ELECTROMYOGRAPHY (EMG) SIGNAL ACQUISITION AND CLASSIFICATION

By

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10524

Final Report submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Electrical & Electronic Engineering)

JANUARY 2011

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CERTIFICATION OF APPROVAL

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Sarfraz Hussain

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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JANUARY 2011

CERTIFICATION OF ORIGINALITY

This project is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgments, and that the original work contained herein have not been undertaken or done by un- specified sources or persons.

Sarfraz Hussain

ABSTRACT

Electromyography (EMG) is obtained by measuring the electrical signal associated with the activation of the muscle. EMG can be used for a lot of studies (e.g., clinical, biomedical, basic physiological and biomechanical studies); consequently, in this project the EMG is used as a diagnostic tool for the rehabilitation purpose. The methodology and instrumentation of Electromyography are presented and the main objectives of this project are to acquire signals and perform classification. In this research, Many signals need to be acquired from EMG system or any Data base source which are experimented on subjects having different age and gender, in order to carry out detailed analysis for the purpose of performing classification therefore, the signals are analyzed using MATLAB and thereafter, feature recognition method is applied by implementing fuzzy logic technique to classify the signals in terms of age groups. The final form of the project consists of a successful finding of signal acquisition to perform classification of EMG signals in terms of age groups using Fuzzy logic.

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CHAPTER 1
INTRODUCTION

1.1 Background of study

Electromyography (EMG) is the discipline that deals with the detection, analysis, and use of the electrical signal that emanates from contracting muscles [3]. Actually, small electrical currents are generated by muscle fibers prior to the production of muscle force and these currents are generated by the exchange of ions across muscle fiber membranes, a part of the signaling process for the muscle fibers to contract [6]. Basically, there are two kinds of EMG which are being used in widespread: intramuscular (needle and fine-wire) EMG and surface EMG. To perform intramuscular EMG, a needle containing two fine-wire electrodes is inserted through the skin into the muscle tissue, therefore; it may be considered too invasive and unnecessary in some cases. While, Surface EMG is the most common method of measurement, since it is non-invasive and can be conducted by personnel other than Medical Doctors, with minimal risk to the subject [6].

As Electromyography is a detection of electrical signal that emanates from contracting muscles [3]. Figure 1 shows the definition of the electromyography [2].

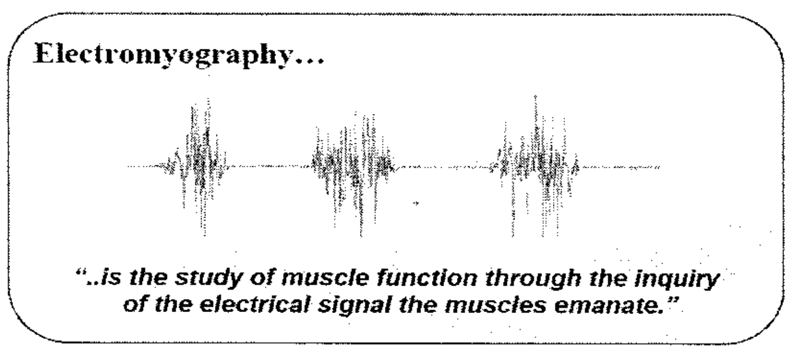


Figure 1: Definition on EMG

Electromyography had its earliest roots in the custom practiced by the Greeks of using electric eels to "shock" ailments out of the body. This technique has evolved from year 1658 with limitedly but nowadays, it has become the diagnostic tools for studies of muscle weakness, fatigue, pareses, paralysis and nerve conduction velocities, lesions of the motor unit or for neurogenic and myogenic problems [4]. This wide spread application of EMG are in the classical Neurological EMG and Kinesiological EMG studies where an artificial muscle response are due to an external electrical stimulation is analyzed in static conditions and the neuromuscular activation of muscles within postural tasks, functional movements, work conditions and treatment/training regimes respectively [5]. Figure 2 shows the application areas using the EMG technique [2].

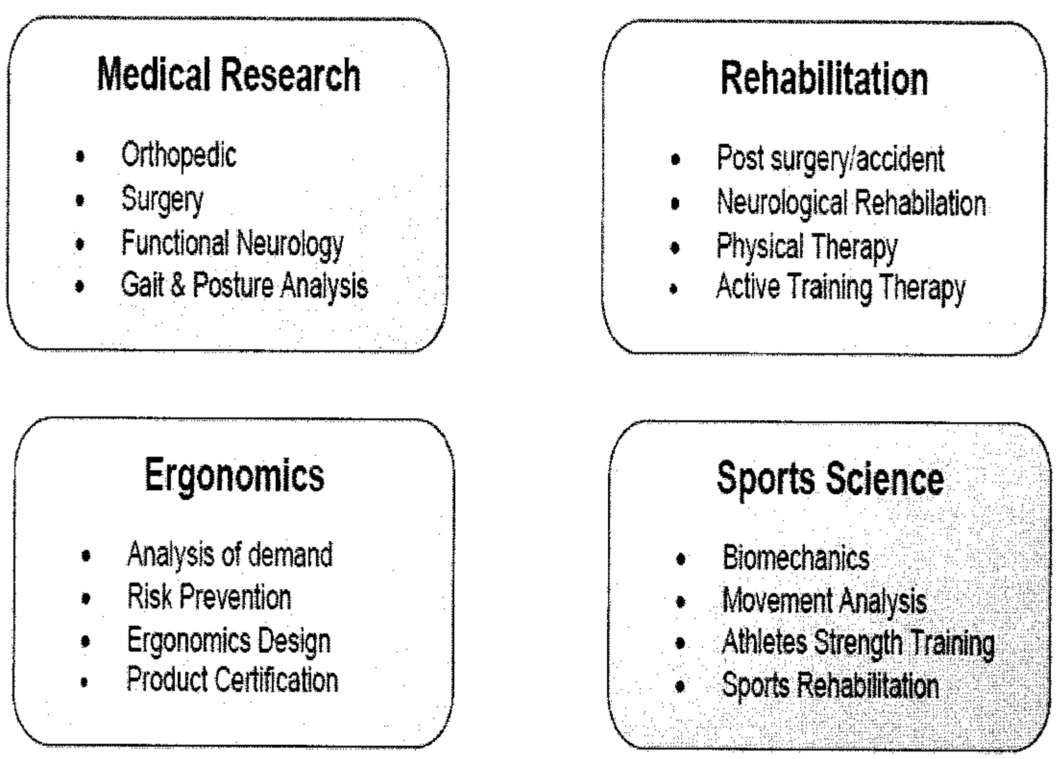


Figure 2: Application areas on the usage of EMG

1.2 Surface Electromyography (SEMG)

Surface Electromyography (SEMG) is a non-invasive technique for measuring muscle electrical activity that occurs during muscle contraction and relaxation cycles. The signal called the electromyogram (EMG) can be measured by applying conductive elements or electrodes to the skin surface of the muscle. Measurement of surface EMG is dependent on a number of factors and the amplitude of the surface EMG signal (sEMG) varies from the uV to the low mV range. The amplitude and time and frequency domain properties of the sEMG signal are dependent on factors such as [6]:

- the timing and intensity of muscle contraction
- the distance of the electrode from the active muscle area
- the properties of the overlying tissue (e.g. thickness of overlying skin and adipose tissue)
- using the same electrodes and amplifier (i.e. same signal conditioning parameters)
- ensuring consistency in the quality of contact between the electrodes and the skin

Measuring and accurately representing the sEMG signal depends on the properties of the electrodes and their interaction with the skin, amplifier design, and the conversion and subsequent storage of the EMG signal from analog to digital form (i.e. A/D conversion). The quality of the measured EMG is often described by the ratio between the measured EMG signal and unwanted noise contributions from the environment. The goal is to maximize the amplitude of the signal while minimizing the noise [6]. Most importantly, the design of the electrode unit is the most critical aspect which is being used to obtain the signal, therefore it is important to devise an electrode unit that provides minimal distortion and highest signal-to-noise ratio.

1.3 Surface Electrodes

There are two categories of surface electrode: passive and active. Passive electrode consists of conductive (usually metal) detection surface that senses the current on the skin through its skin electrode interface. Active electrodes contain a high input impedance electronics amplifier in the same housing as the detection surfaces. This arrangement renders it less sensitive to the impedance of the electrode–skin interface [3]. The current trend is towards active electrodes.

- Advantages
  - Quick, easy to apply
  - No medical supervision, required certification
  - Minimal discomfort

- Disadvantages
  - Generally used only for superficial muscles
  - Cross-talk concerns
  - No standard electrode placement
  - May affect movement patterns of subject
  - Limitations with recording dynamic muscle activity

1.4 Problem Statement

From the background of study mentioned in earlier pages, it can be observed that the electromyography has been used for many usages mostly for clinical purposes. It is because the most common manifestations in patients with idiopathic inflammatory myopathies are on muscle weakness and muscle fatigue. One of it is stroke. Stroke has been the commonest cause of death or even the most frequent cause of severe adult disabilities. The impact of stroke on individual can lead to [7]:

- Pathology (disease or diagnosis): operating at level of the organ system

- Impairment (symptoms and signs): operating at the level of the whole body
- Activity (disability): observed behavior or function
- Participation (handicap): social position and roles of the individual

Figure 3 shows the worldwide statistic of death which caused by stroke.

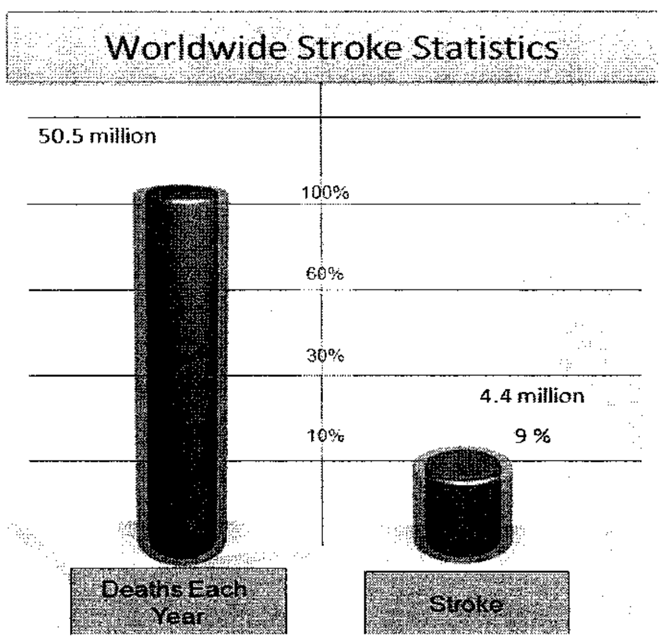


Figure 3: Worldwide stroke statistics

Electromyography is one of the technique which can play a vital role for the rehabilitation of Stroke patients as a diagnostic tool, therefore the implementation of this technique is a very vast process, however the very 1st step is to get the EMG system in order to acquire the signals from the specific Muscle which is being focused for rehabilitation purpose.

1.5 Objective

- To understand and study on the basic concept of electromyography (EMG)
- To have understanding on muscle characteristics and its contraction during the performance of a task
- To analyze and justify the data acquired
- Classification of EMG signals

1.6 Scope of study

The scope of study for this project is to acquire the signal from the muscle activity by doing the simulation using simulink/MATLAB for analyzing the acquired data. For this project, the sEMG signals acquisition will be limited on certain area such as measuring the muscle activity from the human arm such as: Biceps, etc. Once the signals are acquired by using EMG system or some source where signals' data can be achieved from data base then the detail analysis can be carried out. Therefore, it is very important to have several signals from group of people of different age, gender and muscle type as well as the strength of muscles, thus to obtain signals then the comparison can be made so that the classification of those EMG signals could be performed in terms of age group, etc.

CHAPTER 2
LITERATURE REVIEW

Theory:

This section will be discussing on the fundamentals of electromyography (EMG) itself that deals with the single motor unit action relations and the related time frequency-domain. It will also cover the study of the EMG technique, theory, development and its application which are being taken mostly from the books, journals, articles, and the paper work done by previous researchers.

2.1 Basic concept of Electromyography

Our body has being gifted with a very unique system that allows us to communicate with our surrounding in its own ways. One of the systems is the muscular system where to gain the understanding of EMG signals implies the understanding of muscles and the way they generate bioelectrical signals.

2.1.1 Motor units and force

The most fundamental functional unit of a muscle is called the motor unit. It consists of an a-motoneurons and all the muscle fibers that are innervated by the motoneuron's axonal branches. The electrical signal that emanates from the activation of the muscle fibers of a motor unit that are in the detectable vicinity of an electrode is called the motor unit action potential (MUAP). This constitutes the fundamental unit of the EMG signal [3]. Figure 4 shows the on how the force is produced from the motor unit activation [9].

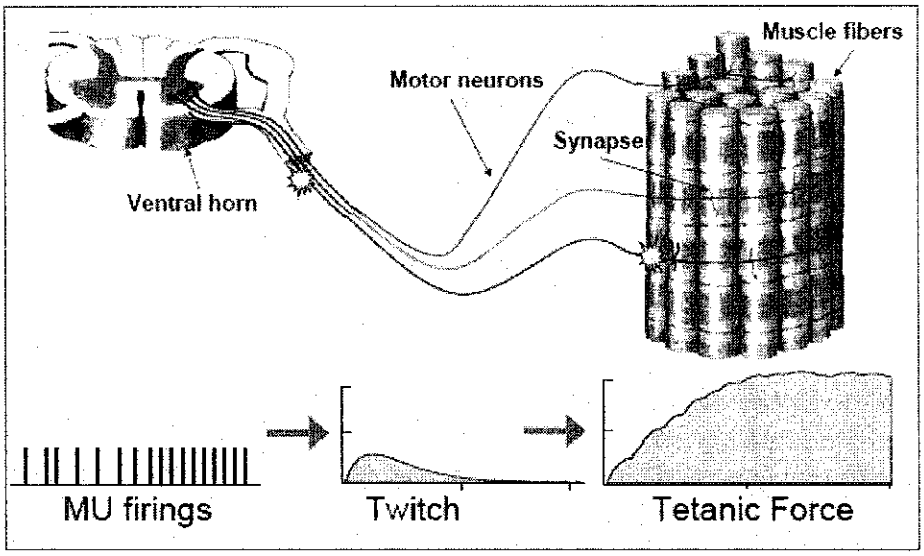


Figure 4: Motor units and force

2.1.2 Motor Unit Action Potential

Motor unit action potential or **MUAP** is the electrical signal that emanates from the activation of the muscle fibers of a motor unit that are detectable vicinity of an electrode [18]. It is also being defined as the spikes of electrical activity recorded during an EMG that reflect the number of motor units (motor neurons and the muscle fibers they transmit signals to) activated when the patient voluntarily contracts a muscle.

There are several factors that influence the shape of the MUAP [18].

- The relative geometrical relationship of the detection surfaces of the electrode and the muscle fibers of the motor units in its vicinity.
- The relative position of the detection surfaces to the innervations zone that is the region where the nerve branches contact the muscle fibers.
- The size of the muscle fibers because the amplitude of the individual

action potential is proportional to the diameter of the fiber.

- The number of muscle fibers of an individual motor unit in the detectable vicinity of the electrode.

Figure 5 shows schematic representation of the genesis of a MUAP [18].

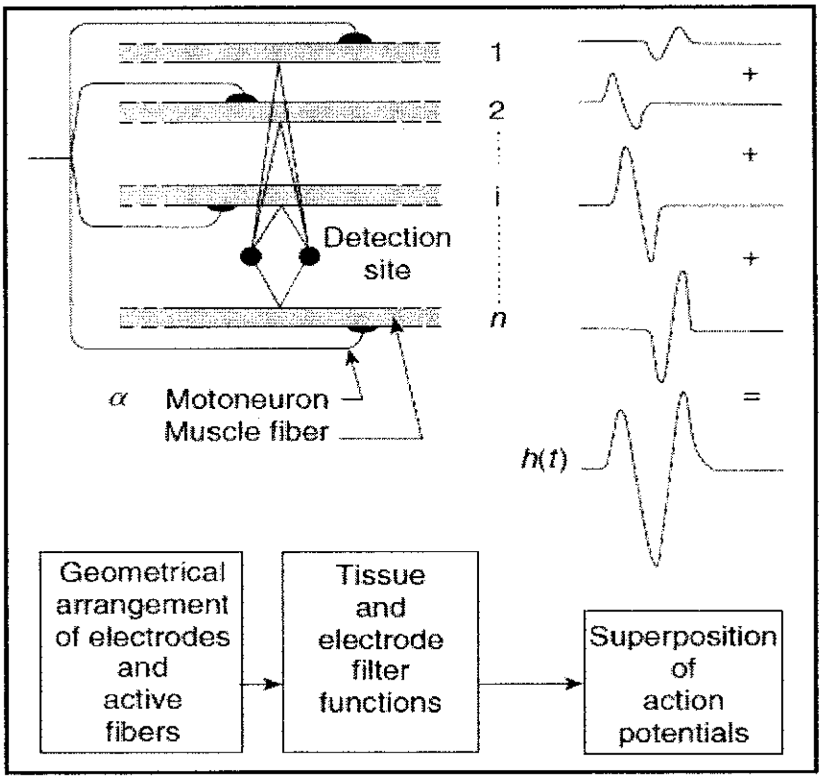


Figure 5: Schematic representation of the generation of the motor unit action potential

The force produced is come from the recruitment of motor units and the regulation of the firing rates which has modulating it. It can be seen from Figure 5 that the muscle force is varying at certain level based on the motor unit firing.

2.1.3 Motor Unit Action Potential Trains

MUAPT or motor unit action potential train is a sequence of motor unit action potential when the electrode placed recorded the pulse (MUAP) whenever a motor unit is stimulated [18, 12]. Figure 6 shows the motor unit control and the EMG produced from the summation of the MUAPT [13].

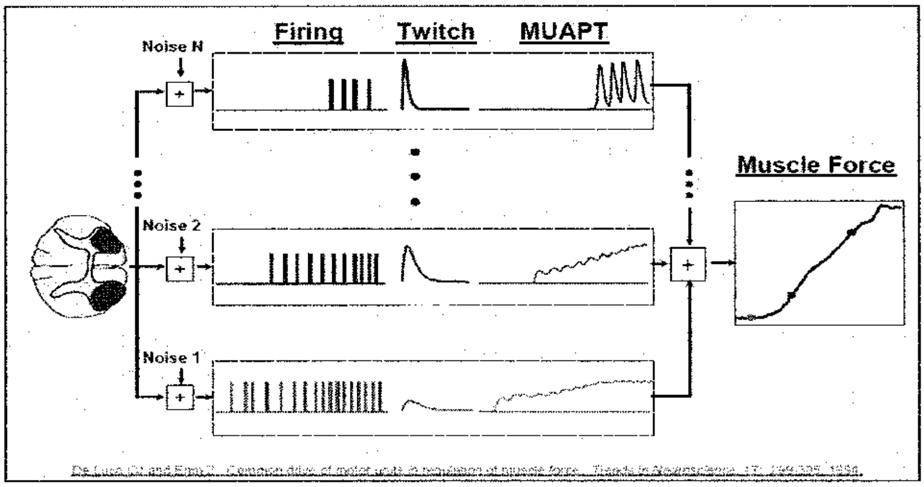


Figure 6: Motor Unit Control and Force

It is called as train because of the repetitive firings by the motoneurons that later creates a train of impulses. Every time the motor units were recruited or de-recruited, the EMG signals will be produced from the variance that happened to it.

The geometric relationship between the electrode and the active muscle fibers need to be constant to ensure the waveform of the MUAPs within a MUAPT will remain constant. Another factor that also needs to be considered is the properties of the recording electrode did not change and if there are no significant biochemical changes in the muscle tissue [18].

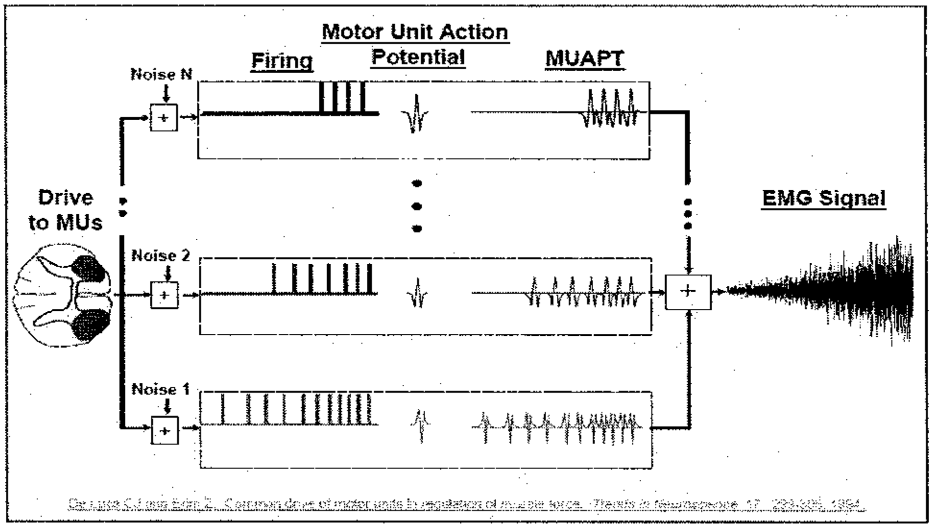


Figure 7: Motor Unit Control and EMG

In above Figures 6 & 7 show the motor unit control and the EMG produced from the summation of the MUAPT [9]. MUAPT or Motor Unit Action Potential Train is the time sequence of the firing of one motor unit which occurs when there are repetitive firings by the motoneurons that later creates a train of impulses [10].
The EMG signal produced from the variance that happened to the motor units every time it were recruited or de-recruited. Basically, in muscle potential work, one should think of the muscle as a source of electrical activity surrounded by a low-resistance conducting medium (the interstitial fluid, blood and other tissues), usually referred to as a "volume conductor". This, in turn, is surrounded by skin, a two-layer membrane consisting of a metabolizing layer of living cells, glands and accessories, having a relatively low electrical resistance, and a non-metabolizing layer of horny, dead and dying cells which has a high electrical resistance [11].

2.2 Description of EMG signal

The EMG signal is the electrical manifestation of the neuromuscular activation associated with a contracting muscle. The signal represents the current generated by the ionic flow across the membrane of the muscle fibers that propagates through the intervening tissues to reach the detection surface of an electrode located in the environment. It is a complicated signal that is affected by the anatomical and physiological properties of muscles and the control scheme of the nervous system, as well as the characteristics of the instrumentation used to detect and observe it.

In order to understand the EMG signal, it is necessary to appreciate some fundamental aspects of physiology. Muscles fibers are innervated in groups called motor units, which when activated generate a motor unit action potential. The activation from the central nervous system is repeated continuously for as long as the muscle is required to generate force. This continued activation generates motor unit action potential trains. These trains from the concurrently active motor units superimpose to form the EMG signal. As the excitation from the Central Nervous System increases to generate greater force in the muscle, a greater number of motor units are activated (or recruited) and the firing rates of all the active motor units increase.

2.3 Basic EMG circuit

The basic circuit of EMG acquisition system was constructed from 3 major sections which are electrode-muscle interface, amplifier and the signal processor. Figure 8 shows the basic EMG circuit of the system [8].

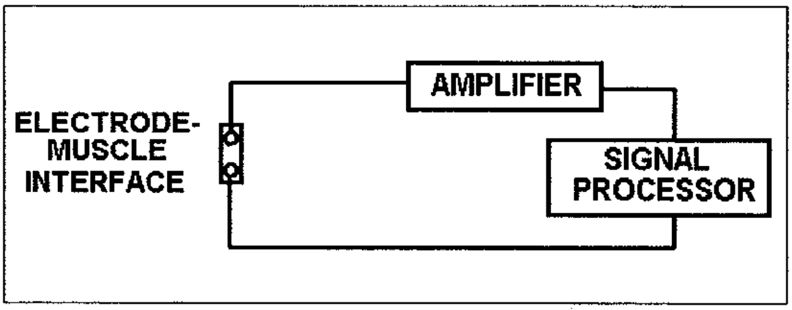


Figure 8: General circuit of the EMG acquisition system

The signals obtained from the electrode-muscle interface will be amplified as it is very small and the signals detected by the surface electrodes are in range of 5mV. The signal processor will processed the signals acquired to obtain the desired signals based on the design specification. The outcome measured of this system is analyzed for voltage reading. A voltage difference or difference in electrical potential (E=Ir) measured between recording electrodes.
The figure 9 shows the outcome desired from the process shown above [13].

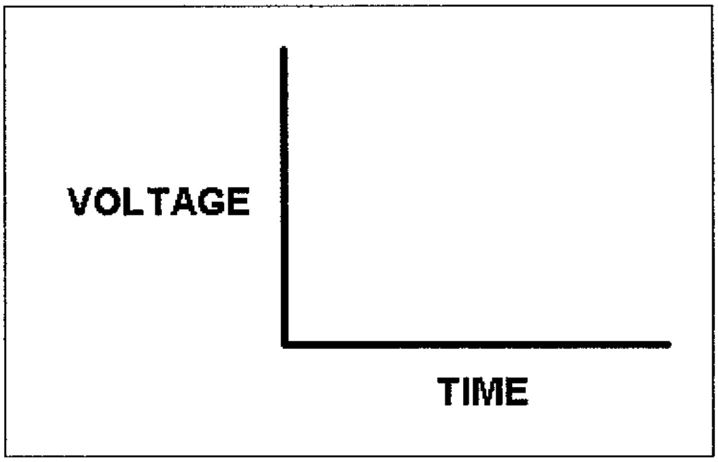


Figure 9: The outcome measured

The signals that being sampled can be analyzed by applying the Ellaway's cumulative sum histogram technique [13]:

$$S_i = \sum x_i - \overline{x}$$

Where S_i = cumulative sum up to sample i

X = mean voltage over trial

x_i = voltage at sample i

The geometric relationship between the electrode and the active muscle fibers need to be constant to ensure the waveform of the MUAPs within a MUAPT will remain constant. Another factor that also needs to be considered is the properties of the recording electrode did not change and if there are no significant biochemical changes in the muscle tissue [18].

To describe a MUAPT can be done via the time between the adjacent MUAPs which is its inter-pulse intervals and the waveform of the MUAP. The shape of the MUAP can be represented mathematically by expressing the inter-pulse intervals as a sequence of Dirac delta impulses $\delta i(t)$ that is convoluted with a filter $h(t)$. Figure 10 shows a graphic representation of a model for the MUAPT [18].

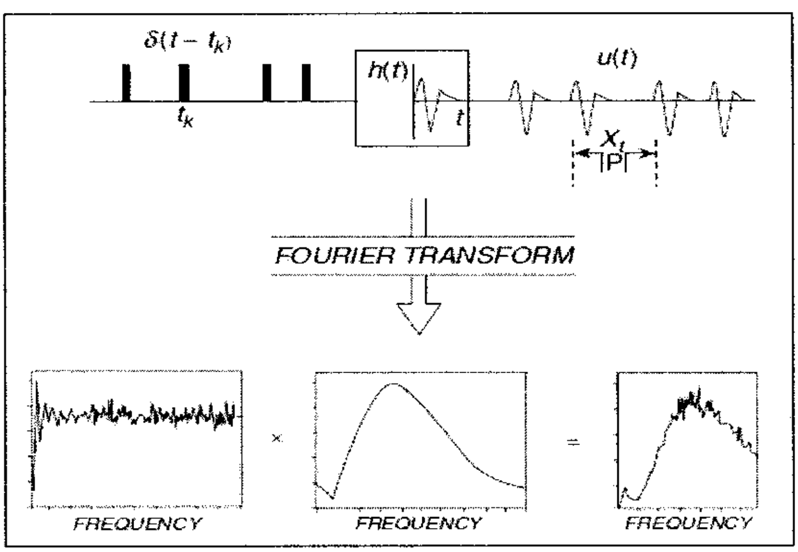


Figure 10: Model for a MUAPT in Fourier Transform modeling

From the model above, the MUAPT, $u_i(t)$ can be expressed as,

$$u_i(t) = \sum_{k=1}^{n} h_i\ (t - t_k) \tag{1}$$

where,

$$t_k = \sum_{i=1}^{k} x_i \; for k, l = 1, 2, 3, \dots, n \qquad (2)$$

In the above expression it represents as:

t_k= time locations of the MUAPs

x = the inter-pulse intervals

n = total number of inter-pulse intervals in a MUAPT

i, k, l = integers that denote specific events

2.3.1 The EMG Signal

By linearly summing the MUAPTs, the EMG signal may be synthesized by expressed it in the equation below where,

$$\mathrm{m}(t, F) = \sum_{i=1}^{p} u_i\,(t, F) \qquad (3)$$

F = force generated by the muscle and is the firing rate of the motor unit

p = the total number of MUAPTs that constitute the signal

This approach is used as in Figure 10 which consists of 25 Motor Unit Action Potential Trains (MUAPT). These are synthesized signals with shapes that closely represent the characteristics of real action potential [9]. Mathematically, these 25 generated MUAPTs were added to yield the signal the signal at the bottom. Figure 11 shows the EMG signal formed from the constituents MUAPTs [18].

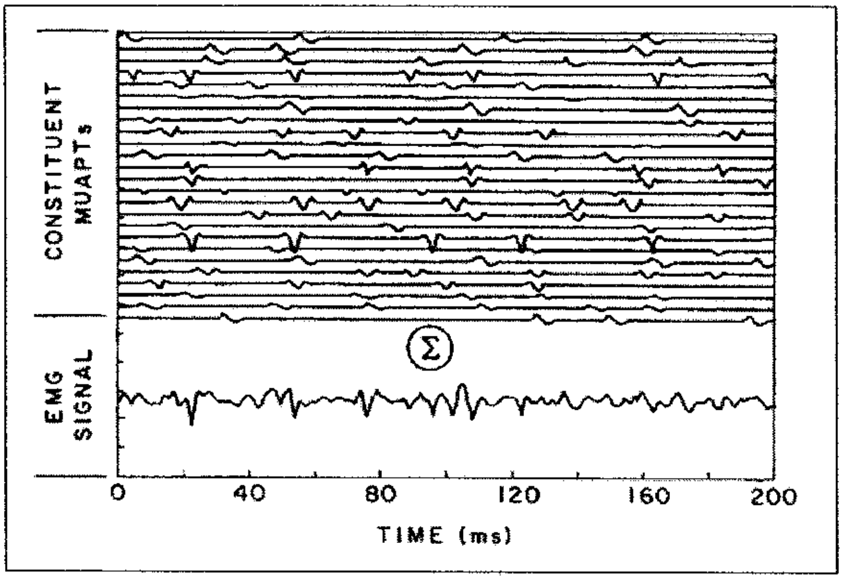


Figure 11: An EMG signal formed by adding or superimposing 25 mathematically generated MUAPTs.

The combination of the muscle fibers action potentials from all muscle fibers of a single motor is the motor unit action potential (MUAP) which also can be expressed by the simple model of the EMG signal as follows [19]:

$$x(n) = \sum_{r=0}^{N-1} h(r)e(n-r) + w(n) \tag{4}$$

Where,

$x(n)$ = modeled EMG signal

$e(n)$ = point processed that represents the firing impulse

$h(r)$ = represents the MUAP

$w(n)$ = zero mean addictive white Gaussian noise

N = The number of motor unit firings

2.4 Concept of Frequency Spectrum

Normally, the EMG signal need to be expressed in term of frequency spectrum where the sEMG signal constructs have to be in the approximate range with the peak place in the middle of the spectrum [9].

2.5 Basic Concept of Filtering

Filter is used to avoid noise from the signal acquired from the muscle. Since the signals need to be free from noise contamination, filter is applied which one can determine type of filter that can be used for example Chebysev or Butterworth and etc. Figure 12 shows the EMG signal with baseline noise and artifact reduced which is being filtered from range 20-450Hz [9].

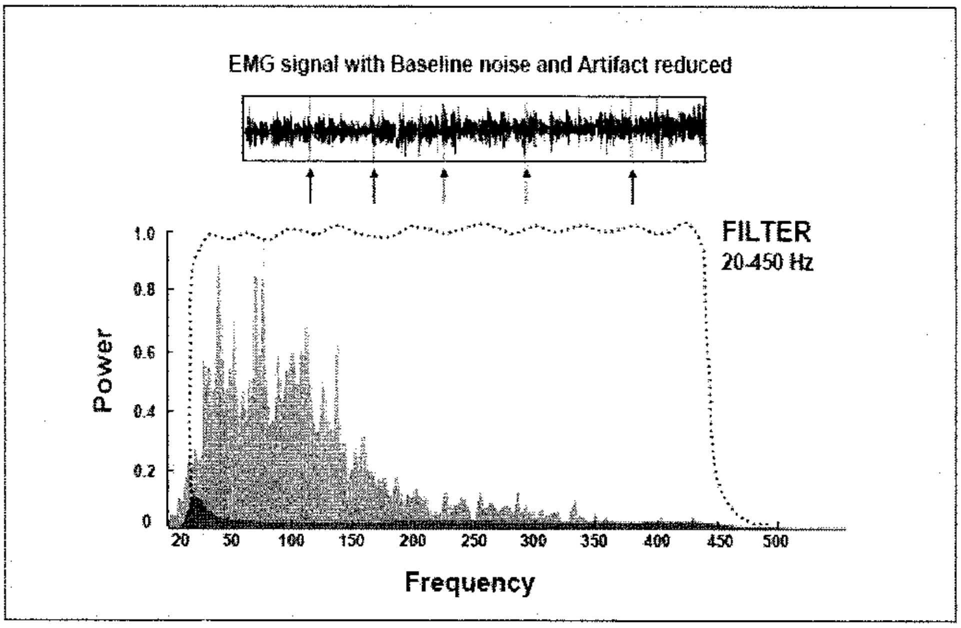


Figure 12: EMG signal with baseline noise and Artifact reduced

2.6 Recent Research and Development of EMG

Since the EMG technique offered many advantages as diagnostic tools, many research and development have been done in order to obtain a good quality of EMG signal.

2.6.1 Analysis on the surface EMG Signal

Many researchers have studied on the sEMG signal characteristics and analyzed it into various forms of mathematical model such as time domain analysis, Fourier Transform, relative wavelet packet energy and many more. Based on the RWPE, this technique has introduced an analysis done for the spectral energy distribution from two stages: preparation stages and action stages which is involved the calculation of the frequency band and rate of change of it during both stages above. It is because the researcher found that by analyzing on the spectral energy distribution, some of the muscle contraction in a different stages of limb actions can be measured compared to time-frequency domain that can only focused on a surface EMG signal at one stage of limb action [14].

As to the Method of Hilbert-Huang Transform, the analysis of the data has been narrowed down by looking into the finite and small number of Intrinsic Mode Functions (IMF) from the Empirical Mode Decomposition (EMD) that can be analyzed on the instantaneous frequency based on the local properties of the signal. However, IMF can only be used if it can satisfy two conditions: (1) the number of external and the number of zero crossing must either equal or differ at most by one from the whole data set; (2) and at any point, the mean value of the envelope defined by the local maxima where the local minima is zero from the enveloped definition [15].

Compared to two methods above, the Autoregressive Model (AR) is being used to represent the sEMG signal with the delay of intramuscular EMG as the input where it had been chosen by many researchers because of its computational speed.

Other methods that widely used is the Neural Network, one of the Artificial Intelligent (AI) technique which one's output is representing the degree of desired muscle stimulation over a synergic but an enervated muscle [14].

2.6.2 Existing Methods using surface EMG

This EMG technique is being used widely in many areas and because of that some researcher have implemented it and used for many purposes. Basically, there are products using EMG that exist today but they were focused on the signal acquired from the muscles and location of measuring the muscle activity that suite with their research like acquiring signal from handwriting and movement[16], measuring the consumer reaction while participating in a consumer activity [17], and etc.

EMG Signal Classification for Myoelectric Teleoperating a Dexterous Robot Hand, a strategy of discriminating finger motions using surface electromyography (EMG) signals, which could be applied to teleoperating a dexterous robot hand or controlling the advanced multi-fingered myoelectric prosthesis for hand amputees. Finger motions discrimination is the key problem in this particular research study. The EMG signal classification system was established based on the surface EMG signals from the subject's forearm. Four pairs of electrodes were attached on the subjects to acquire the signals during six types of finger motions, i.e. thumb extension, thumb flexion, index finger extension, index finger flexion, middle finger extension, and middle finger flexion. In order to distinguish these finger motions. A combination of autoregressive (AR) model and an Artificial Neural Network (ANN) was used in the system. The discrimination procedure consists of two steps. Firstly, the AR model is used to preprocess the surface EMG signals to reduce the scale of the data. These data will be imported into the myoelectric pattern classifier. Secondly the coefficients of AR model are imported into the ANN to identify the finger motions. The theory about grasping and manipulating of dexterous robot hands has been studied in the past three decades. A number of algorithms for grasping, mechanics, and control have been proposed by researchers. Utah/MIT Dexterous Hand [20] is one of the most famous dexterous robot hands in the world and some myoelectric teleoperation studies [21] have been applied to it. The system proves an alternative procedure in finger motion classification. [23].

2.6.3 Similar technique (fuzzy logic) used for Prosthesis control

In this research, fuzzy EMG classification for prosthesis control which proposes a fuzzy approach to classify single-site electromyograph (EMG) signals for multifunctional prosthesis control. While the classification problem is the focus of this paper, the ultimate goal is to improve myoelectric system control performance, and classification is an essential step in the control. Time segmented features are fed to a fuzzy system for training and classification. The fuzzy approach was compared with an artificial neural network (ANN) method on four subjects, and very similar classification results were obtained. It is superior to the latter in at least three points: slightly higher recognition rate; insensitivity to overtraining; and consistent outputs demonstrating higher reliability. Some potential advantages of the fuzzy approach over the ANN approach are achieved.

To perform classification, the EMG signals were divided into several time segments to preserve pattern structure, and features were extracted from these segments. The features included mean absolute value (MAV), mean absolute value slope (MAVSLP), number of zero-crossings (ZC), slope sign changes (SSC), and wave length or wave complexity (WC). This is a new fuzzy approach for classification of EMG patterns. The training process and classification results of the proposed method are superior to those of a neural network-based approach, primarily in that the fuzzy system gives more consistent classification results and is insensitive to over-training. These features may be attributed to the structure of the ISO-FUZ system and the "supervised" selection of fuzzy set initialization data by the Basic Isodata algorithm. More favorably, it can adopt expert experience at the same time by additional fuzzy units in parallel. The fuzzy approach described in this paper can be universally applied to other classification problems as well [24].

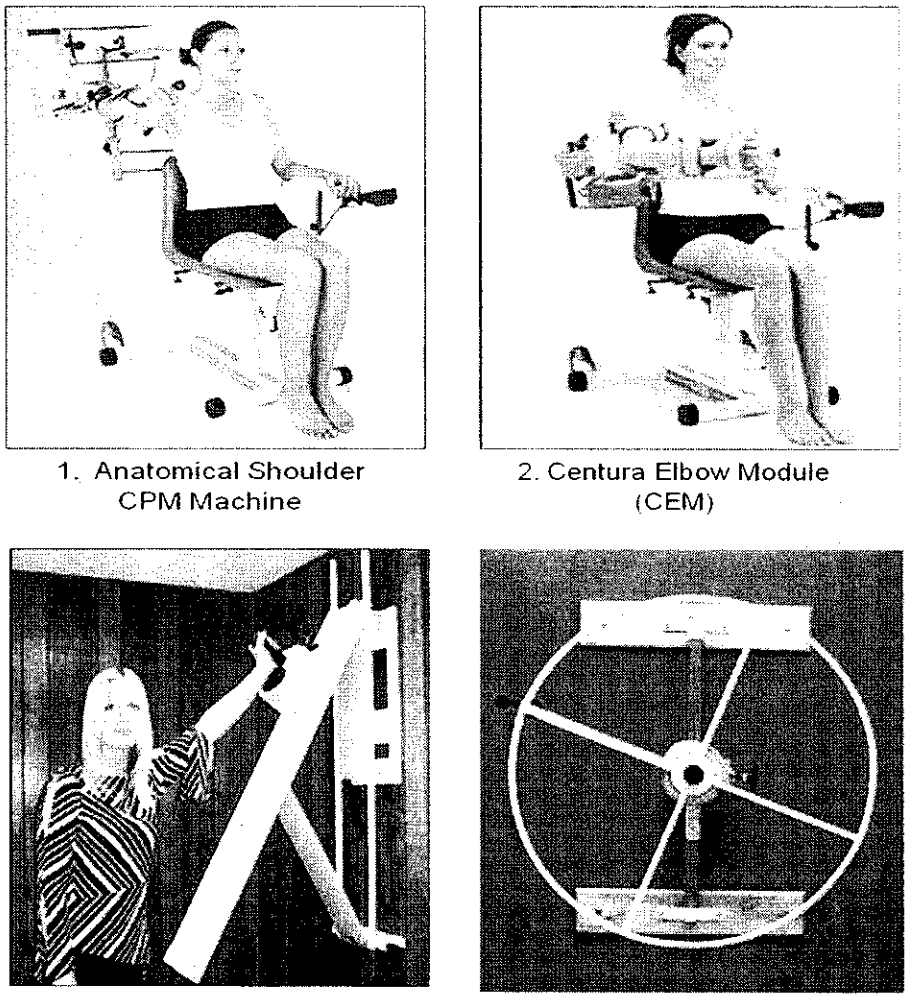
2.7 Current methods for rehabilitation

The health care for the aging has been a popular considered issue. With the growth of ages. the physical condition degenerated so that the diseases were possibly produced. According to the analytical report (Kung, 2008), Cerebrovascular Disease has become the top three causes of death in America. In Taiwan, Cerebrovascular Diseases also occupied the third cause of death for the year 2007 (Department of Health, Executive Yuan of R.O.C., 2008). It is also still a main cause contributes to the stroke.

Upper-extremity motor deficit is one of the main symptoms for the stroke patients (Gowland et al, 1992).. About 85% stroke patients have function impairment on upper-extremity at the beginning stage of the stroke, and still about 40% patients have function impairment at the final stage of stroke (Mccrea et al, 2002). Some common upper-extremity symptoms of stroke patient are feeble muscle strength, unnatural synergies, and deficit in coordination within the joints. (Levin et al, 1996). In order to recover the function for daily life, the rehabilitation therapy is needed for the stroke patients. During the rehabilitation therapy, the doctor need to diagnose the stroke level of each stroke patient, then selected a suitable therapy product for rehabilitation to restore their movement function. A good rehabilitation product can increase the therapy performance and do therapy by themselves.

The current study investigated various rehabilitation equipments in many hospitals and few of the commercial products are as follows:

1. Anatomical Shoulder CPM Machine
2. Centura Elbow Module (CEM)
3. Shoulder Slide
4. Calibrated Shoulder Wheel



1. Anatomical Shoulder CPM Machine
2. Centura Elbow Module (CEM)
3. Shoulder Slide
4. Previous Work / Related Work

Figure 13: Commercial products for rehabilitation

Alterations in Electromyographic (EMG) timing and intensity during moving any part of body which result from both reduced activation and from compensations for loss of force, few studies have described muscle activity patterns in the early post-stroke phase, the impact of reduced muscle activation and resultant weakness on the characteristic patterns of moving after stroke could be identified in individuals.

CHAPTER 3
METHODOLOGY

This section is about the project flow chart that is being design to get the overview on the process throughout the given period and tools that will be used to implement the project from the research done.

3.1 Project Flow Chart

Figure 14 shows the flow of project during the whole semester for FYP 1 and FYP 2.

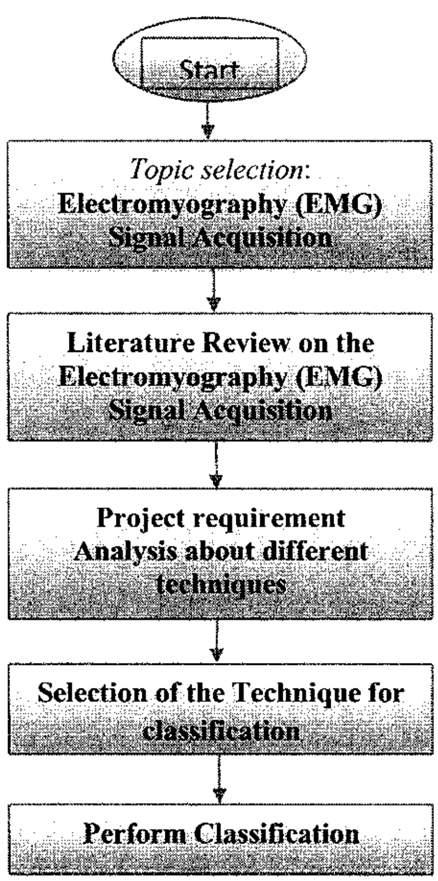


Figure 14: Project Flow Chart

3.2 Topic Selection

At the beginning of the final year first semester, students are required to propose their own projects or to select the topics which have been listed by the FYP coordinators. Thus, this project Electromyography (SEMG) signal acquisition and classification has been proposed by the author as a final year project (FYP).

3.3 Literature Review on EMG Signal Acquisition

Eventually, for further proceeding towards the selected project, it is important to gather relevant data or information as much as possible in order to have understanding in depth of all parameters of selected topic and study about the analysis on the acquired signal by using several techniques which have been implemented previously on this area of research. The literature review has been discussed in Chapter 2.

3.4 Analysis on the Project Requirement

Throughout the review on this topic, an analysis has been carried out to find out the requirements required for this project as well as the tools and equipments which will be used for further processing are discussed below.

3.4.1 Tools and equipment required

- MATLAB/Simulink:

For the data acquisition, MATLAB will be used to analyze the data collected from the several experiments. MATLAB is known as the high level language used for technical computing. Moreover, it can be used in a wide range of applications such as image processing, control design, communication and many more. By using MATLAB, the computation, visualization of image and programming can be integrated using the interactive tools provided [12].

↳ PC (Personal Computer)/ Laptop:

For the data acquisition purpose, PC or laptop needs to be used because the data collected through the MATLAB will be sent to the PC/laptop to be stored for further analysis and processing.

↳ Sensor:

The sensor or electrode is an instrument which is used to detect the electrical potential generated by muscle cells when these cells are electrically activated. It can be measured by applying respective EMG sensor or electrode to the particular muscle and then the acquired signal is analyzed for further processing by using MATLAB/Simulink.

3.5 Project Design

Figure 15 and 16 show the overview on EMG acquisition and the block diagram of EMG system respectively, for this project which is comprised into 3 sections:

1. EMG signal Measurement

2. Processing Unit

3. Software for analysis

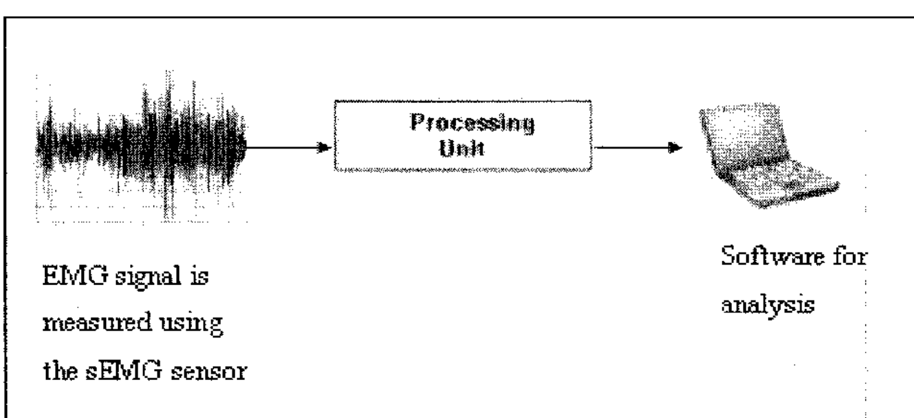


Figure 15: Overview on EMG acquisition

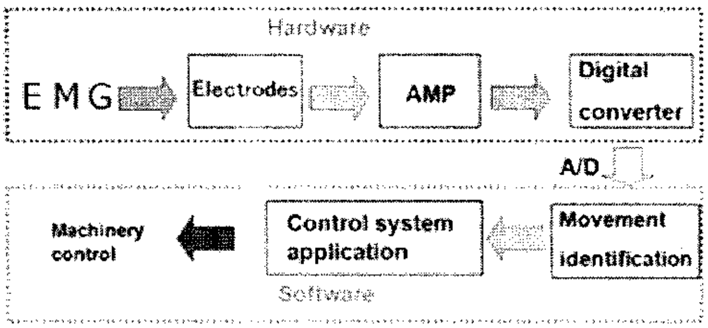


Figure 16: A block diagram of EMG system

3.5.1 *Surface EMG Signal Measurement example*

The surface EMG signal is measured using the surface EMG electrodes. To pick up the EMG signals from the skin surface, electrodes will be needed - two go over the muscle which were recorded to the preamplifier - while the third electrode is a ground and just needs to be connected somewhere close to the muscle that will be recorded. This electrode will be pasted at a particular area on the hand. A clip is used to connect the EMG electrodes with the processing unit. The electrode will be placed as in the positions shown by the black circles in this illustration. However, it is very important that the two electrodes lie ALONG the line of the muscle as shown in Figure 17 and not across the muscle. With the hand relaxed positions, a very little activity can be seen depending on how well one can relax their thumb. By touching the little finger the thumb - this will cause the muscles shown to contract and generate an EMG signal. The EMG signal will be about 100-300mV. Figure 17 shows the illustration of a hand with black circles indicates on the electrodes placement onto the subject palm.

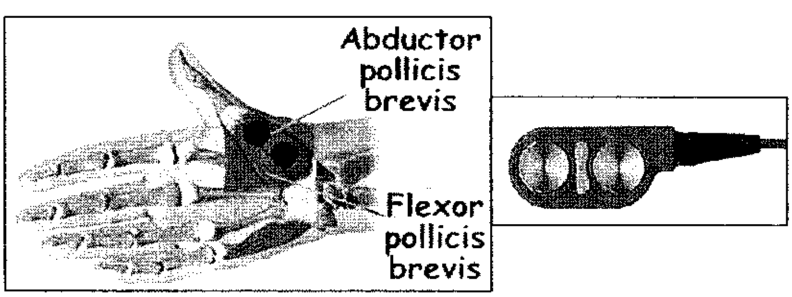


Figure 17: Black circles indicate the position of the electrodes and on the right side shows a sample of Surface Electrode.

Basically, when the hardware is setup, the earlier signal detected is sine wave signal which is the AC line pickup. This is either because one or both of the round electrodes are not pressed firmly against the skin or because of the electrodes is not having a good ground. Thus, adding a ground electrode by just holding a wire that connects to the black lead and central battery connection with the other hand.

3.5.2 Processing Unit

In this processing unit, there will be transmitter and receiver unit. The connection between these two units can be done via wireless transmission as previous research [15] but for this project the transmission maybe can be adjusted using infrared or Bluetooth transmission. All these types of transmission have its own pros and cons.

3.5.3 Software for Analysis

The acquired signal is processed into given software of sEMG system. Moreover, signal will be sent into MATLAB for analyzing it for further processing and to perform classification.

3.6 Project Development

The author has to utilize the knowledge in this project for understanding all aspects of the topic in order to perform classification of acquired EMG signals in terms of groups such as: age group, gender group and muscle group, etc. The final form of the project consists of a successful finding on how the signals from the surface EMG can be acquired from the system or from any data base, thus the performance of the muscles can be determined. Several signal data will be required of individuals of different age, gender and muscle strength, etc, in order to do comparison by selection features of the signals so that classification of signals will be performed. In addition, it is required to process the acquired signals and send the data to a PC and then MATLAB will be used to model the EMG signals for signals' classification in terms of age, gender and muscle type groups, etc.

Table 1 shows the Typical EMG classifications systems

Classifier	Features	Channels	Data window	Correct rate	Year	Delay	Comment
Bayes classifier	Zero crossing (ZC) variance	2	160ms	91%	1984	_	Data set not from Amputee but from Immobilized limb
Nonlinear discriminant function	Coefficients of AR model	1	40ms	99%	1982	2.5s	Based on computer for that period, took hours.
Fuzzy system	FFT results	1	Not specified	80% - 90%	1991	_	Lower rate for test set; inference not robust
Neural Network	MAV, ZC, etc	1	200ms	70% - 98%	1993	<300ms	Rate is subject-dependent

The classification tools covered linear discriminate functions, neural networks, and fuzzy systems. Researchers have applied different kinds of mathematical models and pattern recognition techniques to the problem; however, they are not yet commercially available. Table 1 gives a brief summary of some typical EMG recognition systems [24].

3.7 Selection of Classification tool

Fuzzy logic systems are advantageous in biomedical signal processing and classification. Biomedical signals are not always strictly repeatable, and may sometimes even be contradictory. One of the most useful properties of fuzzy logic systems is that contradictions in the data can be tolerated. Furthermore, using trainable fuzzy systems, it is possible to discover patterns in data which are not easily detected by other methods, as can also be done with neural network. Finally, the experience of medical experts can be incorporated. It is possible to integrate this incomplete but valuable knowledge into the fuzzy logic system due to the system's reasoning style, which is similar to that of a human being. This is a significant advantage over the artificial neural network (ANN). In order to search for an improved solution to the EMG classification technique.

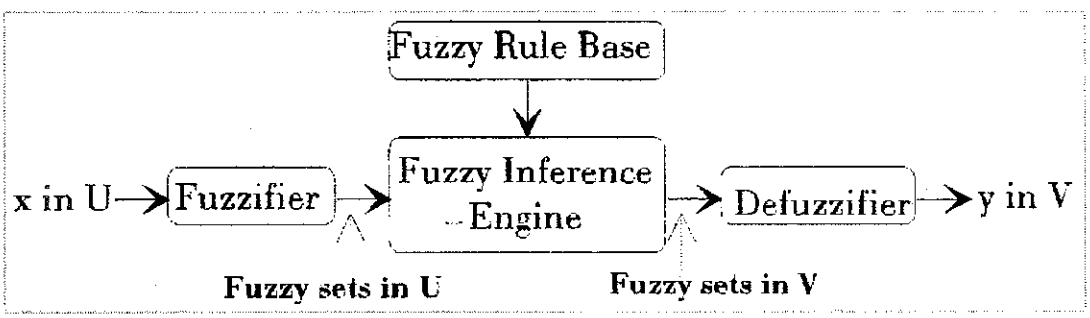


Figure 18: Basic configuration of fuzzy logic system with fuzzifier and defuzzifier

Fuzzy logic systems emulate human decision-making more closely than the ANN. The fuzzy systems at first fuzzify inputs into membership degrees of fuzzy sets, and then infer by fuzzy logic through rules which usually come from experience. Fuzzy systems have been widely applied in solving control problems. In short, soft computing approaches are good at coping with imprecisely-defined situations in a model-free way, without having to model a system beforehand. In other words, they are sufficiently "soft" to be versatile models. The kernel of a fuzzy system is the fuzzy inference engine. The knowledge of an expert or well-classified examples are expressed as or transferred to a set of "fuzzy production rules" of the form IF-THEN, leading to algorithms describing what action or selection should be taken based on the currently observed information. In the fuzzy method, nothing is done at random. Information containing a certain amount of vagueness is expressed as faithfully as possible, without the distortion of forcing it into a "crisp" mold, and it is then processed in a proper manner.

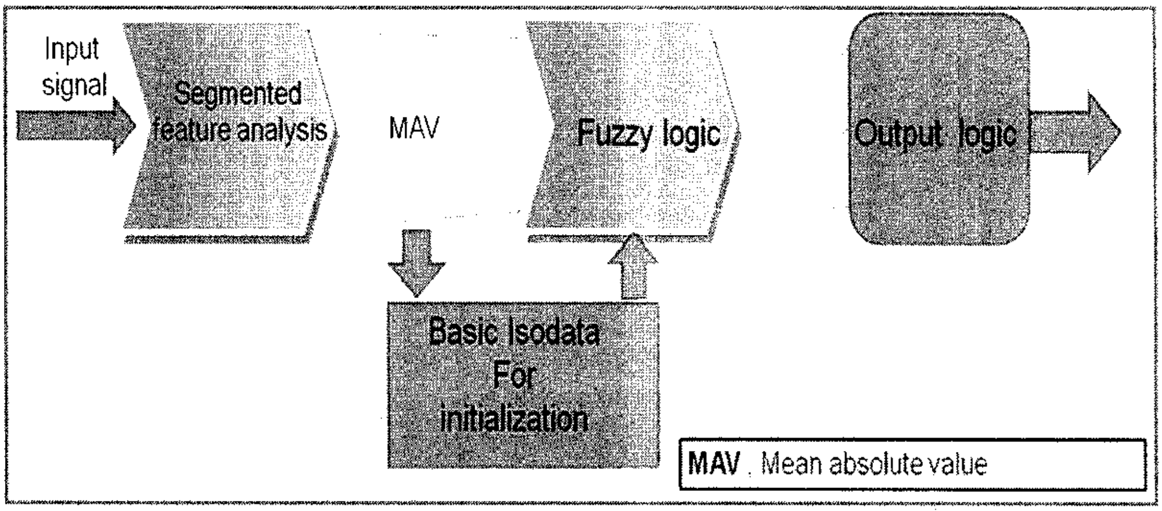


Figure 19: Schematic diagram of Fuzzy approach for EMG classification

The initialization of fuzzy sets in fuzzy logic system is activated only once with clusters generated from Basic ISODATA algorithm; fuzzy logic system is trained and generates four outputs representing the possibility of each function; Output logic makes choice among these three outputs.

CHAPTER 4
RESULTS AND DISCUSSION

The results include the acquired data and the technique implemented to carry out the Classification which is the main objective of this project.

4.1 Results

Table 2 shows the acquired EMG signals from the group of subjects.

No.	Signal Data	Muscle	Age
1.	Data 1	Biceps	38
2.	Data 2	Biceps	25
3.	Data 3	Biceps	29
4.	Data 4	Biceps	54
5.	Data 5	Biceps	27
6.	Data 6	Biceps	38
7.	Data 7	Biceps	39
8.	Data 8	Biceps	36
9.	Data 9	Biceps	35

10.	Data 10	Biceps	37
11.	Data 11	Biceps	34
12.	Data 12	Biceps	35
13	Data 13	Biceps	33
14.	Data 14	Biceps	32
15.	Data 15	Biceps	52
16.	Data 16	Biceps	28
17.	Data 17	Biceps	48
18.	Data 18	Biceps	27
19.	Data 19	Biceps	36
20.	Data 20	Biceps	37
21.	Data 21	Biceps	32
22.	Data 22	Biceps	45
23.	Data 23	Biceps	32
24.	Data 24	Biceps	38
25.	Data 25	Biceps	39
26.	Data 26	Biceps	36
27.	Data 27	Biceps	35
28.	Data 28	Biceps	33

29.	Data 29	Biceps	34
30.	Data 30	Biceps	44

In the above table shows the acquired EMG signals from the data base which are experimented on different subjects' biceps muscles and it is observed from the signals' data base that these signals can be classified in terms of age group such as: (20-30), (31-40), (41-50) and (<50). Hence to perform classification the Mean absolute value is selected as Feature recognition method by using Fuzzy logic technique. When any input signal is fed into the classifier then it will be classified in terms of age group by calculating the mean values of input signal, since the ranges of mean values and conditions have been initialized in fuzzy logic in order to differentiate any input signal to the right group of age. In the table 3 shown below the EMG signals are categorized in terms of age group but if any input of EMG signal to the classifier then it will classify the signal into the related group by monitoring its mean value since it satisfies the condition of a range among the specified age group.

Table 3: Classified EMG signals in terms of Age group

	Age Grouping	No. of signals
A	From 20 to 30	5
B	From 31 to 40	20
C	From 41 to 50	3
D	< 50	2
		30

Figure 20 shows the acquired EMG signals from the subjects of having different age such as age: 33 and age: 27, respectively.

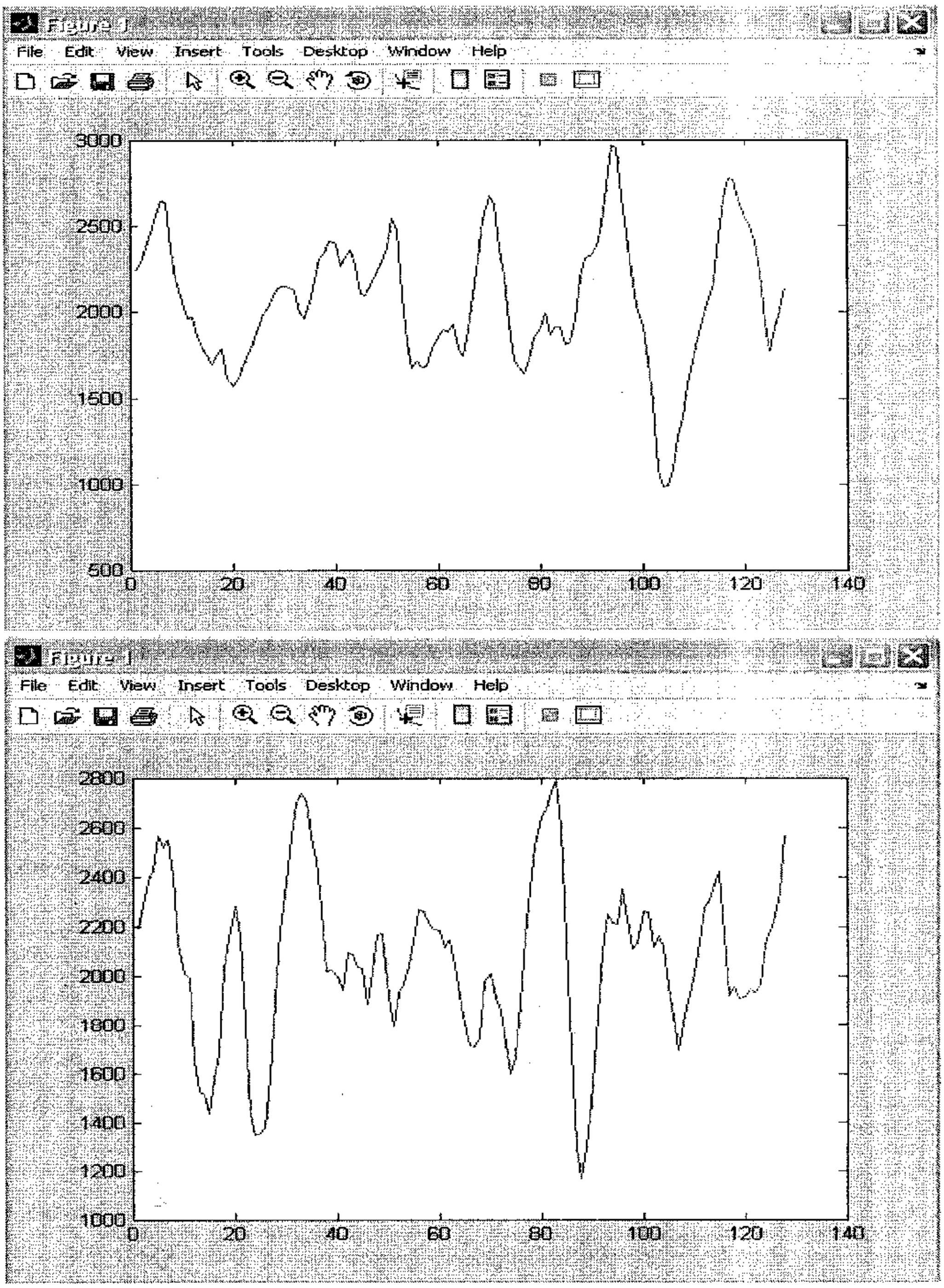


Figure 20: Acquired EMG signals which used for classification

In the above figure 20, Acquired EMG signals are shown and these kinds of several signals are analyzed to specify the ranges of mean values (mean absolute value) used as Feature Recognition method for the classification purpose. The algorithm is implemented in Matlab in order to create a classifier which will classify the input signals in terms of age groups group by monitoring its mean values and then the signal will be stored in the respective group where it belongs and this all operation will be repeated for all signals which are saved in that particular folder which is being browsed by the classifier. In addition, the total no. of signals will be also displayed, and this all will be automatically done by pressing one button. Figure 21 shows the implementation of classification in terms of age grouping.

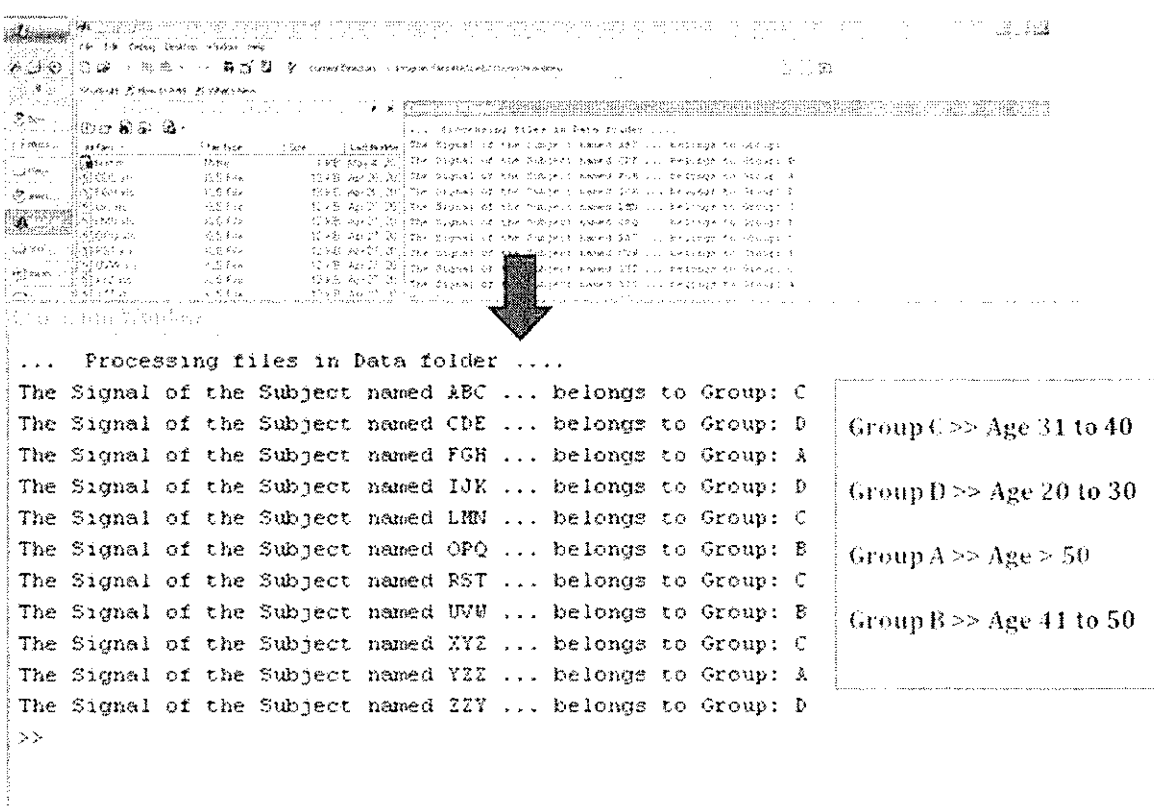


Figure 21: EMG signal classification in terms of age groups

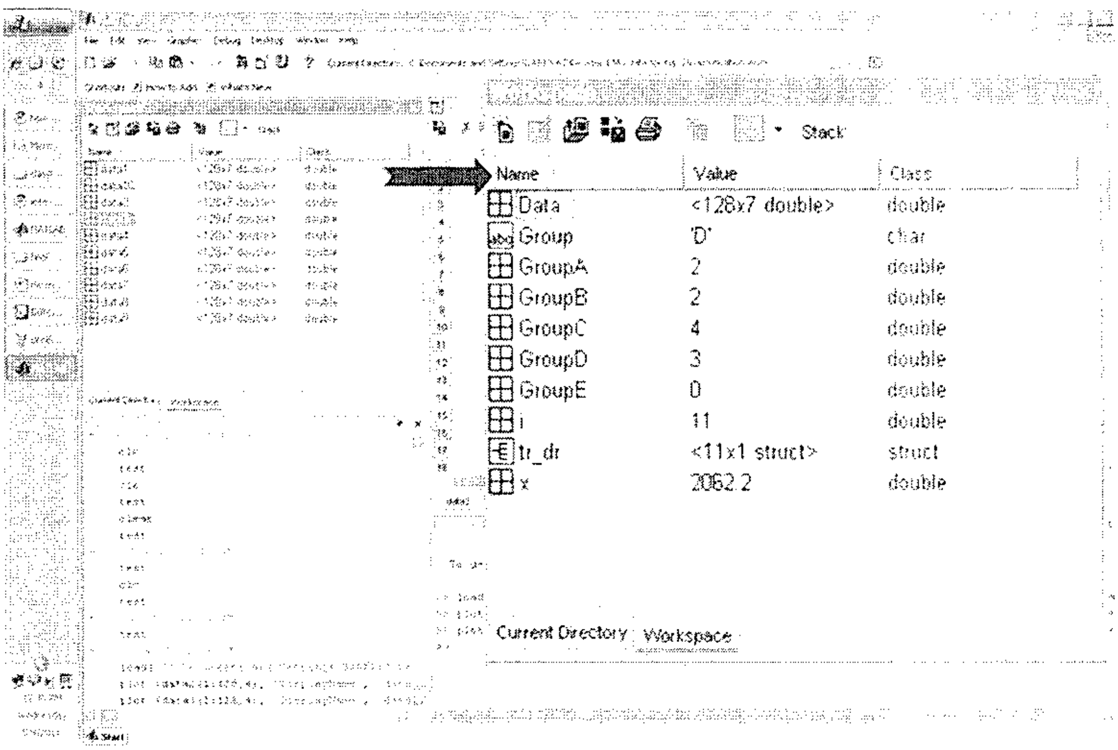


Figure 22: Counting of classified signals in their age groups

4.2 Discussion

The acquired EMG signals shown above in table 2 need to be analyzed by applying the technique. The amplitude of EMG signal has the potential to provide a measure of the magnitude of muscle force, but this relationship is complicated by both the character of the measured EMG and the mechanics of force production in skeletal muscle. The signal measured at an EMG electrode is a voltage differential set up by the summed affect of multiple motor units depolarizing at varying distances from the electrode. The nature of the conduction of these signals through the muscle tissue, the interaction of the signals of different motor units, and variable firing rates of different motor units will all affect the voltage signal that is ultimately measured at an electrode. Even if the EMG gives an honest signal of the relative volume of motor units active, the force actually developed by these motor units depends strongly on the dependence of muscle force output on contractile conditions, such as fiber length and velocity. Direct measurements of muscle force are much less common than are EMG measurements, primarily owing to methodological challenges. It is perhaps counterintuitive that it is relatively easy to measure extremely small currents set up by the movements of ions across the membranes of muscle cells, but technically difficult to measure the very large forces developed by commonly studied muscles [for example the subject of the present study, the turkey lateral gastrocnemius (LG), develops maximal forces exceeding 200 N]. Nevertheless, direct measurements of muscle force have been limited to a handful of studies and a few techniques. Several studies have made use of measurements of muscle force to test assumptions about the relationship between EMG and force and to build mathematical models relating the two results vary. Some studies indicate that the appropriate mathematical model can accurately predict the force profile of the measured muscle from the EMG. However, in most cases it is unclear to what extent a model developed for a given muscle and a fixed set of functions can be extrapolated to other muscles and other activities. Furthermore, it was required to create a classifier which can analyze the acquired signals input to it and then this classifier will differentiate the signals in terms of different groups such as : age, gender and muscle type, etc. Hence, the classification tool which is implemented in this project is Fuzzy logic in order to classify the input signals in terms of age and gender groups and feature recognition method which is used for fuzzy logic is a Mean absolute value (MAV).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion, there is a lot of reading need has been done in order to improve the knowledge on implementation of signal's classification. By reading different techniques and compare those techniques which can be used as classification tool, it is our goal to select the most compatible and feasible technique to implement which could be carried out on this time constraint. Technique is successfully implemented which is Fuzzy logic and the feature recognition method is Mean absolute value (MAV). The acquired signals are fed into the classifier which is able to classify the signals in terms of age group on the basis of those signal's mean value because it is more compatible and feasible to implement and find the mean value of the signals and then differentiate them in terms of groups which are initialized in order to differentiate the input signals into groups of age. Categories for the age groups are age between 20-30, 31-40, 41-50 and <50. It was very hard to acquire signals of all categories by EMG system available to do the analysis, therefore to perform classification, signals are acquired from the data base because there are much more signals to be analyzed, compared and initialized to set the range for feature recognition method.

5.2 Recommendation

Based on the previous research, there were several techniques applied to analyze the acquired signals few of them are discussed in the literature review chapter, hence the Fuzzy logic systems are advantageous in biomedical signal processing and classification. One of the most useful properties of fuzzy logic systems is that contradictions in the data can be tolerated. Therefore, it is recommended to implement any classification tool but the selection of feature recognition method is very important while in this project, the feature recognition method is Mean absolute value (MAV). That is why, if there are more methods like: number of Zero crossings (ZC), Mean absolute slope value (MAV), slope sign changes (SSC) and wave length or wave complexity (WC) could be implemented to improve the accuracy of results.

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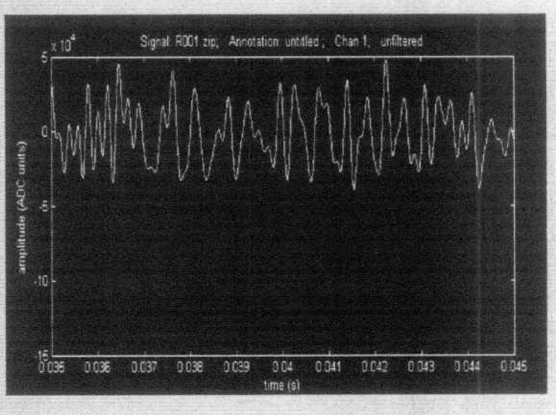
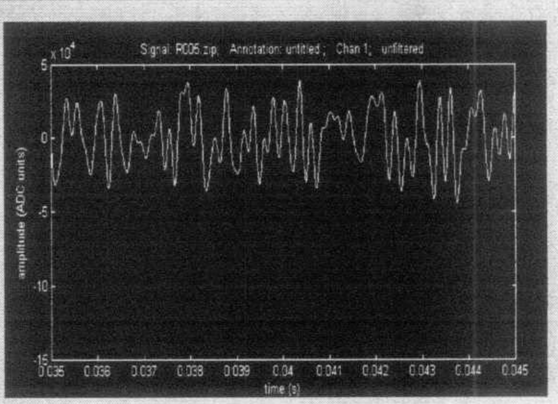
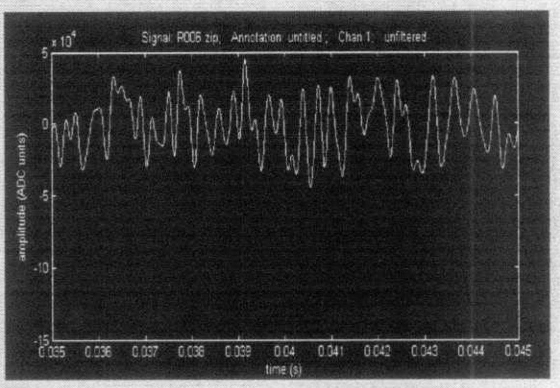
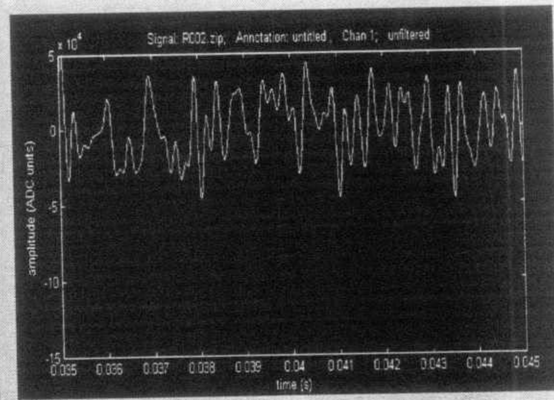
APPENDIX A

No.	Configuration	Muscle	Gender	Age	Protocol	Signals
1.	Electrode	Brachial biceps	Female	25	Steady isometric contraction	
2.	Electrode	Brachial biceps	Male	25	Constant isometric contraction	
3.	Electrode	Brachial biceps	Male	23	Increasing isometric contraction	

4.	Electrode	Brachial biceps	Male	42	Steady isometric contraction	
5.	Electrode	Brachial biceps	Female	23	Steady isometric contraction