EVALUATION OF ANN AND CNN IN GESTURE CLASSIFICATION FOR MYOELECTRIC PROSTHESIS HAND

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Specially dedicated to

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ABSTRACT

The numbers of limb amputees are increasing yearly due to the wars, trauma or illness and they are suffering from different types of pain and reduced health-related quality of life. The existing prosthetic allows an amputee to partially restore the ability and function of the lost limb. However the prosthetic available in the market mostly concentrated on the cosmetic purpose and robotic prosthesis hand are too expensive to be afforded by most amputees. To restore the hand ability, myoelectric signal played a significant role in pattern recognition for gesture classification. In this project, in-depth study in various feature extraction and the classifier include ANN and CNN is conducted to get the high accuracy of gesture classification. By integrating the surface electromyography sensors, the myoelectric signal can be recording from the remaining limb. A pattern recognition algorithm will be developed to identify the motion desired by the amputee and control the actuators accordingly. Finally with the convolutional neural network, it is expected that this project will able to deliver a high accuracy of gesture classification.

ABSTRAK

Bilangan orang yang mengalami amputasi anggota badan semakin meningkat dari tahun ke tahun. Ini disebabkan oleh berlakunya peperangan, trauma atau penyakit. Mereka yang mengalami amputasi anggota badan menghadapi kesukaran untuk menjalani aktiviti kehidupan harian dan kualiti kehidupan yang berkaitan dengan kesihatan amatlah rendah. Tangan prostesis yang sedia ada membolehkan amputee memulihkan sebahagian keupayaan dan fungsi anggota badan yang hilang, namun tangan palsu yang terdapat di pasaran kebanyakannya tertumpu kepada tujuan kosmetik dan tangan prostesis robot terlalu mahal untuk dibelikan oleh meraka yang memerlukannya. Dalam usaha untuk memulihkan keupayaan tangan yang hilang, isyarat myoelectric memainkan peranan yang amat penting dalam pengecaman pola untuk klasifikasi pergerakan tangan. Dalam projek ini, kajian yang mendalam tentang pelbagai pengekstrakan ciri dan pengelas termasuk ANN dan CNN telah dijalankan untuk mendapatkan ketepatan yang tinggi bagi mengklasifikasi pergerakan tangan. Dengan menyatupadukan sensor sEMG, isyarat myoelectric dapat dirakam dari anggota badan yang tinggal. Algoritma pengecaman pola akan direka untuk mengenal pasti gerakan yang dikehendaki oleh amputee dan mengawal penggerak sewajarnya. Akhirnya dengan adanya rangkaian neural konvolusi, projek ini akan dapat memberikan ketepatan yang tinggi klasifikasi isyarat.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
CNN	Convolutional Neural Network
EMG	Electromyography
Hz	Hertz
mV	Millivolt
m/sec	Meters Per Second
RMS	Root Mean Square
ROC	Receiver Operating Characteristic
sEMG	Surface Electromyography

CHAPTER I

INTRODUCTION

This chapter will explain the background of the project. The problem statement and the objective of this project discuss in this chapter. The scope and structure of the report also included in this section.

1.1 Project Background

Due to the wars, trauma or illnesses, the number of limb amputees is increasing yearly. As the activity of daily living (ADL) rely heavily on both of the hand, limb amputees are suffering from many kinds of pain and low quality of health-related life. These days, the most first artificial hands still equipped by the amputees and it mainly just for cosmetic purposes or having a just simple grasping mechanism which having the basic limited functions.

Recently, the amputees can partially restore the ability and function of the lost arm with the advancement in the robotic prosthetic. At the first glance, the human's hand and its functionality seem to be simple. However, a deeper review shows that human’s hand likely to be an exceedingly complicated mechanism, which built in capability for a uncountable number of functions. Most of the amputees cannot afford the robotic prosthesis hand which having such complexities as it just too expensive. Furthermore, the weight of the prosthetic hand is increase and more complicated control system is needed.

Electromyography (EMG) signal usually been use to control the most of these prosthesis hands in the market. The electrodes were used to capture the electromyography signal by attaching on the amputees' remaining limb, and analysis of the signal can be done for the motion classification. As the EMG signal is complicated and non-stationary in nature, hence feature extraction of EMG signals is essential for a classification system to identify the motion command of the prosthetic.

In this project, an EMG sensor array will be used to record the signal in various hand motions. The raw signal will be processed using Matlab where the feature extraction and pattern recognition algorithms will be implemented. These processes will rely on the Neural Network Toolbox and Deep Learning toolbox from Matlab.

1.2 Problem Statement

There are many limitations for upper limb amputees to carry out the daily activities. Prosthesis hand is needed to restore the most of the hands original functionality and appearance. However, without a proper algorithm, the amputees face difficulty to control it and have an insufficient level of dexterity for daily-life tasks. Therefore, signal processing and pattern recognition are necessary to increase the acceptance of the active prosthesis hand by extracting the relevant information from the myoelectric signal and classifying the hand movement.

1.3 Objective

The objective of this project is to analyze the EMG signal captured by the sensor using feature extraction hence to recognize the finger motion.

1.4 Scope

This project included two parts which are signal acquisition and signal analysis. For signal acquisition, eight channels Myo armband was used as the hardware, while Data Capture Window for Myo Market has used as software for captured the raw EMG signal.

For data analysis part, Matlab was used. Feature extraction can be done by using Matlab, and artificial neural network toolbox was used as a classifier. Open, close hand and pointing index finger were the motions that been analyzed.

1.5 Report structure

This report separated into five chapters which stated as below:

- Chapter 1 - Introduction. This chapter covers the overview of the project such as project background, problem statement, objective and scope.
- Chapter 2 - Literature Review. This chapter will discuss the past studies related to the project. Background theory will include in this chapter.
- Chapter 3 - Methodology. All relevant experiments and techniques used in the project will be discussed in Chapter 3. The details of the flowchart for the system design will be explained in this chapter.
- Chapter 4 - Results and Discussion. The result of the project from the experiments will be recorded and interpreted in Chapter 4. This chapter also will analyze and discuss the data which get through the experiment.
- Chapter 5 - Conclusion and Recommendation. This chapter will make a conclusion from the project and recommendation for the future plan which related to the project.

CHAPTER II

LITERATURE REVIEW

This chapter presents the literature survey from the related journals and papers on the theoretical background. The former research that has done or similar to the project's title will be discussed.

2.1 Electromyography (EMG)

Electromyography (EMG) is a technique for evaluating and recording the activation signal of muscles. Electromyograph, an instrument used to perform electromyography, which produces a record named electromyogram. Electromyography undergoes electrical potential detection which generated by muscle cells during contraction and relaxation.

Bioelectrical signals, represented the different electrochemical activities performs within the human body. The bioelectrical signals are the amount of electric currents that generated by the summation of the electrical potential differences across a specified tissue. Electromyography signal considers as one of the great bioelectric signals, and it can be detected over the skin surface or by set in sensors into deeper muscle layers and interacted directly to the electrical activity yields by the contraction and relaxation of muscle fiber [1]. The impulse generated by motion intention is sent from the brain to a muscle fiber via motor neuron in the spinal cord.

When the impulse reaches to the muscle fiber, electrical activity occurs, and then the muscle is contracted. The muscles contraction is a result of the electrical stimulation transferred from the nerve to individual muscle fibers.

Each muscle's movement refers to a particular pattern of activation of various muscle fibers and it can be identified by using multi-channels of EMG signals. The muscle membrane potential is the electrical source which about -70mV and the velocity of conduction for the muscle fiber is about 2 to 6 m/sec. The myoelectric signal measured from the surface having an amplitude of the range from 0 to 10mV and the frequency spread between 0 Hz to 10 kHz, but total energies signal are intense within the range from 30 Hz to 500 Hz. The median frequency is changed from 86 Hz to 112 Hz when included with the white noise [2].

2.1.1 History of EMG

The very beginning of the documented experiment related to EMG was in 1666. Francesco Redi discovered that the electric ray fish are having highly specialized muscle which generated electricity. Walsh demonstrates a spark of electric which produced by the eel fish's muscle tissue in 1773. By 1792, Luigi Galvani demonstrates that muscle contraction can be initiated by the electricity. Six decades later, which by 1849, Emil du Bios-Reymond find out that the electrical activity of voluntary muscle contraction can be recorded. However, the first real recording of the electrical activity was done by Marey, who are the one introduced the term electromyography in 1890.

In 1922, the electrical signal from the muscle was shown by using an oscilloscope and this done by Gasser and Erlanger. There is limited information can be retrieved from the observation due to the stochastic nature of the myoelectric signal. The ability to detect electromyography signals enhanced gradually from the 1930s over the 1950s.

The commercially available EMG system was first introduced in 1950. During the time from 1950 to 1973, it was the analog EMG systems era in which EMG signals were captured, and following analyses were executed manually on the film or paper. Starting from 1973, the first modular digital EMG systems with dedicated analysis modules were introduced, but the complete review still needed to be done on paper. By 1982, the first system that controlled by microprocessor was introduced. Several new ways of studying EMG signals and basic reporting structures were applied in the EMG systems. Started from 1993, personal computer technology such as standard hardware and software components has been implemented in EMG systems to record, evaluate, and document EMG examinations.

Within the last three decades, Erik Stalberg always been in the pole position and has made known the ways of applying novel methods for analyzing nerve signals or EMG activity. The growth of new profitable EMG systems has been reliant on the technology introduced to the market within the particular period [3].

2.1.2 Application of EMG

The EMG covers a broad range of clinical applications. The range of EMG application included gait and vibration analysis, through posture and falls prevention, to biofeedback in the treatment of neurologic swallowing impairment. In the sports area, the EMG application covers on back care, sports and performance medicine, gynecology or urology and orofacial function [4].

In the application of rehabilitation of hand ability, as the complex nature of the EMG signals, especially related to the specific movement, it considers a tough job for the inclusive analysis of feature extraction and its' corresponding classification. To retrieve the specific feature for every movement, various pattern recognition study which included of feature extraction and classification been employed on the raw EMG signals. This notion has been implementing for the growth of myoelectric prosthesis control systems gained by feature analysis with pattern classification of EMG signals [2].

2.2 Myo Armband

The Myo armband consists of eight sensors. Each EMG signal collected from the armband consists of 8 channels which are stored in an array. Five different types of data collectible from the armband which are:

- Accelerometer
- EMG
- Gyroscope
- Orientation
- Orientation Euler Angles[as opposed to Quaternions]

The collected data expose into .csv files. The EMG data comes in at 200Hz, while another data is with the frequency of 500Hz. Every sensor plate of the Myo Armband contains of 2 electrical sensors that are the Medical Grade Stainless Steel EMG sensor and high sensitive 9-axis IMU including 3-axis gyroscope, 3-axis accelerometer, and 3-axis magnetometer. The overview of the Myo armband is shown in Figure 2.1.

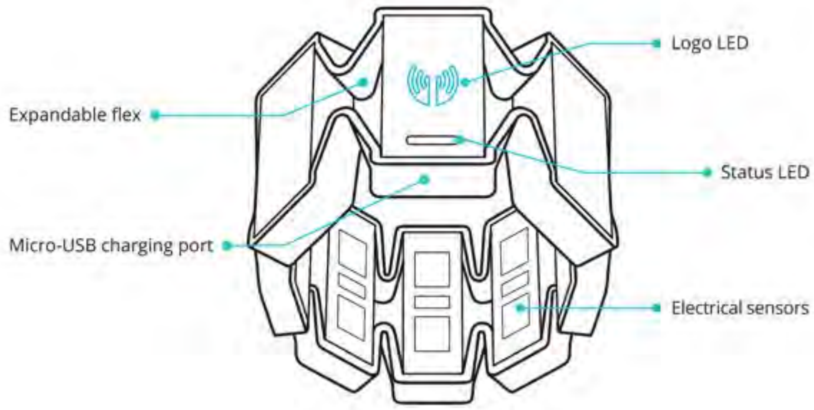

Figure 2.1 Overview of Myo Armband [5]

The Myo armband uses Bluetooth 4.0 LE interface to establish a connection with another device such as personal computer, smartphone and other embedded system having the Bluetooth radio that supports Bluetooth 4.0 LE. The Myo armband has three different haptic feedbacks that are short, medium and long vibrations to communicate with the user [5].

2.3 Prosthesis Hand

In medical field, the prosthesis is the artificial device which uses to replace a missing body part. The body part may lose through trauma, war or disease. Hence the prosthesis hand is for amputees who had lost their hand or the upper limb. Partial hand amputation can consist of different level of transverse and longitudinal loss which dictates, unlike treatment options. The amputee has five basic prosthetic options[6]:

- No prosthetic intervention
- Passive prosthesis
- Body-powered prosthesis
- Externally powered prosthesis
- Multiple tasks specific prostheses

Usually, EMG is used for the regulation of actuated prosthesis which is the electrical activity based on the activated muscles, measured from the surface electrodes. Two types of interfaces commonly used between the amputee and the prosthesis were observed including invasive and non-invasive. The former gather control signals directly from the users' nervous system, either via brain implants or surgical use of electrodes which delivers a high signal quality, since the signals can be gathered exactly from the right areas; but they involve surgery and all related psychological issues. On the other hand, non-invasive interfaces are easier to handle and maintain, but require a much better signal conditioning, since they usually work with surface signals and observation tracking where the muscle activation potentials are gathered by electrodes placed on the patient's forearm skin. These potentials can be used to track which muscles the patient is willing to activate, and with what force. Surface EMG is, therefore, in principle, a cheap and easy way of detecting what the patient wants the prosthesis to do [7].