Biceps Brachii Surface EMG Classification Using Neural Networks

by

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# Contents

Acknowledgments iii  
Contents iv  
List of Tables viii  
List of Figures ix  
List of Abbreviations xii  
Abstrak (Bahasa Malaysia) xvi  
Abstract xvii  

## 1 Introduction  

1.1 Overview .................................................. 1  
1.2 Scope .................................................... 3  
1.3 Motivation ............................................... 4  
1.4 Problem Statements ..................................... 5  
1.5 Objectives ............................................... 6  
1.6 Research Methodology ................................... 6  
1.7 Expected Research Output .............................. 9  
1.8 Thesis Outline .......................................... 9
2 Literature Review

2.1 Introduction .................................................. 11

2.2 Human Muscular System .................................. 11
   2.2.1 Type of Muscle ..................................... 12
   2.2.2 Muscle Structure .................................... 13
   2.2.3 Mechanism of Muscle Contraction ................. 14

2.3 Electromyography .......................................... 17
   2.3.1 Surface EMG (SEMG) ............................... 18
   2.3.2 Intramuscular EMG (IEMG) ........................ 19

2.4 EMG Signal Processing Techniques ...................... 20
   2.4.1 Rectification ....................................... 20
   2.4.2 Integration ......................................... 21
   2.4.3 Average Rectified Signals ......................... 22
   2.4.4 Root Mean Square .................................. 23
   2.4.5 Frequency Spectrum ................................ 23
   2.4.6 Wavelet Transform ................................ 25
   2.4.7 Wigner-Ville Distribution ......................... 25

2.5 EMG Signal Classification Methods ..................... 26
   2.5.1 Fuzzy Logic ...................................... 26
   2.5.2 Hidden Markov Model ............................. 28
   2.5.3 Support Vector Machine ......................... 30
   2.5.4 Artificial Neural Network ....................... 31

2.6 Existing Applications of EMG ............................. 32
   2.6.1 Diagnosis of Neuromuscular Disorders .......... 33
   2.6.2 Intelligent Myoelectric Prostheses .............. 33
   2.6.3 Robotic Hand Control ............................ 33

2.7 Summary .................................................. 34
3 EMG Acquisition

3.1 Introduction ................................................. 36

3.2 Acquisition Setup .......................................... 36
   3.2.1 Hardware Setup ...................................... 36
      3.2.1.1 Computer ..................................... 37
      3.2.1.2 Main Amplifier Unit ......................... 38
      3.2.1.3 EMG Electrodes ................................. 38
      3.2.1.4 Input Module ................................ 39
      3.2.1.5 DAQ Device .................................. 39
   3.2.2 Software Setup ...................................... 41

3.3 EMG Acquisition Platform ................................. 41
   3.3.1 Acquisition Module .................................. 43
   3.3.2 Preprocessing Module ............................... 44
      3.3.2.1 Filtering ..................................... 44
      3.3.2.2 Rectification ................................ 47
      3.3.2.3 Integration .................................. 48
   3.3.3 Feature Extraction Module ......................... 48
      3.3.3.1 Statistical Features ......................... 50

3.4 Experimental Protocols .................................... 53
   3.4.1 Choice of Samples .................................. 53
   3.4.2 Muscle Location .................................... 53
   3.4.3 Biceps Activities .................................. 54
   3.4.4 Data Acquisition ................................... 57
   3.4.5 Skin Preparations .................................. 57
   3.4.6 Electrode Placement ................................ 57

3.5 Results ....................................................... 58

3.6 Discussions ................................................ 62

3.7 Summary ..................................................... 64
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>The standard weight status categories associated with BMI ranges for adults (BMI, 2009)</td>
<td>53</td>
</tr>
<tr>
<td>4.1</td>
<td>Desired BPN vector response with respect to class of biceps activities.</td>
<td>69</td>
</tr>
<tr>
<td>4.2</td>
<td>Parameters and settings for a feedforward BPN.</td>
<td>73</td>
</tr>
<tr>
<td>4.3</td>
<td>Validation results of LM learning algorithm.</td>
<td>76</td>
</tr>
<tr>
<td>4.4</td>
<td>Validation results of RP learning algorithm.</td>
<td>76</td>
</tr>
<tr>
<td>4.5</td>
<td>Classification rate of each biceps activity with LM algorithm.</td>
<td>77</td>
</tr>
<tr>
<td>4.6</td>
<td>Classification rate of each biceps activity with RP algorithm.</td>
<td>77</td>
</tr>
<tr>
<td>4.7</td>
<td>Desired PNN output with respect to class of biceps activities.</td>
<td>80</td>
</tr>
<tr>
<td>4.8</td>
<td>Experiment to study appropriate deviation value for PNN.</td>
<td>81</td>
</tr>
<tr>
<td>4.9</td>
<td>Parameters and settings for PNN.</td>
<td>82</td>
</tr>
<tr>
<td>4.10</td>
<td>Validation results of PNN.</td>
<td>83</td>
</tr>
<tr>
<td>4.11</td>
<td>Classification rate of each biceps activity with PNN.</td>
<td>83</td>
</tr>
<tr>
<td>4.12</td>
<td>Comparison of classification rate obtained from each respective networks.</td>
<td>85</td>
</tr>
<tr>
<td>4.13</td>
<td>Comparison of BPNN and PNN.</td>
<td>86</td>
</tr>
</tbody>
</table>
List of Figures

1.1 Flow chart of the research methodology followed in this project. . . . . 8

2.1 Types of muscle. ©Jin Seok Jeon. . . . . . . . . . . . . . . . . . . . . 13

2.2 Muscle structure. ©2001 Benjamin Cummings, an imprint of Addison
   Wesley Longman, Inc. . . . . . . . . . . . . . . . . . . . . . . . . . . 14

2.3 Relaxed and contracted state of a fiber. ©1999 John Wiley and Sons, Inc. 15

2.4 Innervated muscle fiber by motor neuron. ©Pearson Education. . . . . . 16

2.5 Schematic representation of the generation of the motor unit action po-
   tential. ©John G. Webster. . . . . . . . . . . . . . . . . . . . . . . . . 17

2.6 Disposable surface electrodes with lead wires attached. ©Natus Neuro-
   rology . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 18

2.7 Needle electrodes as part of the IEMG. ©Rochester Electro-Medical. . 19

2.8 Fine-wire electrodes used in a IEMG design. (Quah, 2007). . . . . . 19

2.9 Rectification process. . . . . . . . . . . . . . . . . . . . . . . . . . . 21

2.10 Integrated EMG signal. . . . . . . . . . . . . . . . . . . . . . . . . . 22

2.11 Frequency spectrum of an EMG signal. . . . . . . . . . . . . . . . . . 24

2.12 Wavelet analysis of an EMG signal. . . . . . . . . . . . . . . . . . . 25

2.13 Example of a fuzzy logic model. . . . . . . . . . . . . . . . . . . . . 27

2.14 Example of a hidden Markov model (HMM). . . . . . . . . . . . . . 29

2.15 Example of a non-linear separable classification case. . . . . . . . . . 30

3.1 Experimental setup for the proposed system with all required components. 37
3.2 Main amplifier unit which consists tunable gain, buzzer alarm and a LED. .................................................. 38
3.3 Differential surface electrode and reference electrode. ................. 39
3.4 Input module. .................................................................. 40
3.5 NI USB-6251 multifunction DAQ. ...................................... 40
3.6 Block elements of the EMG acquisition system. ......................... 42
3.7 Data acquisition module. ................................................... 43
3.8 Raw EMG signals. ............................................................. 44
3.9 Preprocessing module. ....................................................... 45
3.10 Highpass FIR filter block. ................................................ 45
3.11 Magnitude response (dB) of a FIR filter ................................ 46
3.12 Filtered EMG. ................................................................. 46
3.13 Absolute block. ................................................................ 47
3.14 Rectified EMG. ............................................................... 48
3.15 Windowed integrator block. ............................................ 49
3.16 Integrated EMG ............................................................... 49
3.17 Feature extraction module. .............................................. 50
3.18 Statistical feature blocks. .................................................. 51
3.19 Location of biceps brachii muscle. ©TeachPE.com. .................. 54
3.20 Biceps activities. ............................................................. 56
3.21 Positioning of EMG electrode and reference electrode on the crossed marking. ................................................. 58
3.22 Integrated EMG obtained from under BMI subjects. ............... 59
3.23 Biceps muscle in rest condition. ....................................... 59
3.24 Integrated EMG for concentric contraction with 90° ROM activity. . 60
3.25 Integrated EMG for concentric contraction with 160° ROM activity. . 60
3.26 Integrated EMG for concentric-eccentric contraction with 90° ROM activity. .................................................. 61
3.27 Integrated EMG for concentric-eccentric contraction with $160^\circ$ ROM activity. ................................................................. 61

3.28 Superimposed of the averaged integrated EMG for different types of biceps activities. ......................................................... 62

4.1 The architecture of a three layered BPN. ................................. 67
4.2 MSE value at different number of hidden neurons. ................... 69
4.3 Learning algorithm which has fast convergence rate. ............. 70
4.4 Learning algorithm which has low convergence rate. .......... 71
4.5 Hyperbolic tangent sigmoid transfer function. ..................... 72
4.6 Sigmoid transfer function. ................................................. 72
4.7 Performance plot of BPN network using LM learning algorithm. .... 74
4.8 Performance plot of BPN network using RP learning algorithm. .... 75
4.9 The architecture of a three layered PNN. ............................... 79
4.10 The influence of a small and large deviations. ..................... 81
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abs</td>
<td>Absolute</td>
</tr>
<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>AMD</td>
<td>Advanced Micro Devices</td>
</tr>
<tr>
<td>ANN</td>
<td>Artificial Neural Network</td>
</tr>
<tr>
<td>ATA</td>
<td>Analog Telephony Adapter</td>
</tr>
<tr>
<td>AUX</td>
<td>Auxiliary</td>
</tr>
<tr>
<td>BNC</td>
<td>Bayonet-Locking Coupling</td>
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<tr>
<td>BMI</td>
<td>Body Mass Index</td>
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<tr>
<td>BPN</td>
<td>Backpropagation Network</td>
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<tr>
<td>C</td>
<td>Celsius</td>
</tr>
<tr>
<td>CMRR</td>
<td>Common Mode Rejection Ratio</td>
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<tr>
<td>DAQ</td>
<td>Data Acquisition</td>
</tr>
<tr>
<td>dB</td>
<td>Decibel</td>
</tr>
<tr>
<td>DDR</td>
<td>Double Date Rate</td>
</tr>
<tr>
<td>Dev</td>
<td>Device</td>
</tr>
<tr>
<td>DLR</td>
<td>German Aerospace Center</td>
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<tr>
<td>D-Sub</td>
<td>D-Subminiature connector</td>
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DVD  Digital Versatile Disc or Digital Video Disc
ECG  Electrocardiogram
EEG  Electroencephalogram
EMG  Electromyogram
F    Fahrenheit
FFT  Fast Fourier Transform
FIFO First In First Out
FIR  Finite Impulse Response
ft   feet
GB   Gigabytes
GHz  Gigahertz
HIT  Harbin Institute of Technology
HMM  Hidden Markov Model
Hz   Hertz
IEMG Intramuscular Electromyography
KB   Kilobytes
kg   Kilogram
LED  Light Emitting Diode
LM   Levenberg-Marquardt
m    Meter
mA   Milliampere
Max  Maximum
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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</thead>
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<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>MLP</td>
<td>Multi-Layer Perceptron</td>
</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>ms</td>
<td>Milliseconds</td>
</tr>
<tr>
<td>MSE</td>
<td>Mean Squared Error</td>
</tr>
<tr>
<td>MS/s</td>
<td>Millions of samples per second</td>
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<tr>
<td>MUAP</td>
<td>Motor Unit Action Potential</td>
</tr>
<tr>
<td>mV</td>
<td>Millivolt</td>
</tr>
<tr>
<td>mW</td>
<td>Milliwatt</td>
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<tr>
<td>NI</td>
<td>National Instrument</td>
</tr>
<tr>
<td>NN</td>
<td>Neural Network</td>
</tr>
<tr>
<td>No</td>
<td>Number</td>
</tr>
<tr>
<td>PNN</td>
<td>Probabilistic Neural Network</td>
</tr>
<tr>
<td>R</td>
<td>Read</td>
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<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>ROM</td>
<td>Range of Motion</td>
</tr>
<tr>
<td>RP</td>
<td>Resilient-Propagation</td>
</tr>
<tr>
<td>RPM</td>
<td>Revolution Per Minute</td>
</tr>
<tr>
<td>RTI</td>
<td>Referred to Input</td>
</tr>
<tr>
<td>RW</td>
<td>Read and write</td>
</tr>
<tr>
<td>s</td>
<td>Second</td>
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SD  Standard Deviation
SDRAM  Synchronous Dynamic Random Access Memory
SEMG  Surface Electromyography
SVM  Support Vector Machine
T  Time
USB  Universal Serial Bus
V  Volts
Var  Variance
VC  Vapnik-Chervonenkis
Vs  Voltage second
w  With
Windows XP  XP means experience. Windows XP is a family of 32-bit and 64-bit operating system produced by Microsoft
WT  Wavelet Transform
WVD  Wigner-Ville Distribution
WXGA  Wide Extended Graphic Array
ABSTRAK

KLASSIFIKASI EMG PERMUKAAN BICEPS BRACHII DENGAN MENGGUNAKAN RANGKAIAN SARAF

ABSTRACT

BICEPS BRACHII SURFACE EMG CLASSIFICATION USING NEURAL NETWORK

This thesis presents an approach of MATLAB-based system for clinical rehabilitation monitoring application. The main rationale for the development of such a system is that the pattern of the EMG signals elicited may differ depending on the activity of the muscle movement. Therefore, this research aims to study EMG signals elicited from biceps brachii muscle and classify the signal pattern to their respective class of activity. The proposed system consists of two main parts. The first part is about the development of an EMG acquisition platform. This platform consists of three modules: acquisition module, preprocessing module and feature extraction module. The acquisition module is used to acquire EMG signals from the subject. Several signal processing methods are carried out in the preprocessing module, where the EMG signal will undergo a series of processes like filtering, rectification and integration. After preprocessing, the signal is passed to the feature extraction module. In this module, statistical features such as mean, maximum, variance and standard deviation are computed to represent the signal pattern. The second part is regarding EMG pattern classification using neural networks. Feedforward Backpropagation Network (BPN) and Probabilistic Neural Network (PNN) are chosen as the classifiers to classify muscle activities. In the experimentation phase, 30 female subjects took part in this study. They were asked to perform several series of voluntary movement with respect to biceps brachii muscle. The experimental results show that EMG signals of different biceps activity is differed and simple statistical features are sufficient to represent the EMG pattern. The proposed BPN with Levenberg-Marquardt (LM) algorithm and PNN had achieved an overall classification rate of 88% while BPN with Resilient-Propagation (RP) algorithm achieved an overall classification of 87.11%. With these satisfactory results, the effectiveness of the proposed classifiers in EMG pattern classification problem is proven.
Chapter 1

Introduction

1.1 Overview

Biosignal is a kind of signal that can be measured from biological beings. It is the electrical signal that is produced by the differences of electrical potential between specialized cells. Electroencephalogram (EEG), electrocardiogram (ECG) and electromyogram (EMG) are among the best known biosignals. Study on electromyography has begun for decades, however it has been in the recent 15 years that it has drawn much interest and passion from 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 electronics and mechanical engineering. This in turn for example can help the disabled to lead a way of life with dignity, peace and longer life. There are quite a numbers of successful products existing in the market, for instance the pacemaker for heart problems, intelligent prosthesis for arm amputees, camera based vision substitution for blind people, medical robots used in surgical rooms and emotion controlled machines for bed-ridden elders.
Since EMG has had a great contribution to various kind of applications, its benefits have become more apparent. Apart from the traditional use of EMG in physiological and biomedical field, EMG is also dedicated to medical research, rehabilitation, sports science and ergonomics. Our research is also along this line of applications, in particular, sensing EMG signals from a group of neurologically intact subjects. We are focusing on studying the pattern of the EMG response elicited through voluntary contraction of the biceps brachii muscle. The raw EMG signals will not be useful without further analysis. A series of signal processing steps will be carried out to extract information from the raw signals. With proper feature extraction, obtained information can be presented and interpreted in a more intelligent way. There are several methods of analysis which can fully utilize the information of the signal. Each method applies differently depending on its application.

Although many researches have been done in the past few decades, the mystification of EMG still remains and some of it still open to questions. However, with trial and error procedures and lots of experimental testing, sufficient experience in dealing with EMG signals can be obtained. This thesis will present the basic knowledge of EMG and the processing techniques applied towards the development of a real-time muscle activity classification system.

In this work, the overall biomedical components for upper limb classification comprised of a sensor placed on the surface of the muscle for detecting EMG signal, a DAQ to transform the analog signal to digital signal, a computer for data storage, software for signal processing and feature extraction and finally the development of neural network algorithms for classification. All these components form the basic construction units for this research.
1.2 Scope

Generally, the scope of this research is limited to the following:

- The human body has numerous muscles, however only the biceps brachii muscle is interested in this study. This muscle is chosen because of its easiness to be recognized and its accessibility for sensor placement.

- The biceps brachii muscle is located in the upper arm and it can be use to perform a variety of movements. It specifically plays a role to perform elbow flexion and forearm rotation. In this research, elbow flexion will be emphasized in which several activities concerning to biceps muscle will be carried out.

- There are several types of EMG sensors particularly meant for EMG analysis, for instance, needle and fine wire EMG. However, in this research, the surface EMG sensor is opted to be applied. This is because surface EMG is a non-invasive procedure and the subject will be free of discomfort when the electrode is placed onto the skin.

- Apart from that, a variety of algorithms have been used for the EMG classification. Each of the classification method has it own approach and advantages. In this research, feedforward backpropagation network with different learning algorithms and radial basis network are chosen for the pattern classification problem.

- In addition, this research will be served as a platform to study the feasibility and practicality of an automated rehabilitation physiotherapy monitoring system.
1.3 Motivation

The main rational to carry out this research is to gain in-depth knowledge and experiences on EMG such that the signals can be extended to be used in an application. An EMG signal can be quite complicated. A nerve impulse could have triggered a reaction which then makes a muscle to contract. Although the confusions arise as to which muscle would response, the benefits of determining this mystery from EMG signals become more perceptible. Therefore, there is a motivation to carry out a study to investigate and solve the problems pertaining to any EMG signals.

Moreover, for the disabled people, analysis of EMG signals can be very useful. EMG signals are easy to be generated and studies have shown that even paralyzed people can produce discernible EMG signals through self effort (Walker et al., 1998). Based on this hypothesis, the brain continues to generate signals to a muscle even though a human has lost a particular limb. Therefore, there is an inspiration of developing a classification system that can classify EMG pattern accordingly to specific muscle activity from a group of intact subjects. From there, the proposition of this study is evaluated and the feasibility to extend the system to amputees can be considered.

Furthermore, it is found that there are very few automated rehabilitation software for patients seeking physiotherapy. For this reason, there is a need to contribute to this area. Software developed for this purpose can have valuable economic value and high return in investment. Hence software development in this field is an area to be explored within the context of this research. In addition, as far as upper limb patients are concerned, most of the biceps injury and motor dysfunction cases must undergo training regimens in order to regain functional control. As such, there is a need to develop a specific system to assist them in their therapy in a more comfortable manner.
1.4 Problem Statements

EMG is very easy to use and consequently too easy to be abused. It is inherently problematic, with many shortcomings and thus has questionable values (Klasser and Okeson, 2006). Most of the biosignals such as ECG, EEG and EMG have very low amplitude levels. Therefore the delicate nature of EMG signals can be problematic in the acquisition stage.

The core problem related to EMG signals is how to preserve the fidelity of the signal from noise contaminations. Any irrelevant contribution of frequencies, for instance, ambient noise, motion artifacts and power line radiation may pollute the real EMG signals. Furthermore, unnecessary filtering will also distort the EMG signals. So, it is vital that the detecting and recording devices are capable of processing the signal properly.

Apart from noise, many other factors such as electrode types, electrode location, cabling and skin resistance will directly influence the reliability of the obtained EMG signals. For these reasons, many considerations need to be given extra attention in the process of developing the proposed system.

In addition to that, EMG signals vary from subject to subject. It is pretty challenging to classify muscle activities according to a specific movement. Even for the same muscle activity, EMG signals elicited by the subjects may differ. Some people may indicate higher signal amplitude while some others may give a lower signal amplitude. All these increases the variability and dependents of the EMG signals to external biological factors.
1.5 Objectives

The objectives of the research are indicated as follows:

• To investigate the effectiveness of using statistical features of the EMG signals as the discriminating factors for the different type of actions performed by the biceps brachii muscle.

• To design a system with neural networks to classify the type of actions performed by the biceps brachii muscle from the EMG signals recorded.

1.6 Research Methodology

The research has been carried out in the following stages:

• First stage

A thorough literature review was done to gather further information and knowledge regarding EMG signals analysis. Basic human anatomy and functional mechanism are studied. Besides that, EMG signals handling and acquisition theories were emphasized. Furthermore, various signal processing techniques and classification methods were studied and analyzed before a decision was made to apply a suitable method. In addition, existing applications of EMG are reviewed.

• Second stage

The data acquisition process was carried out. All the hardware and software were assembled and properly set up. An EMG acquisition platform which containing
several SIMULINK modules was built utilizing blocks units. Experiments were carried out using intact female subjects of varying body mass index. The subjects were requested to perform a series of activities concerning to biceps brachii muscle. The data obtained was then recorded and stored.

- **Third stage**

  In this stage, work was carried out towards the development of a classification system. Several neural network algorithms were used to perform the classification task. The statistical feature vectors computed from the EMG data obtained was then used as an input to the neural network. In order for optimum results, some trials were done to fine tune the uncertain structural parameters of the network. Validation process was carried out to test the reliability of the trained network after completing the learning process. Lastly, the trained networks were applied to classify new cases. The performance rates of each respective algorithm were then compared.

The overall research methodology is shown in Figure 1.1.