UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

PILOT STUDY OF ELECTROMYOGRAPHY ANALYSIS OF THE ARM MUSCLE USING LEVENBERG-MARQUARDT BACK PROPAGATION NEURAL NETWORK

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DECLARATION

I declare that this thesis entitled "Pilot Study of Electromyography Analysis of the Arm Muscle using Levenberg-Marquardt on Back Propagation Neural Network" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature	:	………………………………
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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

Signature : ……………………………

Supervisor Name : PROF. MADYA DR. CHONG SHIN HORNG

Date : ……………………………

DEDICATION

I specially dedicated this thesis to my beloved wife, Sofiatul Anis binti Ramlan, my parents and family.

ABSTRACT

The study on the EMG signal is useful in providing the information regarding to the force and motion command that can be used in clinical research, rehabilitation and assistive technology. However, it is difficult for one feature parameter to reflect as a unique feature of the measured EMG signals to the force and motion commands perfectly. Moreover, it is challenging to identify and classify the muscle force that exerted by a muscle and the muscle activities according to a specific movement. This research aims to propose EMG signal pattern recognition that based on back propagation neural network approach to identify the force and motion commands. This research focuses on the upper arm muscle, which is the biceps brachii muscle that leads in the improvement of the system of the prosthetic upper arm. The proposed EMG signal pattern recognition is consisting of data acquisition, data processing, data classification and data testing. The data acquisition phase is designed to acquire EMG signal from the subject. Features extraction for the EMG signal is carried out in the data processing phase. In this phase, statistical features such as maximum amplitude, mean and root mean square are computed for the features extraction purpose. In data classification phase, the three extracted time domain features are used as inputs to train the measured EMG signal via Levenberg-Marquadt backpropagation neural network training function. Then the EMG signal is classified via conjugate gradient backpropagation neural network training function. In data testing phases, three additional subjects are selected to follow the proposed EMG signal pattern recognition phases. In this research, muscle force model is used to determine the value of the force exerted by the biceps muscle. The muscle force model is based on the lever system in human body, which is third class lever. The results from the statistical analysis shows that the changes of the amplitude of the EMG signal are changing correlated to the changes of the muscle force exerted by the biceps muscle depending on the size of the loads. The analysis of pattern recognition for the measured EMG signal shows a good performance of the classification. The EMG signal can be classified based on the tasks of different weight of loads and different angle of the arm motion. The analysis of the muscle force model shows that the value of the muscle force exerted by the biceps muscle is different for all subjects. As the conclusion, it is proved that this research has been successfully accomplished and the relevance of the relationship between the changes in the movement of the hand towards the EMG signal changes and the changes of the force exerted by the biceps muscle has been proved. These findings are useful to be applied on the development of the assistive technology in helping the disabled person. These findings also can lead to improve the system of the assistive technology, especially for the improvement of prosthetic arms.

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ABSTRAK

Kajian ke atas isyarat EMG yang berguna dalam menyediakan maklumat mengenai kepada perintah daya dan gerakan yang boleh digunakan di dalam kajian perubatan, pemulihan dan teknologi bantuan. Walau bagaimanapun, adalah sukar bagi satu ciri parameter untuk mencerminkan sebagai ciri yang unik isyarat EMG diukur dengan daya dan gerakan arahan dengan sempurna. Selain itu, ia adalah sesuatu yang mencabar untuk mengenal pasti dan mengelaskan kuasa otot yang dikenakan oleh otot dan aktiviti otot mengikut pergerakan tertentu. Kajian ini bertujuan untuk mencadangkan EMG pengiktirafan corak isyarat bahawa berdasarkan pembiakan kembali pendekatan rangkaian neural untuk mengenal pasti daya dan gerakan arahan. Kajian ini memberi tumpuan kepada otot lengan atas, yang merupakan otot brachii bisep yang membawa dalam peningkatan sistem atas lengan yang palsu. EMG corak isyarat pengiktirafan yang dicadangkan itu terdiri daripada perolehan data, pemprosesan data, klasifikasi data dan ujian data. Fasa pemerolehan data direka untuk memperoleh isyarat EMG dari subjek. Ciri-ciri pengekstrakan isyarat EMG yang dijalankan dalam fasa pemprosesan data. Dalam fasa ini, ciri-ciri statistik seperti amplitud maksimum, min dan punca min persegi dikira bagi maksud ciri pengekstrakan. Dalam fasa klasifikasi data, tiga diekstrak ciri domain masa digunakan sebagai input untuk melatih isyarat EMG yang diukur melalui Levenberg-Marquadt rambatan balik neural fungsi latihan rangkaian. Kemudian isyarat EMG itu dikelaskan melalui kecerunan konjugat rambatan balik fungsi latihan rangkaian neural. Dalam data ujian fasa, tiga mata pelajaran tambahan yang dipilih untuk mengikuti isyarat EMG yang dicadangkan fasa pengenalan pola. Dalam kajian ini, model tenaga otot digunakan untuk menentukan nilai daya yang dikenakan oleh otot bisep. Model tenaga otot adalah berdasarkan kepada sistem tuil dalam tubuh manusia, yang adalah tuil kelas ketiga. Keputusan daripada analisis statistik menunjukkan bahawa perubahan amplitud isyarat EMG yang berubah dikaitkan dengan perubahan tenaga otot yang dikenakan oleh otot bisep bergantung kepada saiz beban. Analisis pengiktirafan corak isyarat EMG yang diukur menunjukkan prestasi yang baik klasifikasi. Isyarat EMG boleh diklasifikasikan berdasarkan kepada tugas-tugas berat yang berbeza beban dan sudut yang berbeza gerakan lengan. Analisis model tenaga otot menunjukkan bahawa nilai tenaga otot yang dikenakan oleh otot bisep adalah berbeza untuk semua mata pelajaran. Sebagai kesimpulan, ia membuktikan bahawa kajian ini telah berjaya dicapai dan perkaitan hubungan antara perubahan dalam pergerakan tangan ke arah perubahan isyarat EMG dan perubahan daya yang dikenakan oleh otot bisep telah dibuktikan. Penemuan ini adalah berguna untuk digunakan pada pembangunan teknologi bantuan dalam membantu orang yang kurang upaya. Penemuan ini juga boleh membawa kepada memperbaiki sistem teknologi bantuan, terutamanya untuk memperbaiki senjata palsu.

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SYMBOL/ABBREVIATION	DETAILS
EEG	Electroencephalogram
ECG	Electrocardiogram
EOG	Electrooculugram
EMG	Electromyogram
CRT	Cathode ray tube
MUAP	Muscle unit action potential
sEMG	Surface electromyography
SENIAM	Surface electromyography for non-invasive assessment of muscle
RMS	Root mean square
MAV	Mean absolute value
MU	Muscle unit
ANN	Artificial neural network
F_M	Force exerted by the biceps muscle
W_A	Weight of the subject's arm
W_D	Weight of the dumbbell

X_{CG}	Length from the elbow to the center of the subject's arm
X_M	Length from the elbow to the biceps muscle
L	Length of the subject's arm
F_J	Force at the elbow joint
F_P	Force perpendicular to the arm
F_1	Weight of the dumbbell
θ_1	Angle need to bring the force perpendicular to the arm
θ	Angle of the elbow joint

LIST OF PUBLICATIONS

Journals

1. A. B. Yahya, W. M. B. W. Daud, C. S. Horng, and R. Sudirman, 2014. Electromyography Signals on Biceps Muscle in Time Domain Analysis. *Journal of Mechanical Engineering & Sciences,* 7, pp. 1179-1188.

2. W. M. B. W. Daud, A. B. Yahya, C. S. Horng, M. F. Sulaima, and R. Sudirman, 2013. Features Extraction of Electromyography Signals in Time Domain on Biceps Brachii Muscle. *International Journal of Modeling and Optimization*, 3 (6), pp. 515-519.

Conferences

1. A. B. Yahya, W. M. B. W. Daud, and C. S. Horng, 2013. Electromyography Signals on Biceps Brachii Muscle in Time Domain Analysis. *Prosiding Seminar Hasil Penyelidikan Sektor Pengajian Tinggi Ke-3 2013 (ICT, Teknologi dan Kejuruteraan)*, pp. 567-578.

2. W. M. B. W. Daud, A. B. Yahya, C. S. Horng, M. F. Sulaima, and R. Sudirman, 2013. Features Extraction of Electromyography Signals in Time Domain on Biceps Brachii Muscle. *2013 3rd International Conference on Computer and Software Modeling*.

3. A. B. Yahya, W. M. B. W. Daud, C. S. Horng, and R. Sudirman, 2013. Electromyography Signals on Biceps Muscle in Time Domain Analysis. *2013 Malaysian Technical Universities Conference on Engineering & Technology*.

Exhibition

1. A. B. Yahya, W. M. B. W. Daud, C. S. Horng, and M. S. M. Jasni, 2014. Relationship of Motion and Force during Biceps Curl Exercise via Surface Electromyography Analysis. *IEEE EMBS International Student Conference*.

CHAPTER 1

INTRODUCTION

1.1 Project Background

Biosignal refers to the electrical signal that can be measured and recorded from any organ that represents a physical variable of interest. It was extensively studied and applied in various researches and applications of clinical and engineering field. The biosignal is commonly a function of time and it is definable in terms of its amplitude, frequency and phase. There are different types of the biosignal such as electroencephalogram, EEG (signal recorded from the brain); electrocardiogram, ECG (signal recorded from the heartbeat); electrooculugram, EOG (signal recorded from the movement of the eyes); and electromyogram, EMG (signal recorded from the muscle). Study of electromyography has begun for decades, however, it has been in the recent for the past few decades that it has been drawn much interest and passion from the researchers to evolve it due to the present advanced electronic technology.

Based on the current state of the art, researchers are keen on integrating the expertise in biological components with the devices from electronic and mechanical engineering. This can help the disabled to lead a way of life with dignity, peace and long life. There are quite a number of successful products existing in the market, for example camera based vision substitution for blind people, medical robots used in surgical rooms, an exoskeleton for assistive technology and intelligent prosthetic for arm amputees. Since EMG had a great contribution to various kinds of applications, its benefits have become more apparent. EMG also dedicates to the medical research, physiotherapy/rehabilitation, sports science/training, ergonomics and interactions of human body to industrial products and work condition.

This project is also along this line of applications in sensing the EMG signals from the subject's muscle. This project is focusing on studying the pattern of the EMG response through voluntary contraction of the biceps brachii muscle on a motion and force commands. A series of signal processing procedures will be carried out to extract the information from the raw EMG signals. With a proper feature extraction process, the obtained information can be presented and interpreted in a more suitable and proper way. There are several methods of analysis which can be utilized to obtain the information of the signal. Each method applies differently depending on its application.

The role of the EMG signal within biomechanics has been studied and the setup can be measured by four major areas, which are a body part, forces, movement and muscle activation. The body parts will be controlled by bone and segments which have the analysis in term of structure and proportion. Next, the movement of the body parts will be analyzed based on distance, angle, velocity or acceleration. On the other hand, the muscle force will be analyzed in term of linear force, moment of force and torque. Lastly, the muscle activation will be analyzed on the muscle action potential of the muscle. These four major areas can be categorized as kinesiological analysis, which is used as a fundamental reference to start a research on new findings.

1.2 Motivation of Research

The development of assistive technology has been shown such concern and dedication from the researchers had brought the knowledge to a better way. It has been proven that by having technology advancement can lead improvement in EMG signal especially for the improvement of prosthetic arms (Sudarsan, S. et al., 2012). The information extracted from EMG signals, is represented in a feature vector, chosen to minimize the control error. The extraction of accurate features from the EMG signals is the important kernel of classification systems and is essential to the motion command identification. Therefore, a method for classification and suitable pattern classifier approach will be improved to determine the class output.

1.3 Problem Statement

Collaboration of the researchers from various fields of study such as biological, clinical and engineering, will give advantages to the development of technology approaches that can help the disable person. The study on the EMG signal is useful in providing the information regarding to the muscle force (force command) and muscle activities (motion command) that can be used in clinical research, rehabilitation and assistive technology (Sudarsan S. & Sekaran E. C. 2012). However, there is difficulty on the experimental works references for the study of the EMG signal with the force and motion commands. Furthermore, it is difficult for one feature parameter to reflect as a unique feature of the measured EMG signals to the force and motion commands perfectly. Moreover, it is challenging to identify and classify the muscle force that exerted by a muscle and the muscle activities according to a specific movement. In response to these situations, the author had proposed the use of surface electromyography experimental procedures for the experimental works; while the time domain features for the feature extraction parameters. Furthermore, a back propagation neural networks is use for the data classification to solve the force and motion commands issues with EMG signals.

1.4 Objectives of Research

There are three main objectives are designed:

1. To investigate an electromyography signal (EMG) pattern recognition based on a back propagation neural network for an arm motion (angle) and muscle force commands.
2. To realize an artificial neural network to classify the motion and force commands identification problem.
3. To analyze the proposed EMG signal pattern recognition, which are including data collection, data processing, features extraction and data classification; in experimental work.

1.5 Scope of Research

This scope of research will be a guideline towards achieving the objectives of the research. The muscle that interested in this research is biceps brachii muscle. The elbow flexion will be emphasized in which the activities concerning to the biceps curl exercise will be carried out. The angles for the biceps curl exercise are 45°, 90° and 120° according to the elbow joint. The exercises in the experimental procedures are involving the subject need to lifting, holding and releasing a dumbbell load of 2kg, 4kg and 6kg. The surface EMG sensor is used in this research. The EMG signal feature extraction in this research is applied in time domain. There are three statistical features of time domain for the EMG signal feature extraction, which are maximum amplitude, root mean square and mean. In the fitting tool, the feed forward back propagation neural network with Levenberg-Marquardt training functions is used for EMG signal data training in the neural network. While in the pattern recognition tool, conjugate gradient algorithm is used for EMG signal pattern recognition and classification.

1.6 Contribution of Research

This research will bring benefits especially on development of an assistive technology, which is the prosthetic arm. The research is believed to improve the understandings in fundamental of EMG signals pattern recognition for an arm motion (angle) and muscle force commands. The previous studies were focusing only on the EMG signal with muscle force and the EMG signal with arm movement separately on data collection phase (experiment). However this project is a combination work of EMG signal measurement for muscle force and arm movement simultaneously in experiment. Hence, the relationship of the EMG signal of muscle force and arm movement could be determined and analyzed efficiently. Several experiments were designed (based on the targeted subject) to collect necessary data (results) that related to the objectives of project. In this project, time domain features were used in the features extraction because it is mostly used in force and angle based application researches. The time domain features are used as simple features for better understanding on the characteristics of the EMG signals towards the changes of arm motion (angle) and force (load). Furthermore, Levenberg-Marquardt neural network algorithm was used in this project on the EMG signals classification for muscle force and arm movement. Levenberg-Marquardt is often the fastest back propagation neural network algorithm for training moderate-sized feed forward neural networks (up to several hundred weights) and it is highly recommended as the first-choice supervised algorithm.

1.7 Organization of Thesis

This thesis is composed of five chapters, including the present one. Chapter 1 presents the introduction of the research. It consists of the research background and its motivation. Besides, the problem statement and objectives of the research are described to illustrate the research's goal. The limitations in the research are stated in the scope of the research. Moreover, this chapter also consists of the contribution of the research and the organization of thesis.

Chapter 2 presents an overview of all the topics addressed in this research. First, it explains the introduction of the electromyography (EMG) signal. The explanation involves the theory of the EMG, the measurement techniques that used for the EMG, the procedures that need to obey when dealing with the EMG, the methods used for the feature extraction of the EMG signal, the relationship between the EMG signal with motion and force exerted by the muscle and the methods of neural network that's been used for the EMG signal pattern recognition for a motion and force commands.

Chapter 3 presents the proposed methodology and algorithms that used in this project. First, it explains the pre-experiment and experimental procedures that have been through with this project. Next it explains the signal processing procedures that been done to the surface EMG signal. The parameters that used to study the relationship between the surface EMG signals with motion during the biceps curl exercise and force exerted by the biceps muscle is explained in this chapter. Finally the pattern recognition method is explained to classify the surface EMG signal with motion and force.

Chapter 4 presents the results and discussion. It describes how the acquisition of the surface EMG signal is made and the conditions of the signal during the biceps curl exercise. It discusses about the characteristics of the recorded surface EMG signal. The relationship between the recorded surface EMG signal with the calculated force exerted by the biceps muscle and the motion of the upper arm during the biceps curl exercise is discussed. Finally, the surface EMG signal pattern recognition based on the Levenberg-Marquardt back propagation neural network of a motion and force commands is described explicitly.

Chapter 5 presents the research summary, research objectives achievement, significant of the research and the recommendation of future works.