UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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RELATIONSHIP INVESTIGATION OF HANDGRIP FORCES WITH VARIED WRIST ANGLES USING FOREARM EMG FOR BIONIC HAND

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RELATIONSHIP INVESTIGATION OF HANDGRIP FORCES WITH VARIED WRIST ANGLES USING FOREARM EMG FOR BIONIC HAND

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled "Relationship Investigation of Handgrip Force with Varied Wrist Angles using Forearm EMG for Bionic Hand" 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	:	Muhammad Alif bin Norizan
Date	:	17/11/2017

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 Mechatronic Engineering.

Signature	:	....
Supervisor Name	:	Dr. Fariz bin Ali @ Ibrahim
Date	:	17/11/2017

DEDICATION

To my beloved mother and father, siblings, family and all of the Muslim around the world.

ABSTRACT

Extracting hand grip force and wrist angle information from forearm electromyogram (EMG) signals is useful to be used as an inputs for the control of cybernetic prostheses or robotic hand. The information relating handgrip force and wrist position to forearm muscle activity is important as control algorithm for controlling the prostheses or robotic hand gripping force. By investigating the relationship between forearm EMG and hand grip force/wrist angles, the prostheses or robotic hand can be controlled in a manner that is customized to an amputee's intent. In this research study, a signal processing system which consists of an electronic conditioning circuit to measure and process raw EMG signals into linear enveloped EMG signal and software to record and process the EMG signals were developed. Each circuit development stage is described in detail so that this research can be easily produced by others for future work and improvements. Experimental training and testing datasets from five subjects were collected to investigate the relationship between forearm EMG, hand grip force and wrist angle simultaneously. The wrist angles set for this research is 60°, 90 ° and 120 ° while the forces is set at 5%, 15%, 25% and 35%MVC. At the beginning, 100%MVC were done by each subjects for the normalization of EMG signal. Neural Network were used to represents the relationship and to estimate handgrip force and wrist angle from the EMG signal. The performance of the networks were indicated by Mean Square Error (MSE) and Mean Absolute Error (MAE) values. The results from neural network training shows good accuracy with low MSE (<= 0.0000001) and MAE (< 0.2) value. The data obtained from the experiment has been analyzed and is useful, low-cost method to control a prostheses or robotic hand.

ABSTRAK

Mengekstrak daya pegangan tangan dan maklumat sudut pergelangan tangan dari isyarat electromyogram (EMG) berguna untuk digunakan sebagai input untuk mengawal prostesis cybernetic atau tangan robotik. Maklumat mengenai daya pegangan tangan dan kedudukan pergelangan tangan untuk aktiviti otot lengan adalah penting sebagai algoritma kawalan untuk mengawal prostesis atau daya tarikan tangan robot. Dengan menyiasat hubungan antara lengan EMG dan sudut cengkaman tangan / pergelangan tangan, prostesis atau tangan robot boleh dikawal dengan cara yang disesuaikan dengan niat pengguna. Dalam kajian penyelidikan ini, sistem pemprosesan isyarat yang terdiri daripada litar elektronik penyesuaian untuk mengukur dan memproses isyarat mentah EMG ke dalam isyarat dan perisian linear EMG untuk merekod dan memproses isyarat EMG telah dibangunkan. Setiap peringkat pembangunan litar ini diterangkan secara terperinci supaya penyelidikan ini dapat dihasilkan dengan mudah oleh orang lain untuk kerja dan penambahbaikan di masa depan. Kumpulan latihan dan ujian eksperimen dari lima subjek dikumpulkan untuk menyiasat hubungan antara EMG lengan bawah, daya pegangan tangan dan pergelangan tangan pada masa yang sama. Sudut pergelangan tangan yang ditetapkan untuk penyelidikan ini ialah 60°, 90° dan 120° manakala daya ditetapkan pada 5%, 15%, 25% dan 35% MVC. Pada mulanya, 100% MVC telah dilakukan oleh setiap subjek untuk menormalkan isyarat EMG. Rangkaian Neural digunakan untuk mewakili hubungan dan untuk menganggarkan daya genggaman dan sudut pergelangan tangan dari isyarat EMG. Prestasi rangkaian ditunjukkan oleh nilai-nilai Mean Square Error (MSE) dan Mean Average Error (MAE). Hasil dari latihan rangkaian neural menunjukkan ketepatan yang baik dengan nilai MSE (<= 0.0000001) dan nilai MAE (<0.2) yang rendah. Data yang diperoleh dari eksperimen telah dianalisis dan berguna, kaedah kos rendah untuk mengawal prostesis atau tangan robot.

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LIST OF ABBREVIATIONS

EMG	-	Electromyography
sEMG	-	Surface Electromyography
FDS	-	Flexor Digitorum Superficialis
FCR	-	Flexor Carpi Radialis
ED	-	Extensor Digitorum
FCU	-	Flexor Carpi Ulnaris
FPL	-	Flexor Pollicis Longus
FDP	-	Flexor Digitorum Profundus
PL	-	Palmaris Longus
PT	-	Pronator Teres
ECRL	-	Extensor Carpi Radialis Longus
ECR	-	Extensor Carpi Radialis
EDM	-	Extensor Digitorum Minimi
ECU	-	Extensor Carpi Ulnaris
EPL	-	Extensor Pollicis Longus
TTL	-	Transistor to Transistor Logic
DC	-	Direct Current
CMMR	-	Common Mode Rejection Ratio
ANN	-	Artificial Neural Network
ADC	-	Analog to Digital Converter
DOF	-	Degree of Freedom
AR	-	Auto Regressive

PCB	-	Printed Circuit Board
DRL	-	Driven Right Leg
EEG	-	Electroencephalogram
EOG	-	Electrooculogram
ECG	-	Electrocardiogram
AgCl	-	Argentum Chloride
MVC	-	Maximal/Maximum Voluntary Contraction
MSE	-	Mean Square Error
MAE	-	Mean Average Error

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CHAPTER 1

INTRODUCTION

1.0 Research Background

Robots and robotic technology have progressed from machines in science fiction to nearly commercialized products in last few decades. Robots were mainly utilized as tools in manufacturing facilities to perform tasks like welding, drilling, machining, and assembling. With recent advancement of technology, the robotic fields expanded rapidly. More researches are carried out in different fields of robotics such as industrial robots, aerial robots, mobile robots, cooperative robots, assistive robot and bio-robotics, underwater robots etc.

Among many fields of robotics, assistive robotic technologies have been able to attract much attention in current research community around the world. Recent developments in assistive robotic technology(Iqbal et al., 2014; Mahdavi and Ahmad, 2013; Tucker et al., 2015; Fariz Ali, Herman Jamaluddin, Norafizah Abas, Muhammad Alif Norizan, 2015; Muhammad Alif Norizan et al., 2015) serves in many ways to improve the life quality for a group of people including physically weak, old, injured or disabled individuals. Electromyogram signal (EMG) is the small electrical impulses that are generated by muscular activity (Konrad, 2006; Takala and Toivonen, 2013; Mahdavi and Ahmad, 2013). The technique of development, recording, and analysis of the electrical impulses is referred as Electromyogram (Goen and Tiwari, 2013). Surface electromyography (sEMG) is the non-invasive recording of electrical muscle activity that is used to acquire bio- signal from contraction and extension of muscle's activity.

Some of the applications of EMG include physical rehabilitation, biomechanics, and ergonomics(Norali et al., 2009; Raez et al., 2006). EMG is also used in diverse applications such as operating prosthesis limbs, robotic devices and input interface for small devices such as mobile phones or PDAs(Shenoy et al., 2008; Raurale, 2014; Sikula et al., 2014; Crawford et al., 2010; Lai et al., 2007; Norizan et al., 2016). By using EMG signals which contain vital information regarding the motion of muscles from the human body can be generated.

Surface EMG is recommended due to the non-invasive characteristic that makes it convenient to apply in rehabilitation devices such as prosthesis or exoskeleton. With multi-channel surface EMG signal acquisition, the robotic/exoskeleton application will have smooth and articulated movements (Brunelli et al., 2015). Recent researchers provide information on using raw EMG in operating prosthesis limbs and robotic/exoskeleton hand. The aim of this research is to develop a linear enveloped EMG circuit that gives suitable input for controlling robotic hand or exoskeleton hand.

1.1 Research Motivation

Based on the statistical report published by Department of Social Welfare, Figure 1.1 display the total of a person registered under the department of social welfare with disabilities in Malaysia from the year 2013 to 2015. In this figure, it explains that the number of disabled people is increasing year by year. Another report from Department of

Social Welfare in 2015 mentioned there are about 34% of Malaysian people's suffers from physical disabilities.

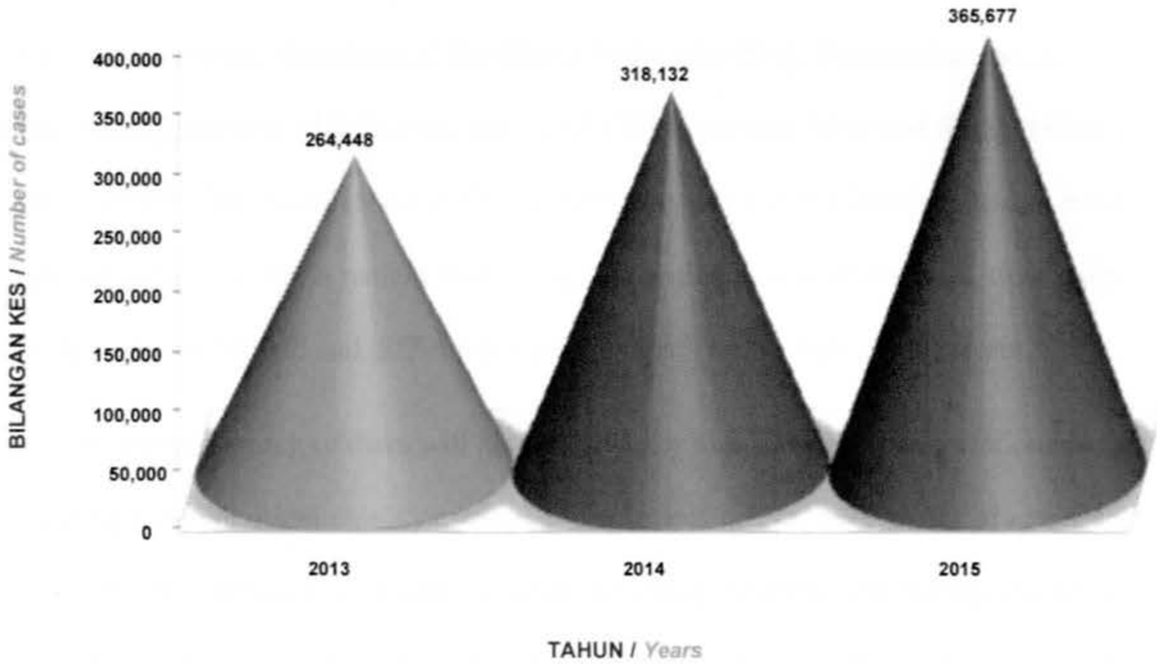

Figure 1.1: Total value of registered person with disabilities in Malaysia, from 2013 to 2015.(Ramli, 2015)

Kategori Ketidakupayaan / *Disabilities Category*	Tahun / *Year* 2015*
Penglihatan / *Vision Impair*	32,807
Pendengaran / *Hearing*	29,636
Fizikal / *Physical*	125,491
Masalah Pembelajaran / *Learning Disabilities*	129,550
Pertuturan / *Speech*	1,827
Mental / *Mental*	29,403
Pelbagai / *Others*	16,963
Jumlah / *Total*	**365,677**

Figure 1.2: Types of disabilities in Malaysia for the year 2015.(Ramli, 2015)