FEATURE EXTRACTION OF FOREARM EMG SIGNAL FOR EXOSKELETON HAND

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"I declare that this report entitle "**Feature Extraction Of Forearm EMG Signal for Exoskeleton Hand**" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

Signature :

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ABSTRACT

Electromygraphy (EMG) signal is non-stationary, non-linear, and have large variation in its signal. It consists of different type of noises in the EMG signal, some of the noises can be eliminated by filtering. However, filtering cannot eliminate random noises of the EMG signals. Therefore, feature extraction has to be performed to the EMG signals to eliminate the unwanted parts of the EMG signals. The first objective of this project includes the forearm raw EMG signals extraction for exoskeleton hand. The next objective is to perform feature extraction on the raw EMG signals that are extracted in objective one. Lastly, the feature extraction performance is analyzed by using the percentage error calculation approach. The method of this research is that, the experiment on extracting the EMG signals are done by using the Muscle Sensor V3 Kit. The performance and analysis of the feature extraction are done by using the MATLAB software. Literature review covers the theory and basic principles and review of previous work on EMG signals, muscle selection, signal conditioning of DAQ, and feature extractions. The movement of hand close (HC), hand open (HO), wrist flexion (WF) and wrist extension (WE) is selected for this research. The selected muscle are FDS, FCR and ECRL muscles. The feature extraction of IEMG and MAV is performed to the EMG signals. The expected result of this research will be the raw EMG signal, feature extracted EMG signal, and also the analysis of the performance. It is expected that the better performance will have the lower percentage of error.

ABSTRAK

Signal Elektromiografi (EMG) adalah signal yang bergerak, tidak linear dan mempunyai banyak signal yang bebeza-beza. Ia terdiri daripada banyak jenis gangguan dan sesetengah gangguan ini boleh di hapuskan menggunakan tapisan signal. Jadi, pengestrakkan ciri harus di jalankan untuk menghapuskan ciri di dalam signal EMG yang tidak deiperlukan. Objektif pertama dalam penyelidikan ini adalah untuk mendapatkan signal EMG daripada tangan manusia untuk kegunaan tangan ekso-skeleton. Seterusnya, objektif kedua adalah melakukan pengestrakkan ciri pada signal EMG. Akhirnya, analisis pengestrakkan ciri pada signal EMG dilakukan dengan menggunakan kiraan peratus kesalahan. Kaedah penyelidikan ini adalah dengan menjalankan eksperimen untuk mengestrak signal EMG daripada tangan subjek dengan menggunakan Muscle Sensor V3 Kit. Prestasi dan analisa terhadap pengestrakkan ciri dijalankan menggunakan MATLAB. Kajian literature telah merangkumi teori dan prinsip asas mengenaik signal EMG, pemilihan otot, penyesuaian isyarat dan pengesektrakkan ciri. Pergerakan tangan genggam, tangan terbuka, fleksi pergelangan tangan dan extensi pergelangan tangan telah dipilih. Otot yang terpilih untuk pergerakan-pergerakan ini adalah otot FDS, FCR da ECRL. Pengesrakkan ciri kaedah IEMG dan MAV akan dilakukan pada signal EMG tersebut. Hasil yang diharapkan oleh penyelidikan ini adalah data signal EMG, pengestrakkan ciri pada signal EMG tersebut dah juga analisa pengestrakkan ciri. Dengan harapan yang tinggin, hasil penyelidikan ini akan mendapatkan kaedah pengestrakkan ciri yang lebih baik. Ini dilakukan dengan pengiraan peratus kesalahan.

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CHAPTER 1

INTRODUCTION

This chapter is introduction of the project that covers briefly about the research background. The motivation and significant of the research is also included in this chapter. By the motivation, the problem statement of this project has been concluded. The objectives of the project are also explained in detail. In this chapter, the project scopes are determined and lastly, the report outline is executed.

1.1 Introduction

In the present time, research on Electromyography (EMG) signals has been vastly developed. The technology that utilized the advantages of EMG signals generated by human muscle had tremendously studied worldwide. In this research, feature extraction of forearm EMG signals is explored for exoskeleton hand application.

EMG signals is the study based on muscle contractions. There are two main methods of extracting the EMG signals; using the skin surface electrodes and fine wire electrodes. Skin surface electrodes, silver/silver chloride pre-gelled electrodes are used frequently. This are also called as Surface Electromyography. Surface electrodes are recommended due to their non-invasive character that makes it convenient to be applied in rehabilitation devices. However, this EMG signals is non-stationary, non-linear, complex, and has large variation. Due to these properties, it is complicated to analyze EMG signals. Therefore, feature extraction of forearm EMG signals plays a significant role for exoskeleton hand movement identification.

Feature extraction is used to emphasize the relevant structure in the EMG signals and rejecting noise and unimportant EMG signals. Since the raw EMG signals from the human muscles are normally very small, EMG-amplifiers are required to act as differential amplifiers as their quality item is the ability to reject or eliminate artifacts.

The main application of EMG signals is the control of the exoskeleton or other rehabilitation and assistive device. Exoskeleton hand is widely used as the rehabilitation and assistive device. This exoskeleton hand can be controlled by the EMG signals. This research will focus on the exoskeleton hand application for rehabilitation. This rehabilitation tool is currently high in demand for training impaired hands.

1.2 Motivation and Significant of The Research

A figure shows that, the statistic data from Hospital Kuala Lumpur in 2004, 30 to 35% out of 1000 case of stroke dies. On the other hand, in three to five years" time there are 20 to 40% post-stroke patients require help from other people to do their daily routine and activities [9]. According to the percentage, the numbers of the post-stroke patients are growing each year. The post-stroke patients normally need rehabilitation session. Exoskeleton hand is a device that is currently popular for rehabilitation. Exoskeleton hand will greatly aid the injured parties for their rehabilitation and to restore the quality of life. With the exoskeleton hand, these injured parties able to use the exoskeleton hand to train their impaired hands. EMG signals are commonly used for the controlling exoskeleton hand [12][4]. The EMG signal controls the exoskeleton hand by muscle contractions of the user. This character of the EMG signal makes the exoskeleton application robust. Due to this matter, the feature extraction is important for pattern recognition of the EMG signals before it able to be applied for controlling the exoskeleton hand.

1.3 Problem Statement

In recent time, the EMG signals technique has explored extensively for exoskeleton hand application. This exoskeleton hand is widely employed for rehabilitation application. Based on the motivation and significant of this research, exoskeleton hand applications are recently popular for training impaired hands of a post-stoke patients. The exoskeleton hand can be control by using the EMG signals. This EMG signal is important because of its character that can control device using muscle contractions.

However, the major drawback of EMG signals is the poor recognition results under conditions of existing noises especially when the frequency characteristic of noise is random. This noise, artifact and interference in recorded EMG signals are electrode noise, electrode and cable motion artifact, alternating current power line interference, and other noise sources such as a broadband noise from electronic instrument [6]. Some of these noises can be easily removed using filtering methods. Despite that, the interferences of random noise that fall in EMG dominant frequency energy are difficult to be removed. Therefore, by feature extraction, the relevant structures in the EMG signals are highlighted and the noise and unimportant EMG signals are rejected.

Feature extraction methods have three categories of time domain, frequency domain and time-frequency domain. Among these categories, feature of the function of time is the most popular in exoskeleton hand application. Feature extraction in time domain is widely used due to its performances of signal classification in low noise environments and their low computational complexity [16]. Therefore, this research will perform the feature extraction method in time domain. The feature extraction methods that will be performed in this research are the Standard Deviation (STD) and Mean Absolute Value (MAV).

1.4 Objectives

1. To obtain forearm raw EMG signals based on indirect handgrip force and wrist angle for exoskeleton hand application.
2. To perform feature extraction in time domain for raw EMG signals extracted.
3. To analyze the performance of feature extraction methods in terms of percentage error calculation.

1.5 Project Scope

In this research, the feature extraction of forearm EMG Signal for exoskeleton hand is explored. The scopes of this research are as follows:

1. The feature extraction of forearm raw EMG signals will be extracted from five healthy subjects.
2. Only four hand movements are considered for the signal extraction experiment, which are hand open (HO), hand close (HC), wrist flexion (WF), and wrist extension (WE).
3. The muscles used to get the raw EMG signals are the Flexor Digitorium Superficialis (FDS), Flexor Carpi Radialis (FCR), and Extensor Carpi Radialis Longus (ECRL).
4. Muscle Sensor V3 Kit will be used to extract the raw EMG signals. The electrodes from the Muscle Sensor V3 Kit are skin surface electrodes.
5. The muscle sensor will be connected with Arduino Mega 2560 and then further process is done using the MATLAB software.
6. Two time domain features will be performed in this research, which are Standard Deviation (STD) and the Mean Absolute Value (MAV)

1.6 Report Outline

This report starts with the introduction of the research; the general view on EMG signals and exoskeleton hand application on rehabilitation is stated. Next, the motivation is build from a figure of post-stroke patients that require rehabilitation. The problem statement is then determined based on the motivation. Then, the objectives to overcome the problem are listed. Next, the research limitations are declared in the project scope.

The literature review starts with theory and basic principles of forearm anatomy, electromyography, feature extractions, and exoskeleton hand. The next section of the report is review of previous related work. This section covers on the previous research work on muscle selection, signal conditioning, feature extraction methods and their performance analysis. Then the next part of this report is the summary of literature review.

The methodology in this research is covered next. The procedures of to achieve the three objectives are stated. After that, the preliminary results of this research is shown and explained. The last part of this report includes conclusion and future works.

CHAPTER 2

LITERATURE REVIEW

This chapter covers on the theory and basic principle, review of previous related works and the summary and discussion of the review. On the theory and basic principle section, it covers briefly on the theory on the exoskeleton hands. Other than that, the theory of Electromyography (EMG), the EMG signal extractions are also included in the section. It covers briefly about the muscles of the anterior compartment of the forearm. On the review of previous related works, the configurations of exoskeleton hands are being covered. Besides that, this part of the chapter is also cover the muscle and hand motion selection of previous works. Lastly, the feature extraction methods that performed by previous works are also listed on this chapter.

2.1 Theory and Basic Principle

In this research, theory and basic principle of forearm anatomy, electromyography and exoskeleton hand are reviewed.

2.1.1 Forearm Anatomy

EMG signals are the study on muscle contractions. In this research, forearm raw EMG signals have to be extracted in order to perform feature extractions. Due to this, the theory of forearm anatomy is reviewed. There are three types of human muscle, which are skeletal, smooth and cardiac. The muscles that produce movement of the skeleton are the skeletal muscles.

This research conducts the experiment concerning the movement of the forearm. Therefore, the type of muscle that is going to be used in this research is the skeletal muscle of forearm. The forearm muscles are divided to three fascial compartments that are anterior, lateral, and posterior.

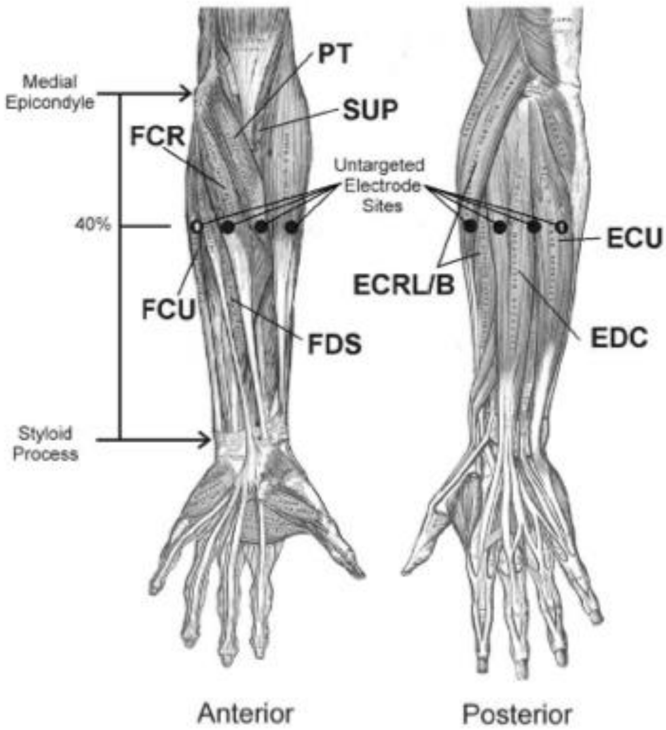

Figure 2.1: Anterior and Posterior fascial compartment of the forearm. [15]

The muscle of the anterior fascial compartment of the forearm consists of pronator teres (PT), flexor carpi radialis (FCR), palmaris longus (PL), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), flexor pollicis longus (FPL), and flexor digitorum profundus (FDP). These muscles have its own of actions to move the forearm. PT has the action of pronation and flexion of the forearm. FCR and FCU have the same action, which is flexes and abducts hand at wrist. PL flexes the hand, FDS flexes the hand, FPL flexes the thumb, and FDP flexes fingers, assist in flexion of middle and proximal phalanges and wrist.

Based on this information, the anterior fascial compartment muscles mostly covers on the flexion of the forearm and wrists. The suitable muscle from the anterior fascial compartment can be selected for flexion movements for the research.

The muscle of the lateral fascial compartment of the forearm consists of only one muscle that moves the hand. The extensor carpi radialis longus (ECRL) extends and abducts hand at wrist joint. The muscle of the posterior fascial compartment of the forearm consists of extensor carpi radialis (ECR), extensor digitorum (ED), extensor digiti minimi (EDM), extensor carpi ulnaris (ECU), and extensor pollicis longus (EPL). The ECR and ECU have the same action of extension and abduction hand at wrist joint, ED extends fingers and hand, EDM extends the little finger, and EPL extends the thumb. [8]. Both of lateral and posterior fascial compartments mostly cover the extension movement of the hand. This forearm anatomy is useful for determining the muscle selection for this research.

2.1.2 Electromyography

Electromyography (EMG) is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes. In other words, Electromyography, EMG is a technique to analyze the muscle activity in human body by getting the myoelectric signal from a medium [1]. EMG signals are based on the study of muscle contractions. The EMG signals are generated by the changes of ion in the muscle. Motor Unit is the smallest functional unit to describe the neural control of the muscular contraction process.

Electromyography is used in many researches and in biomedical approach. This EMG is widely used in Medical Research, Rehabilitation, Ergonomics and Sport Science, which the EMG is used as the evaluation tool. [6] This EMG signals are normally used to control the evaluation device by using the muscle contractions.

The main benefit of EMG is that, this signal allows us to look directly into the muscle. Therefore, it is possible to measure the muscular performance. Muscular performance can be analyze for different type of purpose, for example; to help in decision making before or after a surgery, to help patient „find" or train their muscle, to allow analysis on improving sport activities, or it can also detects muscle response for ergonomics studies [6]. This EMG signals are also explored in rehabilitation and assistive application of exoskeleton hand.

2.1.3 EMG signal extraction

Firstly, the skin preparation must be done before applying the medium on the skin. In addition, the identification of the correct muscle responsible for a particular motion is also has to be decided. Then, the raw EMG signal can be extracted directly by using electrodes. There are various type of electrodes that can be use to extract the EMG signal from the muscle which are, skin surface electrodes and fine wire electrodes. The skin surface electrodes are popular due to their non-invasive character. In A fine wire electrode

The EMG signal is important to be amplified due to its microvolt scaled signals. It is then undergo EMG data acquisition. Next, EMG data segmentation is applied. After that, feature extraction is done to the EMG signal before it can go into the Classifier.

2.1.4 Amplitude Normalization

Amplitude Normalization acts as the calibrator of the microvolt value of the EMG Signal. Performing the Maximum Voluntary Contraction (MVC) technique can process amplitude normalization. Only healthy and trained subjects must perform this MVC technique.

Firstly, identify exercise that allows for effective maximum innervation. Static fix at middle position within the range of motion give the best results. This method may be needed to try out by several candidates. Therefore highest EMG level can be found among the several candidates. The best candidate should perform a random order of exercise move in a period of time. This MVC exercise is done repeatedly with a pausing period. MVC require random order to avoid fatigue effects.

2.1.5 Muscle Sensor V3 Kit

In this research, the forearm raw EMG signal is required to be extracted. Muscle Sensor V3 Kit is used to extract the raw EMG data of the forearm. Muscle V3 Kit sensor is equipped with pre-gelled surface silver-silver chloride electrodes, muscle sensor board and 24” cable leads this is shown in Figure 2.2 and Figure 2.3.

This muscle sensor is designed to be used directly with a microcontroller. This sensor give the output of amplified, rectified and smoothed signal. The schematic diagram of Muscle Sensor V3 Kit is shown in Figure (). This muscle sensor is required to be connected with the power supply of two 9V batteries. The electrical specification of Muscle V3 Kit is shown in Table (). This Muscle sensor is used because it is simple and the signal is accurate.

Figure 2.2: The Muscle Sensor V3 Kit

Figure 2.3: Muscle sensor board

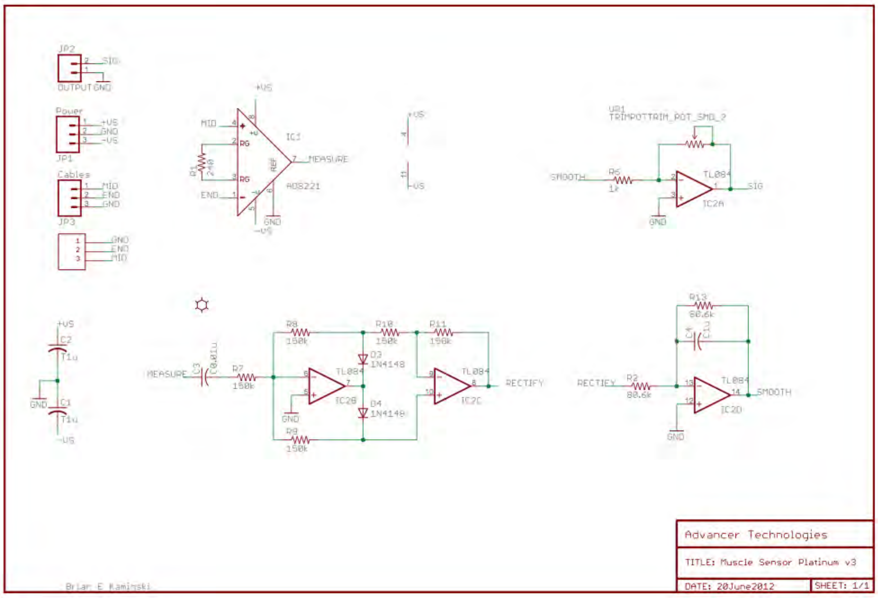

Figure 2.4: Schematic diagram for the Muscle Sensor V3 Kit

Table 2.1: Electrical specification for the Muscle Sensor V3 Kit

Parameter	Min	TYP	Max
Power Supply Voltage (Vs)	±3V	±5V	±30V
Gain Setting, Gain = 207*(X /1 kΩ)	0.01 Ω (0.002x)	50 kΩ (10,350x)	100 kΩ (20,700x)
Output Signal Voltage (Rectified & Smoothed)	0V	--	+Vs
Differential Input Voltage	0 mV	2-5mV	+Vs/Gain

2.1.6 Arduino Mega 2560

Arduino Mega 2560 is a microcontroller that can process and transfer analog and digital signal to the computer. In this project, this Arduino Mega acts as the signal-conditioning device that uses to convert the analog signal from the Muscle Sensor V3 Kit to a digital signal to be compatible with the computer. This process is done to make sure the computer is able to display the output EMG signal extracted from the Muscle Sensor V3 Kit.

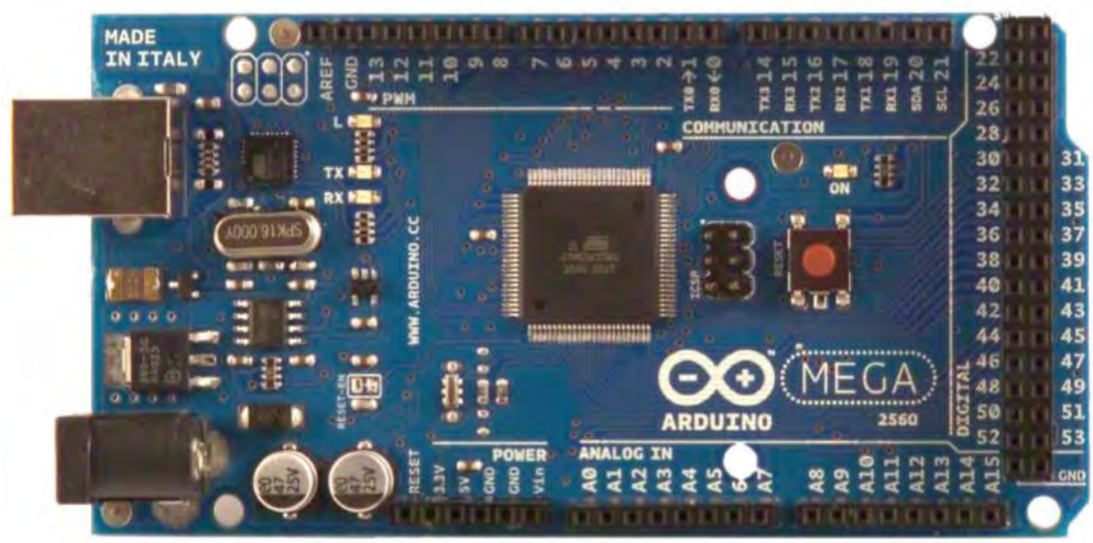

Figure 2.5: Arduino Mega 2560 board

From the datasheet, this Arduino Mega 2560 has 54 digital input and output pins, 14 of the digital pins can be used as PWM outputs, 16 analog inputs, 4 UARTs hardware serial ports, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. This Arduino Mega 2560 is complete with everything required to support the microcontroller. This Arduino is started just simply by connecting it to a computer with a USB cable or power it with an AC-to-DC adapter or battery.

2.1.7 Feature Extraction of EMG Signals

The raw EMG signal is a large number or inputs and randomness; therefore, it is impractical to feed the classifier with these signals. It is necessary to create the feature vector, where sequence is mapped into a smaller dimension vector. Feature extraction is important because the success of any pattern recognition problem depends almost entirely on the selection and extraction of features. Feature extraction for EMG signal normally falls into three categories, which are time domain, frequency domain, and time-frequency domain.

Time domain feature extraction consists of Integrated Electromyography (IEMG), Mean Absolute Value (MAV), Variance (VAR), Root Mean Square (RMS), Waveform Length (WL), Zero Crossing (ZC), Slope sign changes (SSC), Willison amplitude (WAMP), and Auto regressive coefficients (ARC). The time domain features are measured as a function of time.

Frequency domain feature extraction of EMG signals consists of Median Frequency (MDF), and Median Frequency (MNF). Frequency domain features are normally used to detect neural abnormalities, and muscle fatigue. This feature extraction is normally taken by the study of the spectrum of the EMG signals.

Time domain features are the most popular method for EMG signal for hand movement recognition. This feature is calculated on raw EMG time series. However, there is also disadvantage of the time domain features because EMG signals has the non-stationary character. Despite that, time domain features are extensively used because of their performances of signal in low noise environment and have lower computational complexity compared to the frequency and time-frequency domain features. In this research, the performance of Standard Deviation (STD) and Mean Absolute Value (MAV) will be analyzed.

2.1.7.1 Standard Deviation (STD)

From the mathematical point of view, standard deviation of a random variable, statistical population, data set, or probability distribution is the square root of its variance. It is algebraically simpler, despite the fact that in practice less robust, than the average absolute deviation. It is observed that the standard deviation of the raw EMG signal is monotonically related to the number of the activated motor units and the rate of their activation. This standard deviation is used to approximate the magnitude of the muscular electrical activity referred to as EMG amplitude. Standard deviation can be expressed as:

$$SD = \sqrt{\frac{\sum_{W=1}^{N_W} (r_w - \mu)^2}{N_W}} \tag{1}$$

2.1.7.2 Mean Absolute Value (MAV)

Mean absolute value (MAV) is calculated using the moving average of full-wave rectified EMG signal. It is calculated by taking the average of the absolute value of the EMG signal [18]. Other then that, MAV is similar to IEMG that normally used as an onset index to detect the muscle activity. MAV is the average of the absolute value of EMG signal amplitude. It is defined as

$$MAV = \frac{1}{N}\sum_{n=1}^{N}|x_n| \tag{2}$$

MAV is a simple way for detection of muscle contraction levels. Due to this, MAV is a popular feature used in EMG hand movement recognition applications and also myoelectric control application.

2.1.8 Exoskeleton Hand

In recent studies, rehabilitation device has explored the use of EMG signals. Exoskeleton hand is an example of extensively studied rehabilitation device. This exoskeleton hand is specially designed for injured parties of stroke and other cerebral vascular accident. This device provides training for people with impaired hand. An