Faculty of Electrical Engineering

SURFACE ELECTROMYOGRAPHY (SEMG) NORMALIZATION METHOD BASED ON PRE FATIGUE MAXIMAL VOLUNTARY CONTRACTION

Muhammad Ihsan bin Mohd Sabri

Master of Science in Electrical Engineering

2017

SURFACE ELECTROMYOGRAPHY (SEMG) NORMALIZATION METHOD BASED ON PRE FATIGUE MAXIMAL VOLUNTARY CONTRACTION

MUHAMMAD IHSAN BIN MOHD SABRI

A thesis submitted
in fulfilment of the requirements for the degree of Master of Science in Electrical Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this entitled “Surface Electromyography (SEMG) Normalization Method Based on Pre Fatigue Maximal Voluntary Contraction ” 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 :..

Name :..

Date :..

APPROVAL

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

Signature :...

Supervisor Name :...

Date :...

DEDICATION

To my beloved mother and father

ABSTRACT

Surface electromyography (sEMG) pattern recognition task requires high accuracy classification. However, current technology suffers from two main problems. The first problem is inconsistent pattern due to fatigue while the second is robustness of sEMG features due to low signal to noise ratio, SNR. This research intends to address both sEMG problems mentioned by proposing a normalization method named as pre fatigue maximal voluntary contraction (PFMVC) and a feature known as Maximal Amplitude Spectrum (MaxPS). The both method used to carry the objectives, the first is to analyse a normalization method based on pre fatigue maximal voluntary contraction (PFMVC) and the second objective is to design and verify a new features known as Maximal Amplitude Spectrum (MaxPS). It is found that the proposed method improves sEMG pattern recognition accuracy by 98.48% when compare to 97%. The performance of PFMVC normalization method is measured by mean variance of boxplot across several subject which is reduce inconsistency from $3.41x10^{-3}$ to $1.73x10^{-3}$, p-value of one way analysis of variance (One- Way ANOVA) is reduce from p=0.25 to p=0.035 and variance of mean intra class correlation co-efficient, (ICC) is reduce from $26x10^{-4}$ to $7.089x10^{-4}$. The precision and robust of MaxPS features is determine by lowest Error to mean percentage (%ETM) which is 0.213 , lowest in Euclidean distance,(Ed) which is 0.0034 and lowest hoteling t^2 which is 0.27. From the results, it shows that the MaxPS is a robust and precise feature for force and fatigue indicator. This will give the benefit for force and fatigue mapping application.

ABSTRAK

Surface Electromyography (sEMG) tugas pengiktirafan corak memerlukan klasifikasi ketepatan yang tinggi. Walau bagaimanapun, teknologi semasa mengalami dua masalah utama. Masalah pertama adalah corak konsisten akibat keletihan manakala masalah kedua ialah sifat 'robust' sEMG kerana isyarat ini lebih rendah frekuansinya kepada nisbah bunyi, SNR. Kajian ini adalah bertujuan untuk menangani kedua-dua masalah sEMG disebut dengan mencadangkan kaedah normalisasi dinamakan sebagai pra keletihan maksimum penguncupan sukarela (PFMVC) dan ciri-ciri adaptasi yang dikenali sebagai Maximal Amplitud Spectrum (MaxPS). Kedua-dua kaedah yang digunakan untuk menjalankan objektif, yang pertama adalah untuk mereka menganalisa kaedah normalisasi berdasarkan keletihan pra penguncupan maksimum sukarela (PFMVC) dan objektif kedua adalah untuk mereka bentuk dan mengesahkan ciri-ciri baru yang dikenali sebagai Maximal Amplitud Spectrum (MaxPS). Ia didapati bahawa kaedah yang dicadangkan meningkatkan sEMG ketepatan pengiktirafan corak dengan 98,48% apabila dibandingkan dengan 97%. Prestasi kaedah normalisasi PFMVC diukur dengan varians min boxplot di beberapa subjek yang mengurangkan percanggahan dari 3.41x10-3 untuk 1.73x10-3, p-nilai satu analisis varian sehala (satu Way ANOVA) adalah mengurangkan dari p = 0.25 untuk p = 0.035 dan varians bagi min korelasi kelas intra bersama cekap, (ICC) adalah mengurangkan dari 26x10-4 untuk 7.089x10-4. Ketepatan dan mantap MaxPS ciri adalah ditentukan oleh Ralat rendah bermaksud peratusan (% ETM) iaitu 0,213, paling rendah dalam jarak Euclidean, (Ed) iaitu 0.0034 dan terendah t2 perhotelan yang 0.27. Daripada keputusan, ia menunjukkan bahawa MaxPS adalah ciri yang mantap dan tepat untuk tenaga dan penunjuk keletihan. Hal ini dilihat dapat memberi manfaat kepada aplikasi pemetaan yang menggunakan daya dan keletihan sebagai subjek.

ACKNOWLEDGEMENT

First of all, Alhamdulillah thanks to Allah Almighty because of His blessing I would able to finish out my research. During in the making of this research I have gain a lot of new knowledge in a practical. Next, I would like to address my gratitude and appreciation to my supervisor and co supervisor, Dr. Muhammad Fahmi bin Miskon and Encik Rusdy bin Yaacob for his supports, trust, supervision, encouragement and advices throughout this research.

I would like to give appreciation to Ministry of Higher Education (MOHE) and Universiti teknikal Malaysia Melaka (UTeM) especially bursury division, registrar office for financial supports. I also want to thanks my late father, Mohd Sabri bin Ismail and my beloved mother, Zamilah bte Omar for their endless support, spirit, motivation and advices for continue my studies. Behind that entire process they also have contribute financially.

Next, I would like to thank my siblings and all my family for their help and support. A deepest appreciation for their unconditionally love and support. My acknowledgement would not complete without my friends from Ceria Lab who had give me support and cooperation in completing this thesis. Finally, my sincere appreciation also goes to those who directly and indirectly in helping all the way through this research. Thank you to all the parties above, without their helps I can never go through this mission alone. Thank you very much.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PUBLICATIONS

JOURNAL

1. **M I Sabri**, M F Miskon & M R Yaacob. 2013. "Robust features of surface electromyography". IOP Conference Series: Materials Science and Engineering, Volume 53,conference 1 (**Index: Scopus**)
2. **M I Sabri,** M.F Miskon, M.R Yaacob, Abd Samad Hasan Basri, Yewguan Soo, W.M Bukhari. 2014. "MVC based normalization to improve the consistency of EMG signal". Journal of Theoritical and Applied Information Technology, Vol. 65, July 2014, issue 2 (**Index: Scopus**)
3. **M I Sabri,** M.F Miskon, M.R Yaacob & Abd Samad Hasan Basri. 2014. "The Study of Principle Component Surface Electromyography Signal on Biceps Brachii Muscles". ROMA 2014 IEEE International Symposium on Robotics and Manufacturing Automation

CHAPTER 1

INTRODUCTION

1.1 Research Background

Electromyography can be defined as an experimental technique concerned with development, recording and analysis of myoelectric signal. Myoelectric or electromyo signal (EMG) is referred to biosignal acquired from contraction and extension of muscle's electric activities (K.Najarian & R. Splinter, 2012). In other words, surface myoelectric that acquired from contraction and extension of muscle's electric activities was named as surface electromyo signal (sEMG). The past thirty years have witnessed rapid advances in the field of assistive robotics technology as alternative ways to blend sensing, movement, and information-processing capabilities. Recently, assertive robot uses sEMG pattern recognition as a way to extract human intent for controlling a robotic arm. It is proved that by using sEMG pattern recognition the control strategy is more nature and has the ability to mimic human activity (Angkoon et. al, 2013). The aim of this system is to improve the accuracy of sEMG pattern recognition. Many researchers reported of having difficulties in getting high accuracy in sEMG pattern recognition (Xinpu Chen et al., 2010). Moreover, the reason why they having difficulties solving this problem is surface electromyography known as a non stationary signal and have dynamic characteristic (Adewuyi et al., 2015). This is the main reason why accuracy of sEMG feature recognition still debateable.

Figure 1.1 shows the feature recognition block diagram. Refer to the block diagram, signal normalization is one of the method used in sEMG feature recognition. This makes the normalization method more challenging. Another important aspect of sEMG pattern recognition is features extraction method. During the implementation of this method, a valuable information is extracted from the sEMG signal. Any error or disturbance happens in either method will influence the accuracy of sEMG feature recognition.

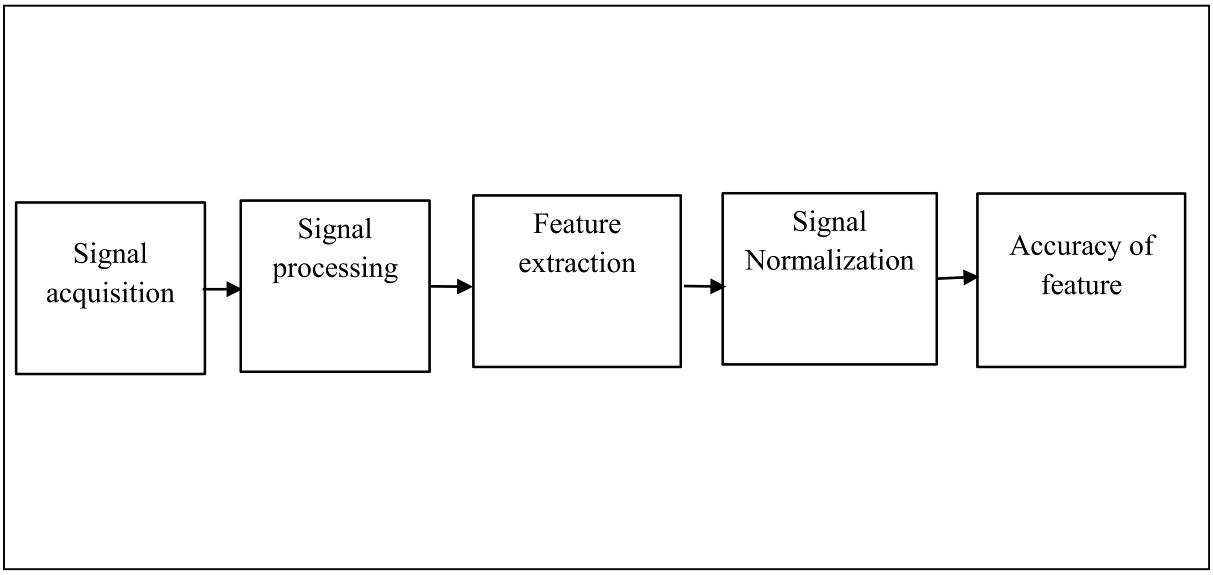

Figure 1.1 : Block diagram of surface electromyography (sEMG) feature recognition.

Generally, two processes are the most crucial process which are feature extraction and signal normalization. The normalization method is important to generalize all EMG data that are acquired from inter and intra samples. Next, the feature extraction method gives first manifestation about information contains in it. It also plays an important role to choose which feature is dominant among all extracted features and determine which feature is the most robust.

1.2 Problem statements

This project addresses two main problems in sEMG feature recognition.

The first problem is sEMG features are highly inconsistent due to fatigue and hence will affect the accuracy of sEMG feature. Inconsistency occurs across different time, different subject and different environment. For this reason, normalization procedure is important in order to solve the inconsistency problem. The hypothesis of this research is the inconsistency of sEMG signal can be reduced by normalize sEMG signal based on pre fatigue maximal voluntary contraction (PFMVC). PFMVC is a condition where a maximal voluntary contraction take into account before muscle start fatigue. The recovery time of muscle is considered in implementation of PFMVC normalization method.

The second problem is sEMG features are sensitive to changes in environment especially changes due to noise. In other word, the sEMG features are not robust. According to Angkoon *et al*.,2012 ,most of features in time domain and frequency domain are not robust. However, the robust features among existing sEMG features are still debatable. On the top of knowledge, each of sEMG activities in time has their own dominant frequency. The maximum of the amplitude spectrum (MaxPS) shows a consistent value at the same strength applied across the different sample and also give the significant frequency value during the activity. It is hypothesized that, if the maximum amplitude spectrum contain in sEMG signal remains and give a consistent value, it has a great potential to be a robust feature.

By solving this two problem, the main aim in sEMG feature recognition which is to get a highest accuracy of sEMG feature recognition will be achieved.

1.3 Objectives of the research

There are three objectives highlighted in this thesis:

1. To analyse a normalization method based on percentage of pre fatigue maximal voluntary contraction (%PFMVC) as to reduce the inconsistency of sEMG signals.
2. To develop and verify a new feature named as Maximal Amplitude Spectrum (MaxPS) which is robust to noise.
3. To verify the accuracy of sEMG feature recognition for mapping application.

1.4 Scope of works and limitation

In this project sEMG data were collected using a bipolar electrode. The experiment was done by controlling the environment of the laboratory. Subjects of the experiment are between 19 years to 31 years old with randomly volunteer and did not have any accident history of their dominant hand. Experiments only focused on biceps brachii muscle on the dominant hand. The lifting task was designed based on isotonic/dynamic contraction of muscle. Only one joint movement which is elbow flexor and extensor locomotion is considered. The works only focus on accuracy of the feature.

1.5 Significants of research

This research will bring many benefits especially on pattern recognition system. The pattern recognition system is depend on feature. The normalization of feature needed in order to have the more consistent feature value. It is believes that by reduce inconsistency of sEMG feature, it will increase the accuracy of sEMG feature. In addition, the robustness to noise of sEMG feature need to be consider in development of new feature. For the result, the system that developed will be same exactly as the human movement.

1.6 List of contributions

This research contributes on designed a method of normalization sEMG signal and developed a robust feature of sEMG signal. This is how this can increase the accuracy of sEMG feature. The contribution of this thesis is stated as follows:

1. A normalization method for inter different sample data and intra individual data is presented because the inconsistency data will lead to low accuracy performance in sEMG to load pattern.
2. A new feature which is Maximal Amplitude Spectrum (MaxPS) that is robust to noise is demonstrated .
3. The improvement of the accuracy of sEMG feature recognition is presented in order to verify the result.

1.7 Thesis outline

The rest of the thesis is organized as follows.

Chapter 2 presents a literature review about sEMG theory, sEMG issues and related works in the pattern recognition of sEMG including all the methods that exist in solving the problem in EMG signal. Also, the knowledge gap that exists in this research field is defined.

Chapter 3 presents the proposed method and the research methodology in acquiring data and test the hypothesis. In addition, this chapter also highlights about the theoretical of PFMVC normalization method and MaxPS feature.

Detail discussions on the experimental results are described in Chapter 4. All results are discussed in detail, including the inconsistency of sEMG data due to fatigue and a statistical result of boxplot analysis,one way Analysis of Variance (ANOVA), intra class coefficient analysis (ICC), error to mean percentage (ETM) analysis, Euclidean distance analysis, Hoteling t^2 analysis and accuracy analysis.

Last but not least, the research findings are concluded in Chapter 5 together with recommendation of future works. This chapter can be a measurement tool to indicate that the objective has been achieved or not. The future recommendation that is proposed in this chapter could lead to futher sEMG research investigations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, EMG system overview will be discussed starting with the description on the theoretical background of EMG consists of muscle physiology, surface electromyography (sEMG), factor influencing the sEMG signal and type of muscle contraction. Then, the reviews on the inconsistency as newly considered problem of sEMG are presented. This chapter discusses some constraints about achieving high accuracy in pattern recognition of sEMG that cause by inconsistency problem. Then, the reviews on the feature of sEMG are presented. The feature of sEMG is not robust. So, it will contribute in lowing the accuracy feature of sEMG. The needs of a robust feature is highlighted as a support objective in this works. At the end of this chapter, the available gap of knowledge in feature recognition of sEMG is summarized and presented.

2.2 Theoritical background of Electro Myo Gram (EMG)

Elecro Myo Gram (EMG) is one of the biosignals that is acquired during muscle activity such as muscle flexor or muscle extensor (Ball & Scurr, 2010). The technique used to visualize and to analyse Electro Myo Gram signal is known as electromyography. The key to understand EMG signal is by understanding the muscular anatomy and the way the muscle generates bioelectric signals.

2.2.1 Muscle physiology - the basics

There are three main types of muscles in the human body: skeletal muscle, smooth muscle and cardiac muscle tissues. This thesis concentrates on the skeletal muscle and the skeleton motor system which control human force and movement. The motor activity takes place in the cortex, where the nerve signals converge and excite (or inhibit) various neurons. The output from the cortex influences the spinal cord, where links that exit to the motor neurons providing direct control of muscle activity in the muscle fiber (Hall, 2003).

A motor unit action potential (MUAP) is the term given to detect a waveform resulting from the propagation of the depolarizing and depolarizing wave along all muscle fibers associated with given MU. The shape and amplitude of the MUAP are not only a function of the MU (size, spatial distribution of the fibers, and propagation velocity) but also a function of the electrode type (contract area, material, inter wire spacing) and the electrode location (distance from the MU and conductivity of innerving tissue). All the factors, have to be taken into account when observing the sEMG signal. A myoelectric signal is the name given to the total signal, came from all the active Motor Units (MU) , detected at an electrode or the difference between electrodes based on electrode configuration (Kumar and Mital,1996).

2.2.2 Surface electromyography (sEMG)

Surface electromyo signal (sEMG) is a surface biosignal acquired from contraction and extension of muscle's electric activities. In the study of electromyography, two methods are used to acquire the EMG signal. The first method is by using an invasive technique (wire-needle) and another one is by using a non-invasive (surface electromygraphy). The invasive technique is normally used on minor muscle that is small size and deep under the skin such as intramuscular muscle, which is commonly used in clinical trials. The non-invasive (surface electromyography, sEMG) technique is commonly used for the surface muscle that can see the changes in shape for examples biceps brachii and triceps brachii muscle. In this research non-invasive technique was used in order to acquire the myoelectric signal from the biceps brachii muscle. Basically, the sEMG technique provides "general information" about the muscle that relate to the muscle activity. It reflects both numbers of active MUs and the firing rate of MUs. Typical sEMG amplitude of voltage during measurement is between a microvolt (μV) and a millivolt (mV) depends on the quality of the myoelectric signal. The absolute magnitude of these registrations allows determination of the force of contraction which permits a comparison between different tasks, stress, force etc. (Sandsjö, 2004).