
3. Prepare the EMG signal in order to patterning and classification stage.

REFERENCES

1. The ABC of EMG- A practical introduction to Kinesiological Electromyography.
2. Techniques of EMG signal analysis: detection, processing, classification and applications

LIST OF EQUIPMENTS

1. NIHON KOHDEN VITRODE *Disposable Electrodes* EMG surface electrode.
2. Muscle Sensor V3 as preamplifier.
3. NI myRIO as data acquisition.
4. LabVIEW myRIO toolkit as data display and recorder.
5. Alcohol Swab.
6. Key.
7. Pencil.
8. Button.
9. Cylinder.
10. Card.
11. Multimeter
12. A Stop watch.

THE PROCEDURE

1. Firstly, all the subject that selected randomly must be briefly explain on the experiment conducted.
2. The subject/participant consist of 5 person are normal without medical history. Then, the entire subject must complete the survey form.
3. Then, demonstrate the experiment that to perform 5 types of patterns which are lateral, tripod, tip, power and extension.
4. Next, get ready for the entire respondent to undertake the skin preparation before start the experiment.
5. Experiment will be start after participant known about the experiment and agree.
6. Lastly, before start the experiment, check the skin impedance by using multimeter in order to make sure the resistance on the surface area low.

APPENDICES C

THE CODING OF FEATURES EXTRACTION

```
data=xlsread('data.xlsm');
%Calculate Root Mean Square
data_squared = data.^2;  %squares each term in the vector
mean_data_squared = mean(data_squared );   %mean of the squared values
RMS = sqrt( mean_data_squared );  %square root of the mean of the squared values
%Calculate Mean Absolute Value
MAV=[meanabs(data(:,1)) meanabs(data(:,2)) meanabs(data(:,3)) meanabs(data(:,4))
meanabs(data(:,5))];
%Calculate Standard Deviation
STDE=[std(data(:,1)) std(data(:,2)) std(data(:,3)) std(data(:,4)) std(data(:,5))];
%Calculate Variance
VARI=[var(data(:,1)) var(data(:,2)) var(data(:,3)) var(data(:,4)) var(data(:,5))];
Features=[RMS;MAV;STDE;VARI];
%ANOVA test between pattern
>> Pattern=Features';
>> p=anova1(Pattern);  % Type anova1 at help menu in matlab for description
```

APPENDICES D

THE CODING OF FUZZY C-MEANS CLUSTERING TECHNIQUE TO REDUCE THE FEATURES EXTRACTION

```
opts=[nan;nan;nan;0];
[center,U,obj_fcn]=fcm(Pattern,5,opts);
maxU=max(U);
index1=find(U(1,:)==maxU);
index2=find(U(2,:)==maxU);
index3=find(U(3,:)==maxU);
index4=find(U(4,:)==maxU);
index5=find(U(5,:)==maxU);
line(Pattern(index1,1),Pattern(index1,:),'linestyle','none','marker','*','color','g');
line(Pattern(index2,1),Pattern(index2,:),'linestyle','none','marker','*','color','r');
line(Pattern(index3,1),Pattern(index3,:),'linestyle','none','marker','*','color','b');
line(Pattern(index4,1),Pattern(index4,:),'linestyle','none','marker','*','color','y');
line(Pattern(index5,1),Pattern(index5,:),'linestyle','none','marker','*','color','m');
```