"I hereby declare that I have read through this report entitle "*Features extraction of Surface Electromyography (sEMG) in term of force*" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

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FEATURES EXTRACTION OF SURFACE ELECTROMYOGRPAHY IN TERM OF FORCE

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

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2014

I declare that this report entitle "*Features extraction of Surface Electromyography (sEMG) in term of force*" is the result of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

The research of feature extraction based on surface electromyography in term of force is done to help the people with upper limb amputation disabilities. Therefore, this research will focus on the relationship between the normalized electromyography (EMG) signal and force. This objective of this research is to do feature extraction of electromyography (EMG) in term of force in time domain. Then, the statistical analysis by using a simple linear regression technique on scatter plot was done to analyze the relationship between force and electromyography (EMG). 10 subjects are selected that mainly based on criteria of weight and the health condition of the person. The selected muscle is long head biceps brachii. The experiment is divided into three main tasks which consist of angles of 45^0,90^0 and 120^0. In addition, three tasks which consist of loads of 2kg, 4kg, and 6kg are done. The feature extractions with mean absolute value, root mean square (RMS), variance and standard deviation are analyzed by using simple linear regression analysis. The calculation of force formula from electromyography (EMG) signal is used to predict force. The average value is used to develop the equation of force because it has high value of correlation coefficient as compared to the value for all the subjects. Two methods to determine the reliability of the equation are based on the percentage of calculating force error and percentage of average predicted force error. The result has stated that mean shows the best feature extraction based on simple linear regression analysis characteristics. The result has shown that the performance for calculating force and average predicted force are inaccurate because the value of percentage of error is high. Hill-Based model and neural network are ways to improve the inaccuracy of simple linear regression technique to predict force.

ABSTRAK

Penyelidikan pengekstrakan ciri-ciri elektomiografi permukaan dari segi daya tenaga telah dilakukan untuk membantu rakyat yang cacat di bahagian tangan . Oleh itu, penyelidikan ini akan memberi tumpuan kepada hubungan antara isyarat elektomiografi (EMG) dengan daya tenaga. Objektif pertama kajian adalah untuk melakukan pengekstrakan ciri elektomiografi(EMG) dari segi daya tenaga di dalam domain masa . Kemudian , analisi statistik dengan menggunakan teknik regresi linear pada graf berselerak telah dilakukan untuk menganalisis hubungan di antara daya tenaga dan elektomiografi (EMG). Skop projek ini adalah dengan memilih 10 orang subjek berdasarkan kriteria berat badan dan keadaan kesihatan subjek. Kemudian, otot yang telah dipilih adalah bisep dan senaman yang telah dilakukan adalah senaman lengkungan bisep. Eksperimen itu dibahagikan kepada tiga tugasan utama yang terdiri daripada sudut 45^0,90^0 dan 120^0 .Kemudian, tugasan akan di bahagikan kepada tiga lagi tugasan di dalam satu tugasan utama yang terdiri daripada berat 2kg , 4kg , dan 6kg . Daya tenaga ini dikira dari formula model daya tenaga otot yang telah dikawal oleh beban dan sudut. Kemudian,teknik pengekstrakan yang mempunyai ciri yang terbaik di kalangan purata, RMS, varians dan sisihan piawai telah dianalisis dengan menggunakan analisis regresi linear. Teknik regresi linear telah digunakan dengan mengunakan graf berselerak yang mempunyai hubungan voltan dan daya kuasa. Pengiraan formula daya tenaga dari isyarat elektomiografi(EMG) adalah kaedah untuk meramalkan daya tenaga. Nilai purata telah digunakan untuk membangunkan persamaan daya tenaga kerana ia mempunyai nilai pekali korelasi yang tinggi berbanding dengan nilai untuk semua teknik pengekstrakan. Terdapat dua kaedah untuk menentukan kebolehpercayaan persamaan iaitu untuk mengira peratusan ralat bagi pengiraan daya kuasa dan purata ramalan daya kuasa. Hasilnya telah menyatakan bahawa purata mempunyai ciri pengekstrakan terbaik berdasarkan ciri-ciri analisis regresi linear. Hasil kajian menunjukkan bahawa prestasi buruk apabila pengiraan daya tenaga dan ramalan purata daya tenaga mempunyai nilai peratusan ralat yang besar.

This research of "Features Extraction of sEMG in Term of Force" (ID-51) has been accepted to be presented in IEEE EMBS INTERNATIONAL STUDENT CONFERENCE 2014 (ISC2014).

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CHAPTER 1

INTRODUCTION

This chapter will give a brief explanation of the theory and application of the EMG signal. Other than that, this chapter will show the purpose of this research and the problem that can be solved from this research. Lastly, the objective was set to ensure that this research will fulfill its target while the scope will ensure that this research will always be on track based on the criteria chosen.

1.1 Project Background

The electromyography (EMG) is the inquiry of the electrical signal when the muscles emanate. Myoelectric signal is formed by a variation in the state of muscle fiber membranes. There are many widespread use of electromyography that is in the rehabilitation part, medical research, ergonomic and sports science. This widespread use can help in the measurement of muscular performance through looking into the muscle signal. There are two types of electrodes which can be used to detect electromyography (EMG) signal that is surface and needle electrodes. Feature extraction of electromyography signal can be done by using three basic methods that are in time domain analysis method, frequency domain analysis method and time-frequency analysis method. Other than that, there are two types of contraction which is done by our muscle, which consists of isometric and non-isometric (dynamic) contraction.

The role of Electromyography within biomechanics studied and setup can be measured by 4 major areas that is, a body part, forces, movement and muscle activation. The body parts will be controlled by bone and segments which will have the analysis in term of structure and

proportion. Next, the movement will be analyzed based on distance, angle, velocity or acceleration and force will be analyzed in term of linear force, moment and torque. Lastly, the muscle activation will be analyzed on the muscle action potential of the muscle. These four methods can be categorized as kinesiological analysis, which is used as a base to start a research on new things. This research will be based on EMG in term of force which can be used to aid many applications such as prosthesis design, rehabilitation of muscle and designing a workout regime.

1.2 Project Motivation

The upper limb amputation is an less fortunate individual which unable to live their normal life and will hold the progress of the individual to earn a living. Therefore, prosthesis arm is needed to aid the upper limb amputation individual to earn a living without the help from others. Therefore, the development of enhancement of prosthesis equipment is needed to ensure that the operation of prosthetic hand is the same as the operation of a normal human hand. This enhancement of prosthesis equipment needs an analysis which can be used as a guideline or data to develop the enchancement of prosthesis arm. Therefore, a use of bio signal is important in analyzing the reaction of the body that will be useful to aid in the processes of designing the prosthetic hand based on the reaction of an electrical signal or bio signal send toward the muscle. The electromyography is an electrical signal that is obtained when the reaction of muscle happens and this data could aid in the designing a new prosthetic arm.

The feature extraction technique is a method to ensure that the characteristic of the electromyography signal. Feature extraction of electromyography consists of time domain feature extraction, frequency domain feature extraction and time-frequency domain feature extraction. Every domain feature can analyze the muscle in different ways and in this project the suitable domain that will be used is the time domain. The time domain features normally are used for muscle contraction and muscle activity detection. The feature extraction from muscle contraction is important in determining the force that will be applied to the muscle through biceps curl exercise. The higher the value of force is applied to the muscle will make

the value of feature extraction to increase. However, the problem that will occur in this project is to choose the best feature extraction. The best features extraction has to be selected for the purpose of designing prosthethic arm.

The prosthesis arm design should consider many factors that could affect the movement and the load that could be lifted by the arm. The design of the arm also depends on the experiment setup. Therefore, the next motivation of this project is to determine the force by determining the movement of the elbow angle and the load that will be lifted in the biceps curl exercise. Lastly, the force that is needed by the prosthehic hand must be the same with normal hand force to ensure that the human can control the movement of the prosthethic hand.

1.3 Problem Statement

Prosthetic arm capabilities is not the same as normal human hand. This has limited their life capabilities and may cause disadvantages to another person to help them to live as normal person. Therefore, a proper analysis of muscle behaviour was needed. The analysis of muscle has many criteria and this research will be focusing on the force that is apply to the biceps muscle. The force will be varied by the weights and angles that will be applied to the muscles for analysis to help in designing of prosthesis arm. This could help to enhance the prosthesis arm in term of lifting many variables of loads with different angles.

Therefore, by using surface electromyography (sEMG) to do the analysis on the behaviour of muscle when force is applied to muscles, it could assist in development of a prosthesis hand which could lift loads based on angles set. The surface electromyography (sEMG) signal will be extracted to obtain the characteristic of the muscle and will be evaluated by using statistical analysis on scatter plot to produce an information for the other researcher to develop a better prosthesis arm.

1.4 Objective

There are two objectives that will provide to achieve the target of this research:

1. To extract the feature of surface electromyography (sEMG) in term of force in time domain.
2. To analyze the feature of the extracted signal by using statistical analysis

1.5 Scope

This research scope will be a guideline to guide towards achieving the objectives and the scopes of this project was shown as below:

1. The muscle that involved in this research is biceps brachii.
2. The exercise that is conducted in this research is by using biceps curl method.
3. Electromyography sensor that will be used is a Muscle V3 sensor (appendix G) and the output of the sensor will be in normalized electromyography (EMG) signal.
4. A surface electrode will be used in this research.
5. The Arduino Mega 2560 will be used as the microcontroller that acts as a data acquisition
6. The feature extraction that will be used is in the time domain which is mean, root mean square (RMS), standard deviation and variance.
7. The analyze part of feature extraction electromyography (EMG) is by using a simple linear regression technique in the scatter plot.
8. There are 10 subjects based on criteria in Table 1.1:

Table 1.1: The criteria of target subject

Specifications	Age	Height	Weight	Load applied to the muscles	Health Condition
10 Male	18-35	160cm to180cm	50kg to 90kg	0kg to 6kg	Normal

CHAPTER 2

LITERATURE REVIEW

This chapter will give a brief explanation of the theory and the history of EMG. Other than that, this chapter will also describe on the study based on the featured extraction and relationship between force and electromyography signal. Lastly, this chapter will also provide the knowledge of force and electromyography (EMG) mathematical model based on the statistical analysis that will focus more on the scatter plot.

2.1 Electromyography (EMG) Background

Electromyography is a study of bio-signal that is produced from the movement of the muscle. The main contributor to this electromyography or bio-signal from body movement is related to motor unit which consists of motor neuron and muscle fibre [1]. Normally, during voluntary contraction a combination of motor unit recruitment and changes in motor unit activation frequency can be modulated to force [2]. The build-in low pass filter inside the human body which consist of connective tissue and skin layers has caused the surface electromyography (sEMG) to cause the firing frequency to produce non-originality to electromyography (EMG) signal firing and amplitude signal characteristic .

The bio-signal appears when muscle membrane movement or excitation allows the muscle to go through the process of depolarisation and repolarisation . This process is called an action potential where the muscle membrane potential is produced when sodium (Na+) influx exceed a certain threshold voltage and will cause a depolarisation process happen.

Figure 2.1 shows the process of depolarisation and repolarisation when there is a movement in muscle membrane.

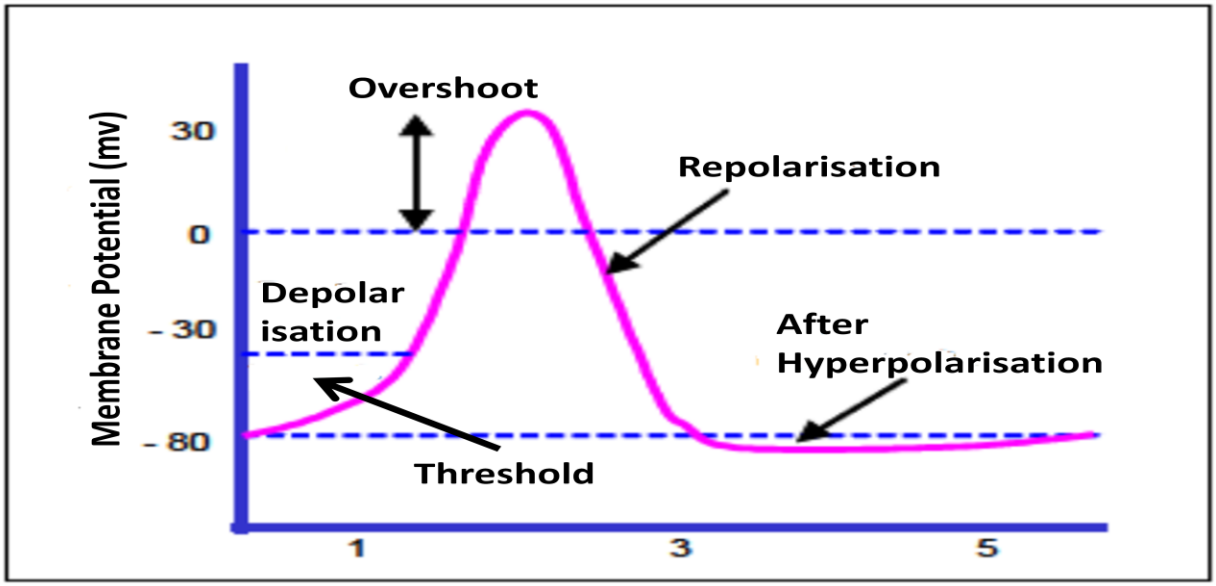

Figure 2.1: The action potential of electromyography (EMG) signal [1].

The raw surface electromyography (sEMG) has several noises that affect the purity of the signal. The noises that are present when obtaining the surface electromyography (sEMG) are tissue characteristic, cross talk, surrounding noise and the internal amplifier noise [1]. The tissue characteristics such as temperature of the skin, physiological changes and thickness of the skin will affect the electrical conductivity, thus affect the surface electromyography (sEMG) signal. Other than that, cross talk will also affect surface electromyography (sEMG) signal by the interferences of the Electrocardiography (ECG). Surrounding noise is another factor that could affect the surface electromyography (sEMG) which the noise in the surroundings will make the signal to be distorted. Therefore, the experiment of the electromyography should be run in the surrounding with less noise condition.

2.2 Electromyography (EMG) History

Electromyography research began when Francesco Redi [3] discovered that muscle could generate electricity in 1666 by documented that electrical ray fish generated electricity by using a specialized muscle. Then Alessandro Volta [4] had created a device which could generate electricity and could be used to stimulate muscle. The next invention that was done by Luigi Galvani has done a research to a frog in 1971 and has shown that electrical stimulation of muscular tissue produces contraction and force. The lack of limited instrumentation has limited Luigi Galvani work and has held his work for 40 years until a galvanometer is developed in early 1800. In year 1838, Carlo Matteucci has proved that bioelectricity can be developed or produced by muscular contraction and in 1842 he has demonstrated that from the frog's muscle, action potential can be produced from it. Guillaume Duchenne [5] has stimulated electrically by contacting it to skeletal muscle and he is the one that initiated that medical electricity could be used for medical purposes.

Guillaume Duchenne also systematically mapped out function of nearly every facial muscle and founded out that the muscles around the eye are only active during genuine smile, meanwhile for a not genuine smile; it will only affect the muscle in the mouth. Willem Einthoven has developed a thin conductor wire that could be used for electromyography in 1903 which has allowed Forbes to be the first person to use floating electrode in a moving body which has allowed them to record electromyography signal of an elephant and Forbes also used Cathode Ray Tube (CRT) to amplify the action potential. Then, the development of concentric needle electrode was developed by Adrian and Bronk in 1929 and has used it for researching motor control and muscle schemes. This has enabled the detection of electromyography signal in individual and small group of muscle fibers and the innovation of concentric needle electrode has been changed to the hypodermic needle with insulated wire in its barrel.

Then, Herbert Jasper [6] has constructed a first electromyography and created a unipolar needle electrode during his research from year 1942-1944. In 1962, John Basmajian has compiled all the information of electromyography and also created a fine-wire electrode which

is more comfortable compared to needle electrode. Lastly, the most important person in the surface electromyography history is Carlo J. De Luca [7] and has written a cited-paper on 'The Use of Surface Electromyography in Biomechanics.

2.3 Time Domain Feature Extraction of EMG Signal

There are three types of features analysis in the electromyography (EMG) signal which are time domain, frequency domain and time, frequency domain or time scale representation [8-9]. The time domain features are normally a fast and simple method to do features extractions of electromyography (EMG) signal. This is because the features are because electromyography (EMG) signal is already in time domain, therefore, the transformation of the signal to another domain is not needed and the calculation of the electromyography (EMG) signal of time domain can be calculated from raw EMG signal time domain [10-12]. However, there is a disadvantage of time domain because of the non-stationary properties of the electromyography (EMG) signal which is not featured in time domain feature extraction which the data is assumed in stationary signal [13]. Variation in the features in the time domain will largely obtained because of usage of surface electromyography (sEMG) in recording the dynamic contraction and the interferences through recording has caused major disadvantages to the features that are extracted from energy property [14]. However, the time domain frequency is mainly used in many fields because of the classification in low noise environment and can just use raw electromyography (EMG) signal to extract the features. The electromyography (EMG) extracted features in time domain is mainly will be used in the force based research application. Kamal Kothiyal [15] has used root mean square (RMS) to compare the influence of experimental setup of experimental condition on muscle strain. Angkoon Phinyomark [16] has found out that mean absolute square (MAV) was an easy way for detection of muscle contraction level and a popular feature used in prosthesis control application. S. Thongpanja [17] has found out that time domain feature were frequently used as a muscle force detection tool and Variance, root mean square (RMS) and mean absolute square (MAV) as the feature extraction for the research.