EMG BASED NEUROMUSCULAR DISEASE CLASSIFICATION

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by

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CERTIFICATE

This is to certify that the dissertation titled "**EMG BASED NEUROMUSCULAR DISEASE CLASSIFICATION**" is a bona-fide record of work done by **RASHI SHARMA, Roll No. 2K15/SPD/12** at **Delhi Technological University** for partial fulfilment of the requirements for the award of degree of Master of Technology in Signal Processing and Digital Design Engineering. This project was carried out under my supervision and has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma to the best of my knowledge and belief.

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DECLARATION

I hereby declare that the project entitled **"EMG BASED NEUROMUSCULAR DISEASE CLASSIFICATION"** being submitted by me is an authentic work carried out under the supervision of **Associate Professor Rajesh Birok,** Electronics and Communication Engineering Department, Delhi Technological University, Delhi.

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Generally, individuals set aims, but more often than not, their conquest are by the efforts of not just one but many determined people. This complete project could be accomplished because of contribution of a number of people. I take it as a privilege to appreciate and acknowledge the efforts of all those who have, directly or indirectly, helped me achieving my aim.

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(SIGNAL PROCESSING AND DIGITAL DESIGN)

ABSTRACT

Electromyography (EMG) is the recording of electrical activity of the skeletal muscles. Various muscle related and neuromuscular diseases are diagnosed by analyzing an EMG signals. Myopathy, Neuropathy and Normal subjects are analyzed by using discrete wavelet transform (DWT). In time domain analysis, root mean square value is calculated to classify neuromuscular diseases. But DWT based feature extraction scheme gives the better results than RMS value because in that case, signal analysis is carried out both in time and frequency domain simultaneously. EMG signal is divided into a number of frames and a signal analysis is performed in frame by frame manner. DWT based feature extraction scheme is utilized for feature extraction so as to separate normal person to that of diseased patients.

Higher valued DWT coefficients are considered by arranging these coefficients in descending order which are used for feature extraction. Maximum and average value of first five higher valued coefficients is calculated to reduce feature dimension. But even for better classification of these two main neuromuscular diseases namely Myopathy and Neuropathy and Healthy signals is performed using cross-correlation based feature extraction technique.

For this purpose, cross-correlation of Healthy, Myopathy and Neuropathy disease EMG signal is done with a reference Healthy signal. Selective features like Hjorth, and statistical features comprising mean, standard deviation and power are extracted from the cross-correlated signals. Support Vector Machine (SVM) and k-Nearest Neighbor (kNN) are the two classifiers used for this work. Higher classification accuracy is obtained using SVM.

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INTRODUCTION

1.1 OVERVIEW

Study of muscle function through analysis of muscle fiber that produces an electrical signal when a muscle contracts is called as Electromyography (EMG). Development, analysis and recording of myoelectric signal (which are formed as a result of physiological variations in muscle fiber membrane) is known as electromyography (EMG). Activation of muscle which give rise to EMG signal can either take place through our willing action or neither through our actions. EMG signal arises by willing action of muscle contraction arises because of some tense nature.

Motor unit is the basic or the key unit of muscle contraction, that includes only one alpha motor neuron and all the fiber included in it. Contraction of muscle fiber takes place when motor nerve impulse supplied to it reaches a depolarizing threshold which will generate an electromagnetic field around the muscle fiber. This electromagnetic field can be measured as voltage called as muscle action potential which dissipates in the fiber of muscle or the membrane of muscle along its full length. This potential so obtained from the motor units is the sum of all single motor action potential emanated from all the motor unit of only one fiber. Hence EMG signal is sum of all motor potential in the region where the electrode was placed. Any part of muscle comprises of fibers which are including twenty to fifty units of motor neuron. A single unit of motor neuron comprises of three to 2000 muscle

fibers. Muscle managing small motions have small number of muscle fiber per units of motor neuron hardly ten units of motor neuron as compared to muscles which control gross movements which have large number of muscle fiber per motor unit like hundreds to thousands of fibers per unit of motor neuron. When a muscle contraction takes place there is a hierarchy in their arrangement as it is found that units of motor neuron with few muscle fibers are considered more than motor units with motor units with more number of muscle fibers. But units of motor neuron per muscle varies all over in our body.

When a muscle contracts its electrical activity is measured by Electromyography (EMG). With the era of modern integrated circuits and computer technologies EMG can measure more effectively muscle strength and endurance. When a muscle contracts its relative amplitude can be non –invasively measured by its EMG signal which can access its muscle strength. This method makes our task easier when we have to measure collective contribution of all muscle acting simultaneously when it is not possible to measure them individually. Hence it is important to determine the endurance properties of our muscle in order to find if there is any disorder with our nerve or muscle or both. As metabolic efficiency of muscle is determined by its ability to perform a desired task during fatiguing contraction. Muscle metabolic rate can be determined by fatiguing contraction of muscle which is determined by EMG signal analysis. A more complex analysis of waveforms is required to know about the contraction of the muscle. Latest software and technologies can make the complex mixture of frequency components which constitute the waveform pattern of the EMG signal can be calculated and plotted as a function of time. Biochemical reactions occurring in our body give rise to EMG signal. When a nerve impulse contracts it triggers the muscle fiber then there is ion movement between inner and outer membranes. An electromagnetic field is generated in the surrounding by this motion of ions near the fiber of muscle which propagates along the length of the

fiber. If we place an electrode along the muscle fiber then a voltage is developed which detects the depolarizing zone i.e. the region of changing membrane potential. The potential or voltage measured by electrodes is called as muscle fiber action potential or motor unit active potential. When a muscle contracts and an electrode held near the surface of skin then a signal pattern is developed which tells us about summation of action potential muscle fiber from all activated muscle fibers. This signal is called as ELECTROMYOGRAM

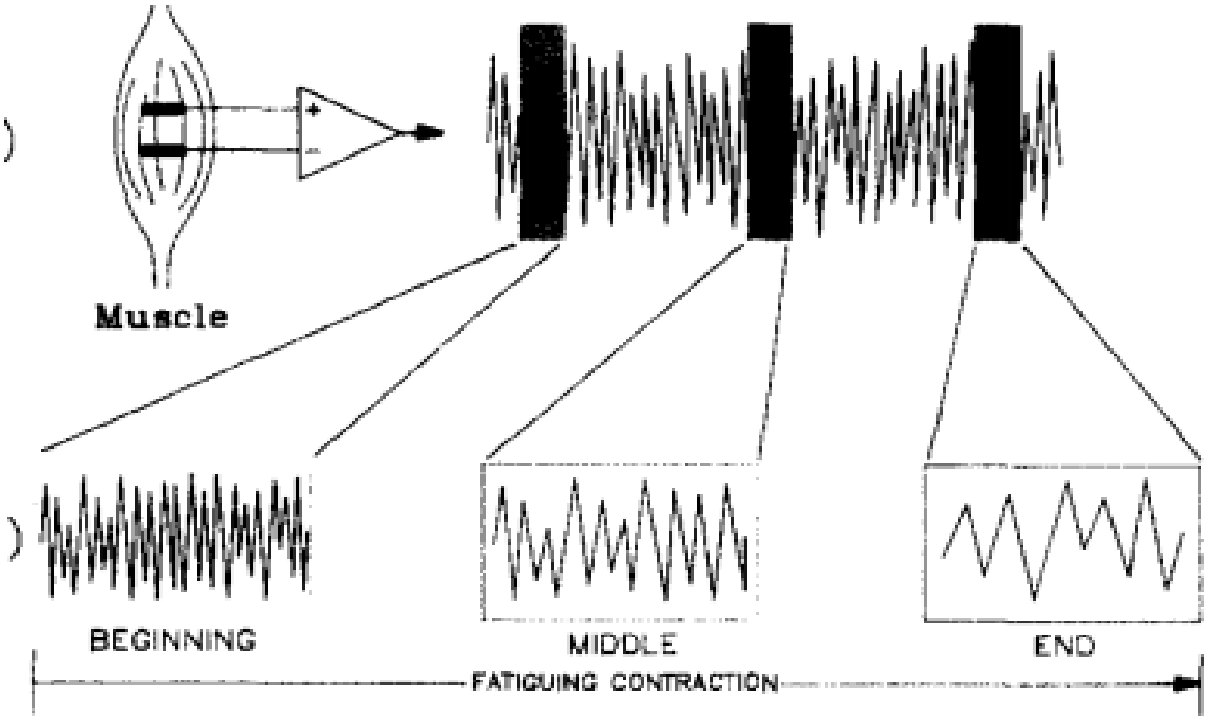


Figure 1.1 A surface myoelectric potential

From the above figure it can be noted that the above pulse pattern is similar to the band-pass filtered white noise as the waveform can be defined in terms of amplitude and pulse duration as a function of time. Amplitude ranges from 20 microvolt to 500 microvolt and pulse duration varies from 2 millisecond to 50 millisecond. Amplitude

of the signal obtained by placing an electrode on the skin surface will tell us about the number of muscle fibers actively contributing to the contraction. When the force applied increases then there is increase in the amplitude of the signal obtained. The pulse duration of the waveform obtained tells us the speed or the velocity with which the motor unit active potential propagates along the muscle fiber whereas the pulse duration in the waveform tells us about the type of fiber and the net metabolic state of the muscle. The pulse duration can be used to determine muscle endurance effectively. If the muscle contractions are constrained then the metabolic byproducts cause delay or can decrease the speed of active potential resulting in the longer pulse duration of action potentials. It is very difficult to visually understand the contribution of individual shapes due to highly complex superposition of the motor action potentials detected at surface of skin. So we can transform our signal from time-domain to frequency domain in order to understand the spectral distribution as a component of frequency .Hence when a muscle contraction takes place its changes in frequency components can be easily understood by its spectral distribution. But this procedure is more complex as frequency measurement is a difficult task as compared to amplitude measurement. New techniques has ease the task of frequency measurement.

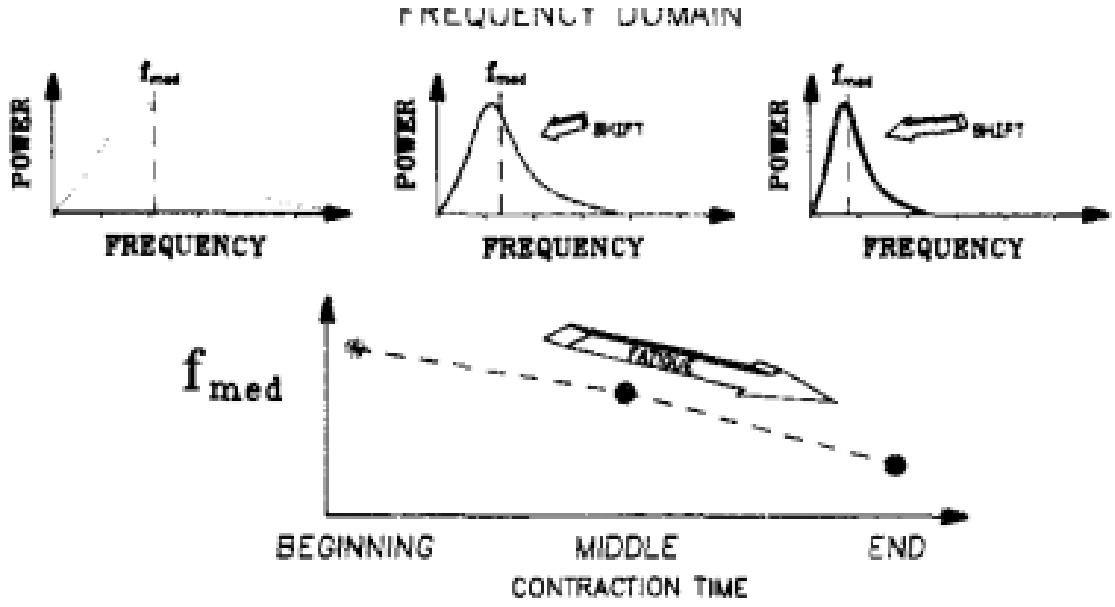


Figure 1.2 Power density spectrum

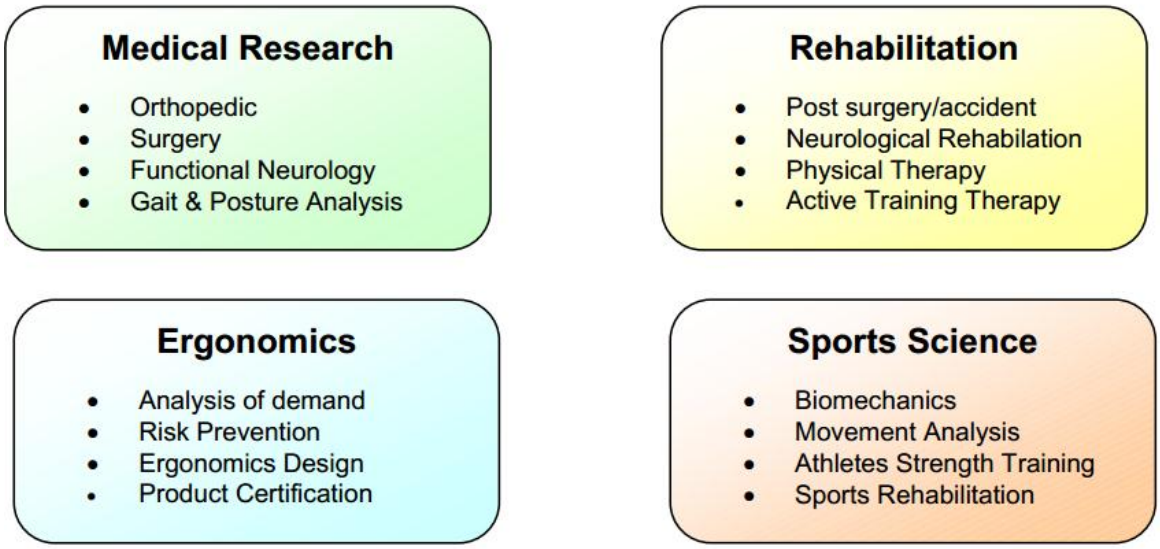
The above figure shows the power density spectrum of beginning, middle and end of the fatiguing contraction. Motor action potential with longer pulse duration corresponds to lower frequency components in the frequency spectrum. As contraction proceeds the frequency shifts to lower side resulting an increase in pulse duration from metabolic by products .This amount of shift can be easily measured by a parameter which can easily tell us about the frequency at which our spectrum is divided into equal intervals known as median frequency. The slope of median frequency plot tells us about the rate of fatiguing, steeper the slope more is the fatiguing. Thus the median frequency plot gives us a crucial information about the metabolic changes occurring in muscle during contractions.

1.2 TYPES OF EMG

- **CLINICAL**
- **KINESIOLOGICAL**

Clinical or Diagnostic EMG is the study of amplitude and duration of motor unit action potential and is mainly done by neurologists and physiatrists. They are typically done to diagnose neuromuscular pathology. By their evaluation we can isolate single unit motor unit action potential and spontaneous discharge by relaxation of muscles. Neurological EMG is done when our muscle responds to external electrical simulation by analyzing it under static conditions.

Kinesiological is the type of EMG which is calculated by movement analysis. It give us a relationship between muscular function and movement of body segments and also calculates the time of muscle activity with regard to movement of muscle. It is the study of neuromuscular activation of muscles within posture, work condition treatment, functional movements. It is method used in various fields such as sports response of human body to various conditions of work etc.



1.3 BENEFITS OF EMG

- EMG allows us to look directly into the muscle
- Muscular performance can be easily measured
- Decision before and after surgery can be easily taken

- Finds and trains muscle
- Helps in improvement of sports activity
- Muscle response can be easily detected in ergonomic studies

1.4 COMPONENTS

a) THE MOTOR UNIT

The most important working unit which tells us about the muscular contraction of neurological control is called as MOTOR UNIT. It is defined as the cell body and dendrites of a motor neuron, the multiple branches of its axon, and the muscle fibers that innervates it . The term units refers to behavior such that all muscle fibers act as a single unit of intervention procedure.

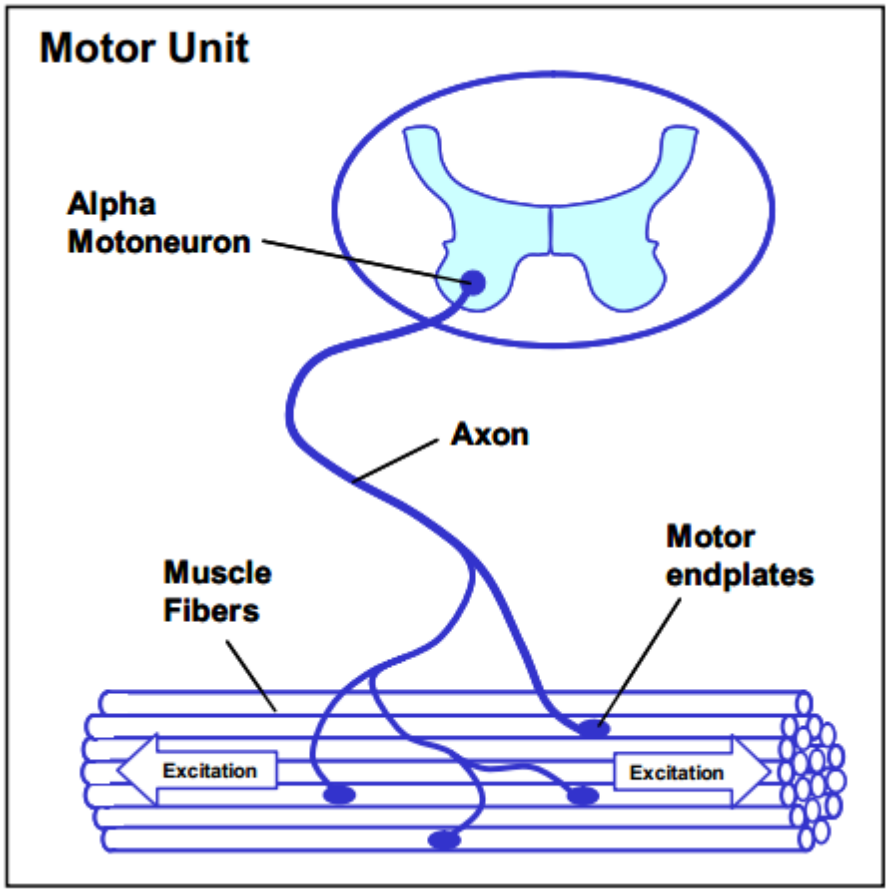


Figure 1.3 Motor unit

b) EXCITABILITY OF MUSCLE MEMBRANE

It plays a significant role in muscle physiology. A semi-permeable model will explain this phenomena. An equilibrium of ions is established between the outside and inside membrane of muscle fiber which results in a resting potential which has a typical value of about -80 to -90 mv. As a result of this difference in potential a negative intercellular charge is produced compared to external surface which is maintained by the physiological process. This results in conduction along motor neuron nerve due to the activated alpha motor neuron which is induced by central nervous system. After the release a potential is developed at the end of muscle fiber supplied by this motor unit and after this modification of muscle fiber Na+ ion flows in which makes the membrane as DEPOLARISATION which can be suddenly retorted by backwards interchange of ions in the active ions procedure called REPOLARISATION.

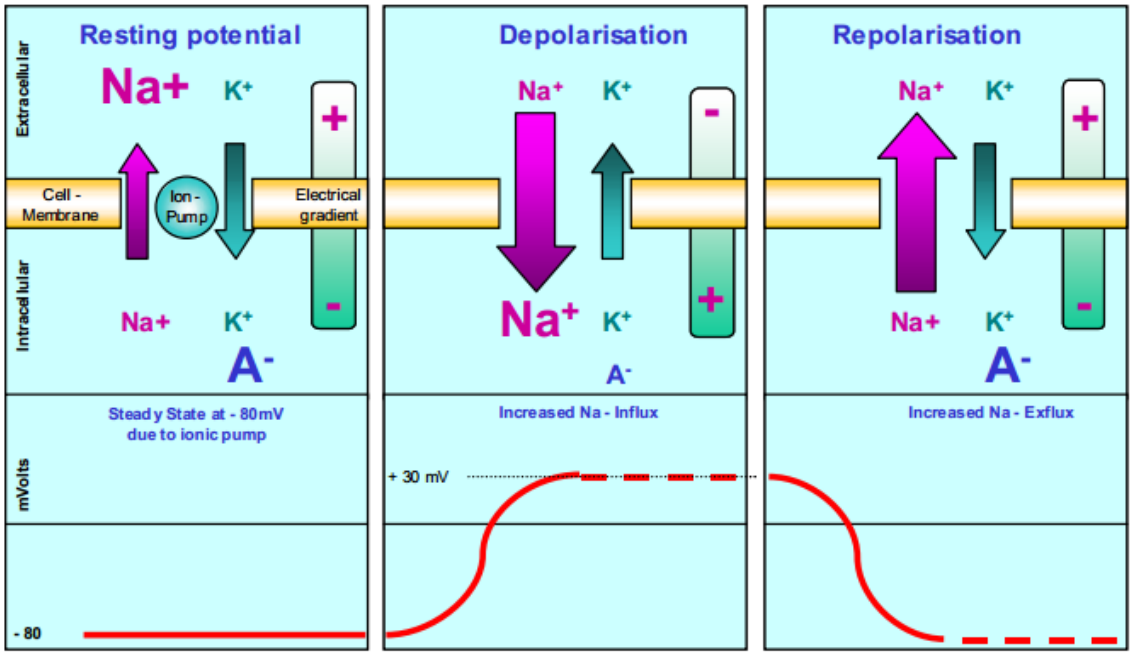


Figure 1.4 Repolarization and depolarization

c) ACTION POTENTIAL

If a certain level of threshold is greater for Na+ inflow then action potential certainly changes from -80mV to +30 mV. It is just an impulse which is again retorted by after hyperpolarization period of membrane.

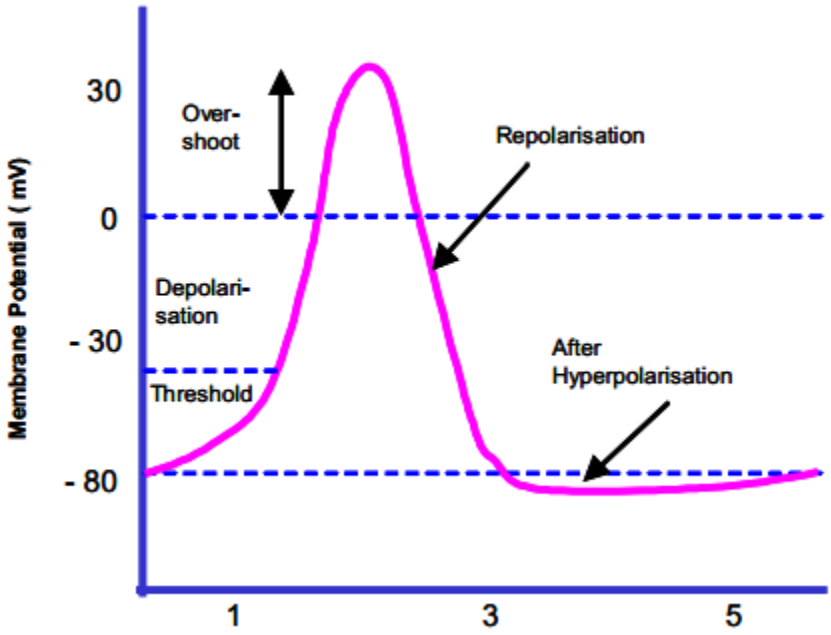


Figure1.5 Action potential

1.5 RECORDING THE EMG SIGNAL

There are two different ways to acquire the EMG signal

a) Keeping an electrode on the surface of skin i.e. SURFACE ELECTRODES

b) Insertion of a needle type electrode deep in the surface of skin i.e. FINE ELECTRODES

The surface electrodes are classified mainly as two main types of electrodes. First is the ACTIVE ELECTRODES which can improve the impedance as they have already amplifiers built in them at the site of electrode. ACTIVE ELECTRODES do not require any gel, can increase signal to noise ratio and decrease movement artifacts.

Second is the PASSIVE ELECTRODE which do not have built – in amplifiers to detect EMG signal and hence decrease resistance of skin to an extent which is maximum as possible. PASSIVE ELECTRODE requires gels which can conduct, preparation of skin to a large extent and decreases ratio of signal and noise Artifacts can also be increased with true signal.

ADVANTAGES

- Easy to apply
- Good for movement applications
- More reproducible
- Minimal pain on application

DISADVANTAGES

- Can be used only for surface muscles
- Have large pick up area so more cross talk
- Low Bandwidth i.e. 10-600 Hz

FINE WIRE

They require a needle for their application

ADVANTAGES

- increased band width i.e 2-1000 Hz

- pick up region is highly specific in nature
- deep muscles can be easily tested
- specific parts of large muscles can be easily isolated
- Discomfort less crosstalk so can detect small muscles

DISADVANTAGES

- due to needle insertion
- Electrodes are less repeatable
- Cramping occurs

1.5 FACTORS INFLUENCING EMG SIGNALS

a) ELECTRODE CHOOSEN

The main aim is that we need a signal which has reduced noise (noise due to motion etc). In recorded EMG signal the potential of motor neuron which is active has an amplitude which varies with muscle fiber diameter, activeness of a muscle fiber and the site of detection distance and filtering characteristics of the electrodes. Therefore, the type of electrode and characteristics of the amplifier being used play a significant role in resulting of high signal to noise ratio.

b) TISSUE CHARACTERISTICS

Electrical conductivity of human body varies with type of tissues, broadness, physiological change, temperature. These changes from person to person thus affecting EMG signal amplitude.

c) PHYSIOLOGICAL CROSSTALK

EMG is also produced by neighboring muscle which can be detected by electrode site .This is called as crosstalk and should not exceed 15%.

d) EXTERNAL NOISE

Incorrect grounding of external devices may produce direct interference of hum.

1.6 EMG SIGNAL COMPOSITION AND NATURE

Motor unit active potential of all active motor units are electrically superimposed at electrical site thus form MUAPs which is also known as an interference pattern .This is a signal which is bipolar in nature in sense that it has a distribution which is a mirror image of amplitudes in positive and negative side.

Unprocessed and unfiltered superimposed MUAPs form raw EMG. Raw EMG is selected in real time just like in an oscilloscope but it requires processing as we cannot differentiate between signal and noise signal. So filtering is done by High pass filter, low pass filter or Notch filter in order to remove noise from Raw EMG signal. Forth order butter-worth filter with cutoff frequency between 10-15hz is used .Analog Low pass filter with cutoff frequency 600Hz is used as anti – aliasing filter for surface EMG whereas low pass filter with cutoff frequency 1000Hz is used as anti – aliasing filter for fine EMG.

Clean EMG when obtained is used to find information about on and off and depending upon the application various processing techniques are used for the EMG such as: half-wave rectification, root mean, integrated EMG and frequency analysis.

1.7 EMG ARTIFACTS

Due to range of EMG signal (which is of few microvolts), it can be easily affected by external noise disturbances and other artifacts. Some of them can be avoided with proper positioning of electrodes and proper skin preparation

a) INTERFERING POWER HUM

An EMG amplifier's baseline noise can be increased if it catches ground noise from power net and this happens due of to poor electrical grounding. It can be solve by changing power plug and avoiding multiple plug connections for EMG amplifier so that grounding of all devices can be done.

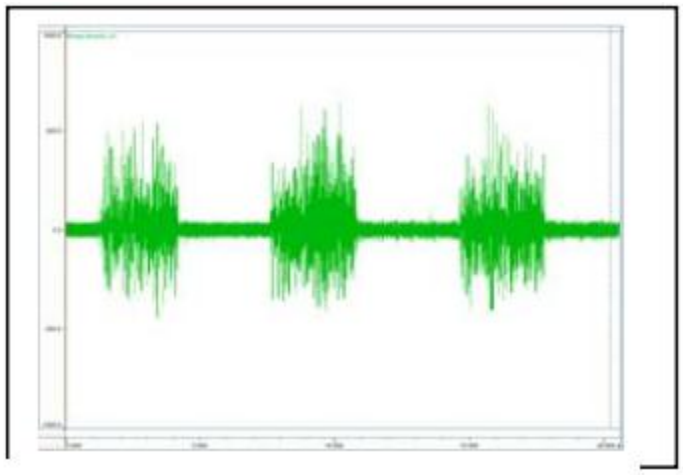


Figure 1.6 Interference in EMG signal

b) BASELINE OFFSET

It occurs if our subject has not properly relaxed at measurement site or if there is change within application site. It can be avoided easily by using an offset correction before measurement of data.

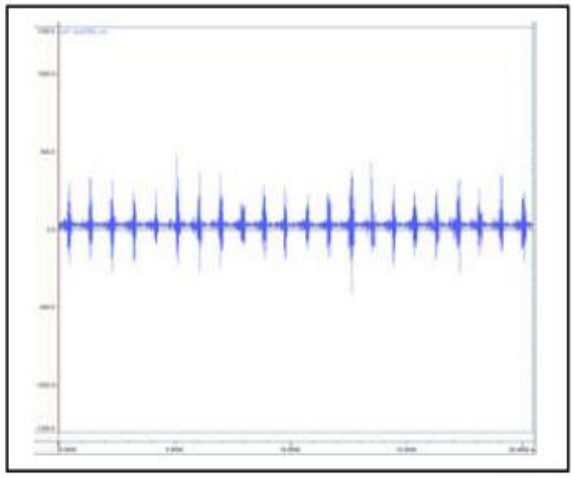


Figure 1.7 Baseline offset

c) BASELINE SHIFT

As we know that EMG baseline stays at a constant zero i.e. it returns to a zero value within few millisecond, any shift in the EMG signal greater than 5 millisecond indicates an artifact and it occurs due to more movement in the cable used for measurement. This problem can be solved if we take good skin preparation and cable fixation in account.

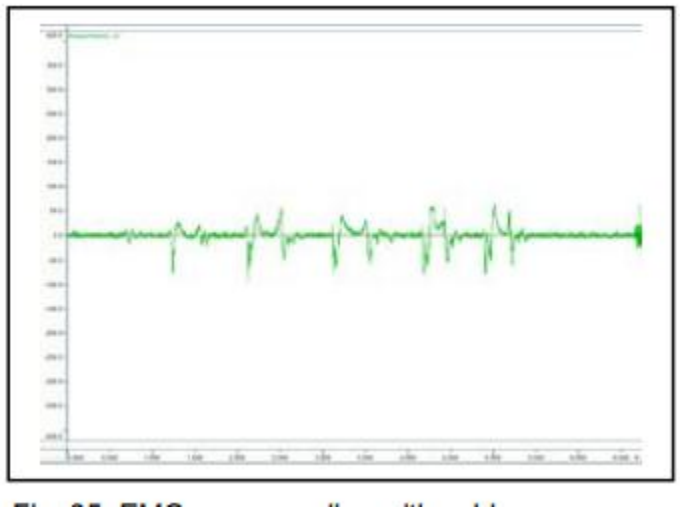


Figure1.8 Baseline shift

d) ECG ARTIFACTS

Whenever we take EMG signal near heart like shoulder or our muscle of trunk on the left side then ECG will culminate our EMG signal and this is a biological artifact and it cannot be removed completely but can be reduced to some extent by proper grounding of electrode and good skin preparation.

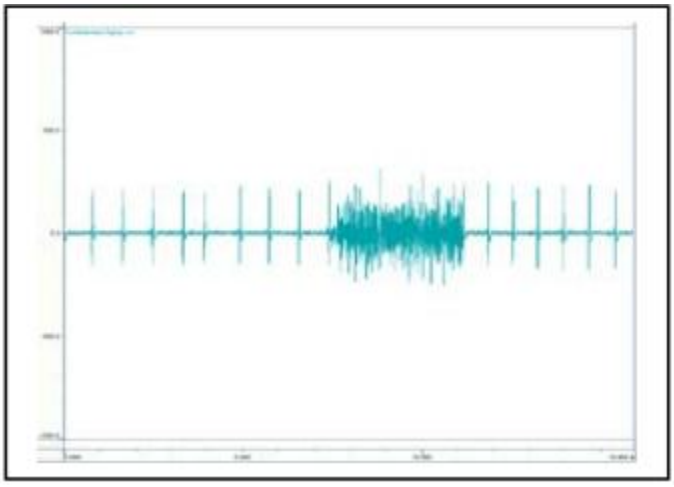


Figure1.9 EMG artifacts

1.8 NEUROPATHY

General disease or malfunction of nerves is known as Neuropathy. Any injury or disease can damage any nerve in our body. Neuropathy can be classified in accordance with the types and affected nerves position. Neuropathy can also be divided in accordance to the diseases responsible for it like diabetes affected neuropathy is also known as neuropathy diabetes.

Diseases, Vitamin deficiencies, alcoholic neuropathy, diabetes, infection or tumors may cause nerve damage.

1.8.1 TYPES

a) PERIPHERAL NEUROPATHY

When the nerves outside the brain or our spinal cord are damage `it is known as peripheral neuropathy. It affects toes, feet, legs, arms, fingers and hands. Proximal neuropathy is nerve damage that causes pain in shoulders, hips and thighs.

b) CRANIAL NEUROPATHY

It occurs when the nerves that leave the brain are destroyed .It is again classified as either Optic neuropathy or Auditory Neuropathy depending upon whether the nerves of retina are affected or the inner ear nerves are affected.

c) AUTONOMIC NEUROPATHY

This affects the nerves of involuntary muscles which control our heart and blood circulation, digestion, bladder function, respiration and perspiration.

d) FOCAL NEUROPATHY

This is either affecting a single nerve or a herd of nerves and is limited to specific area of body.

1.8.2 SYMPTOMS

There is a slow loss of feelings, insensibility, irritation or pain which might proceed with time towards the main center of our body which may involve arms and legs also. There may be resulting clumsiness or falls due to inability to determine joint positions. This sensation of insensibility or irritation of skin is paresthesia. There

might be possibility of development of blisters and sores on feet which with time may spread to deeper tissues thus affecting the bones. These may include weakness, loss of reflexes, loss of muscle mass, cramping or loss of dexterity.

1.8.3 DIAGNOSIS TEST

EMG is a test which measures the electrical activity of muscles by inserting a thin needle into the skin of the muscle. The needle has an electrode that measures the electrical activity of muscle.

The treatment involves the treatment of symptoms and measures to be taken to remove the affects which neuropathy causes to the body .The treatment is specific according to underlying conditions depending on the types of neuropathy. Sometimes treatment may reduce or eliminate the symptoms of neuropathy

1.9 MYOPATHY

If the muscle fibers don't function properly that type of disease is known as myopathy. MYo means muscles and PATHY means suffering. It results in weakening of muscles.

Disorders characterizing primary structural or functional impairment of skeletal muscles is known as myopathy. They results in muscular weakness by affecting the muscles which does not involve nervous systems.

1.9.1 SYMPTOMS

Myopathies can either have positive or negative symptoms. Negative symptoms involve muscle weakness, fatigue, exercise intolerance, muscle cramps and fatigue. Positive symptoms include encompassion of cramps etc.

EMG is a test which measures the electrical activity of muscles by inserting a thin needle into the surface skin of the muscle. The needle has an electrode which detects the muscle's electrical phenomena.

As myopathy is caused by different pathways so there is no single treatment of this disease so treatment has a variation from treatment of symptoms to various targeting tissues treatment. Drug therapy, massage, physiotherapy may be some of the treatments.

1.10 RESEARCH OBJECTIVE

The main aim of this research is to classify neuromuscular disease as myopathy and neuropathy with the help of EMG signal. EMG signal is collected with the help of passive electrode by inserting a needle deep inside the muscle. The collected EMG signal is processed and decomposed and certain features are extracted from the decomposed EMG signal .Such features are then given to the classifiers for discrimination. Also RMS method and wavelet decomposition is also used for the neuromuscular disease classification.

CHAPTER 2

LITERATURE REVIEW

2.1 FEATURE EXTRACTION

a) EMG SIGNALS CATEGORIZATION BY PCA & FFT

In this concept the frequency spectrum of EMG signal can be directly determined by FFT method i.e. (First Fourier Transform).BY identifying the frequency spectrum we can easily determine fatiguness of the muscle, how much force is produced, and what is the speed of signal in the fiber of our muscles . Earlier people used Fast Fourier transform or any other transforms in frequency domains as the analyzing methods.

FFT algorithm is not complex in nature so it can be easily applied to a non-stationary signal like EMG. Here framing of signal is done in powers of 2 such as 128,256. Then frequency spectrum of each frame is evaluated by windowing technique which also presents the non-existing frequency components in the spectrum. Zero padding is also applied to same signal after the windowing procedure which is an overhead task. For data analysis Fourier analysis is a powerful tool which decomposes a signal to its residual sinusoidal components of varying frequencies. This makes it a useful tool to be used in areas such as image and signal process which has tasks such as filtering, convolution and frequency analysis of power spectrum estimation is done.

Fast Fourier Transform has a disadvantage as it gives us a huge number of values of factors usually greater in comparison to our original signal components so we need to reduce these coefficients using PCA. The disadvantage of this method for feature extraction is that it increases overhead to first calculate FFT coefficients with zero padding and then reduce its dimension by PCA, all this is a lengthy procedure.

Further PCA was used as a data reduction method as we know that PCA reduces dimensionality by decomposing a covariance matrix of variable that are dependent into perpendicular components by evaluating the Eigen value and their corresponding Eigen vectors of the data matrix in which covariance is calculated. Eigenvalues play a significant role in determining the decision about the number of orthogonal components that will be used for further analysis, and Eigen vectors play an important role by determining relationship among the previous variables and the new values. The transformation of the original variables into a new set of variables known as principal components are determined by Eigen values and Eigen vectors. Then according to variance the FFT variables are arranged in descending order which shows their decreasing effort to accumulate the whole content of information from the original dataset for the reconstruction of the signal. PCA's power to reduce the hardness of feature space PCA has a wide usage in various pattern recognition and biomedical application for the discrimination of neuropathy and myopathy conditions Thus for a feature set FFT is computed, and feature set is reduced by using PCA so as to have a classifier work on a lower dimension data.

b) EMG SIGNALS CATEGORIZATION BY PSD

Spectral analysis of signal either of healthy, neuropathy and myopathy by Power spectral density i.e. PSD gives us an important information about distribution of power over a range of frequency and this distribution is different I case of a healthy person and neuromuscular disease affected person. Spectral analysis provide information more in frequency domain which can lead to better encoding of EMG signals as compared to STFT i.e. short time Fourier transform which provides time and frequency domain features systematically and simultaneously. EMG signal is a random process or signal which has different values to different instants of time. Fourier transform used earlier express signal as a weighted sum of functions in sinusoidal in nature. So the weighted function of a ergodic process like EMG in some

ways refer to rate at which the function of all time ensembles function changes . The PSD is computed as X(t) is calculated through the Fourier transform of the autocorrelation function R(t;) :

$$Sx(f) = \int_{-\infty}^{+\infty} R(\tau).e^{-j2\pi ft}d\tau$$

where, the autocorrelation function

$$R(\tau) = E[X(t+\tau)X(t)$$

By PSD we can differentiate the signals of healthy, neuropathy and myopathy diseased person by estimation of location and scale parameters.

EMG signals spectral density of power are calculated by hamming window and Kaiser window This involves a method which divides data into some series of time (which may be overlapping in nature) segments, by calculating a modified (windowed) for every segment, and then finding the mean values for all these PSD estimates. During contraction the EMG signal of the surface becomes slower thus compressing the spectral power densities towards lower frequencies thus signifying a change in speed of muscle fibers to a great extent. The power spectral density estimation with hamming and Kaiser window signifies the how the frequency is distributed along length of EMG signal and this changes in frequency is observed in healthy neuropathy and myopathy people EMG data where the signal which is neuropathy in nature is distributed in -400to400Hz and healthy signal scattered to -100 to 100Hz. The above method of classification is simple, fast and reliable .EMG signal decreases due to fatigueness which changes the statics of the signal thus making it difficult to analyze and this method is limited only for small sets of data.

a) DISEASE CATEGORIZATION BY SCANNING EMG

To study motor units of skeletal muscles three dimensional motor unit drawing is drawn using scanning EMG. Motor neuron of neuropathy diseased person loses its function so it needs to be re-innervated to make it functional again .If this is not done then there is possibly an increase in the oscillation of motor unit potential. New constituents which are added to the motor unit also increases amplitude and phase duration. Clustering of the fibers occurs at some location motor unit which also increases number of fibers at motor unit.

For myopathic diseased person muscle fiber degenerates, which decreases the fiber density which further makes diameter of fiber variable and the diameter of motor unit decreases. This makes the phase duration to be low and motor unit potential to be high. Myopathic person motor unit amplitude is low and are generally of short duration.

Scanning EMG is used to study motor unit structure .Motor unit potential are recorded by placing needle and changing the position of needle electrode. Thus by change in its position potential is recorded and a motor unit tertiary map is constructed.

EMG stimulator is used in which has the capability to have more than a single motor neuron addition in it which helps observation of motor unit action potentials .This helps in determining diameter of motor neuron and the number of fibers. Various other parameters like diameter of fiber, position of the endplates or the jitter values can also be determined. We can use different types of needle electrode in the program like needle which is concentric, single fiber EMG and macro EMG needle. It has an advantage of determining the Contraction level of muscle by putting the needle close to a junction of neuromuscular or in the vicinity of a tendon .The disadvantage of this method is that it has limited the number of classification to be used so we need a three dimensional map which shows the distribution of fiber

density within the motor unit region is needed for the progress of the diseases classification and by which if a new feature is available can also be easily classified.

b) MEL FREQUENCY CEPTRUM

As we know EMG signal consists of MUAP, in which motor unit refers to only one Neuron of the motor fiber and the activated muscle fibers. We can classify EMG signals as direct or MUAP based either by frame to frame analysis or by analysis on extracted MUAPs. It includes analysis of features such as duration of the signal, amplitude, area, phase number etc. Only selected MUAPs are used for analysis as there may be some wrong information due to some non-stationary MUAPs Potential based feature i.e. mel-frequency cepstral coefficient (MFCC) of MUAP signal is used and motor unit active potential is extracted from motor neurons by the use of a matching technique which is by the matching of templates and the MUAP with maximum dynamic value is chosen .EMG signal from needle is taken rather than the surface electrode. Decomposition of EMG signal is done into corresponding into MUAPs and features are extracted from these MUAPs. Motor action potential summation and cancellation of phases is shown by MUAPs. Diseased person have different shape of MUAPs. EMG signal is deteriorated into its respective components MUAP by a pattern based decomposition method which differentiates by subtracting the effect of interference. Mel cepstrum is a traditional approach for disease classification by sound of audio values heard in the loudspeaker .The MUAPs which have high value of their amplitude and duration is longer are rejected.

A mel is an unit which measures pitch received and the mel-frequency cepstrum which uses a perceptual frequency scale as its positive point. Firstly the spectrum of MUAPs signal is made to be processed through various filters and energy of these

filters is used to extract mel-frequency cepstral coefficient. These MFFC coefficients have significant information which helps in distinguishing between diseased coefficients depending on the sound of loudspeaker. The disadvantage of this method is that it has computational overhead.

c) DISCRETE COSINE TRANSFORM

DCT i.e. discrete cosine transform can be used for the analysis of neuromuscular diseases by extraction of features. DCT is calculated on the motor unit action potentials (MUAPs) obtained from the EMG signal by decomposition technique – based on matching of the template. In this method only one MUAP with larger dynamic value is selected for the analysis. Features extraction from MUAPs coefficients include features such as magnitude and frequency values which not only decreases the burden of calculation unlike mel ceptrum coefficients but also offers better feature quality by classification among class and compactness between the classes. In this method the EMG signal is collected via needle electrode rather than surface electrode. Then the MUAPs are extracted by template a matching-based decomposition technique.

This method uses discrete cosine transform (DCT) which produces a real spectrum of real signals and reduces the computation of data unlike the earlier used Discrete Fourier Transform (DFT). Also it is easy to be implemented in practical applications. The MUAPs are extracted from the EMG data by using EMGLAB but the processing is done on only one MUAP which is among maximum of its dynamic range. Maximum dynamic value of MUAP is selected by summation of their maximum absolute amplitudes located in the higher and lower sides. EMGLAB has advantage that it reduces the effect of interference between the MUAPs and also does not

remove MUAP with considerable amplitude. DCT coefficients which have higher energy along with respective frequencies are absorbed from the selected MUAP.DCT is superior to DFT for calculating the transform of the real signals in terms that for signal real in nature, the DFT gives spectrum which is complex in nature and is difficult to understand than which leaves most of the data as unused but the DCT generates a spectrum which is real in nature and reduces the computational head of data. DCT allows presentation of data in lower dimension due to energy compaction. It reduces the number of features which are used for the classification. Because of the highly compacted energy property, few low-frequency DCT coefficients have maximum of the significant information accumulated in them and hence thus lower noise in other words has high noise immunity. Also it is easy to be implemented in our practical applications.

The DCT Coefficients which have higher energy are arranged in a decreasing order, where first and M values are taken into consideration as the proposed feature for neuromuscular disease categorization. In DCT temporal information is not retained .DWT is a powerful tool for processing of non-stationary signals like EMG instead of DCT. Wavelet transform provides both frequency and spatial description.

CHAPTER 3

PROPOSED METHOD

3.1 NEUROMUSCULAR DISEASE CLASSIFICATION BY WAVELET DECOMPOSITION TECHNIQUE

EMG signals are acquired by either passive electrodes or surface electrodes. Superficial muscle fiber activities are measured by surface electrodes. To measure muscle fiber activity by deep fiber muscles is measured by needle electrodes. EMG signal is used to determine muscle contraction whose functional and structural unit called is motor neuron. They have single alpha motor neuron and muscle fiber Dominant Motor unit active potential is used in analysis of neuromuscular disease classification. EMG signal is random and non-stationary in nature. It is ergodic in nature and for its analysis signal is divided into locally stationary segments. We have classified neuromuscular disease by time domain analysis of EMG signal and for this analysis Root mean square value is found out .We have classified EMG signal by frequency analysis by Wavelet analysis.

a) WAVELET ANALYSIS

Morphological characteristics such as duration, amplitude, frequency potential of the most active motor neuron is used for neuromuscular disease classification. Wavelet Transform of signal which is discrete in nature is applied at EMG signal by breaking it into frames and analyzing each frame.

1. EMG RECORDING

EMG signals are recorded by passive electrodes which is done by putting a passive electrode inside the surface of skin Passive electrodes are used as it attenuates cross talk and provides better sensitivity.

2. PROCESSING

EMG signal is decomposed and is divided into number of frames. The energy content of each frame is calculated by computing the Root Mean Square (RMS) value of

each frame. Different patterns of EMG signal are obtained by calculating RMS value. RMS value is computed for each frame

The RMS value of an EMG signal x(n) having N number of sample for i^{th} frame is

$c_1=\sqrt{\sqrt{1/N}\sum_{n=0}^{N-1} x\text{^}2(n)}$

b) WAVELET DECOMPOSITION

Wavelet Transform is used to transform the signal from one form to another such that by transformation signal features and some properties are made clear. The transform of a discrete signal x(n) i.e. the wavelet one is written in the following

$d(a,b)=\sum x[n] \cdot \omega[n]$

Where a is the dilation factor and b is the translation factor.

And ω[n] represents discrrete wavelet transformation function expressed as

$\omega[n]= 1/\sqrt{a} \quad \omega[n - \frac{b}{a}]$

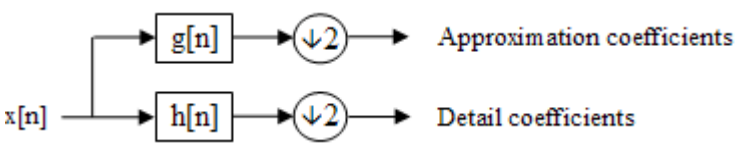
here $a=2^{-j}$ and $b=k. 2^{-j}$

and $\omega[n] =2^{j/2} \ \omega[2^j n-k]$

DWT of a signal x is obtained by passing the signal through a low pass filter with impulse response g thus it means there is a convolution

Signal is also decomposed using high pass filter h and approximate and details coefficients are thus obtained.

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k]$$



$$y_{\text{low}}[n] = \sum_{k=-\infty}^{\infty} x[k]g[2n-k]$$

$$y_{\text{high}}[n] = \sum_{k=-\infty}^{\infty} x[k]h[2n-k]$$

Discrete Wavelet Transform decomposes a signal into approximate and details coefficients .To achieve this a low pass filter is used to analyze low frequency signals and a high pass filter is used to analyze high frequency content of a signal. Resolution of signal can be changed by filtering either by uplink or downlink.

c) DIMENSION REDUCTION METHOD

DWT coefficients obtained for each frame makes the number of DWT coefficients to be large enough and hence to minimize them DWT coefficients with high values are considered and their statistical properties such as average or maximum value is used for calculation.

d) EXPERIMENTAL ANALYSIS

1. DATABASE

EMG signal of a normal i.e healthy persons ; neuropathy diseased and myopathy diseased persons is taken as a dataset y inserting a 25mmconcetric needle electrode into the tibialis anterior muscle of each person. Then the patient had his foot gently dorsiflexed against resistance. The needle electrode had to be repositioned until motor unit potential gave a rapid rise time .Thus data was collected for several seconds and then patients were asked to relax and the needle was removed.

2. **FEATURE EXTRACTION**

EMG signal is highly random in nature so it is not possible to distinguish between the normal and diseased person by looking simply at the waveforms so we divide the EMG signals to be distinguished into frames and analyze the EMG signal frame by frame. But again the waveforms patterns are not distinguishable so we take RMS

value of these finite frames to be considered and then take average RMS value of these frames which form the basis for disease classification.

From the result we observed that normal and myopathy can be easily classified but there is problem in classification of neuropathy and normal so we use the technique of DISCRETE WAVELET TRANFORM for classification of diseases.

Wavelet Decomposition is used to extract DWT coefficients and we have observed that Daubechies mother wavelet gives better performance as our EMG signal is passive in nature Two level decomposition is done to extract DWT coefficients and these extracted values are put in a diminishing ordered and first five value of the extracted ones are considered in order to reduce feature dimension. Maximum and Average value of these First Five Wavelet coefficients are considered as features and are used to discriminate between normal, myopathic and neuropathic person.

DWT based feature extraction technique gives better results as compared to other time domain analysis and feature reduction is achieved by dividing signal into frames such that analysis is done frame by frame and by consideration of only few higher DWT coefficients. But still this method does not provide a clear solution of discrimination between signals and hence we follow up a next method of feature extraction by cross correlation function.

3.2 CROSS-CORRELATION BASED FEATURE EXTRACTION FROM EMG SIGNALS FOR CLASSIFICATION OF NEURO-MUSCULAR DISEASES

EMG signal is obtained by passive electrodes and is used for namely classify diseases as neuropathy, myopathy and a normal person.

Cross co relation is a feature extraction technique in time domain which is used to extract features in order to classify diseases. There are lot of advantage of using correlation method as feature extraction as it has low computational burden and it

has a reduced effect of random noise when features are extracted. In this method cross correlation is performed on neuropathy, healthy and myopathy EMG signal with respect to healthy signal. Statistical and Hjorth parameters are extracted from the resulted cross co-related signal. Finally classification is done using classifiers such as KNN and SVM.

a) EMG SIGNAL SET

EMG signal of a normal i.e. healthy persons ; neuropathy diseased and myopathy diseased persons is taken as a dataset y inserting a 25mmconcetric needle electrode into the tibialis anterior muscle of each person. Then the patient had his foot gently dorsiflexed against resistance. The needle electrode had to be repositioned until motor unit potential gave a rapid rise time .Thus data was collected for several seconds and then patients were asked to relax and the needle was removed.

b) CROSS CORELATION FOR FEATURE EXTRACTION

Let two signals be x(n) and y(n) the cross co-relation is given by

$W_{xy} = \sum_{n=0}^{N-b-1} x\,(n+b)\,y(n)$

$= W_{yx}\,(-b)$

where b indicates the time shift and W_{xy} cross co-relation sequence and if our signals are of length N then cross co-relation is of length (2N-1).

c) EXTRACTED FEATURES

In this method cross co-relation is founded for healthy, neuropathy and myopathy diseased people. Cross co-relation is calculated of healthy and healthy people, neuropathy vs. healthy and myopathy vs. healthy.

After calculating the cross co-relation function different features are extracted from the cross co-relation function such as statistical feature and Hjorth parameters.

Mean, standard deviation and power are the statistical features calculated and Hjorth parameters calculated from the cross co-relation function are as follows

Activity = variance of the signal of cross co-related healthy vs. healthy, myopathy vs. healthy, neuropathy vs. healthy.

Activity=var(x(t))

Mobility= $\sqrt{\boldsymbol{activity}\,\frac{\frac{dx(t)}{dt}}{activity\ x(t)}}$

Complexity= mobility dx(t)/dt÷ (mobility x(t))

So after calculation we got six features corresponding to the cross co-relation of healthy and healthy, neuropathy and healthy and finally myopathy and healthy. There were eight datasets of healthy, neuropathy and myopathy respectively. So after calculation of cross co-relation eight sets were obtained and six features corresponding to each set was taken. So our feature vector used is of the form 8xm where m represents the features taken for classification Two classifiers were mainly used SVM i.e. Support Vector Machine and KNN i.e. K- Nearest Neighbor

d) CLASSIFIERS

In general classification may involves a pattern which consists of both a group of variables called as features and the class to which the pattern belongs. The aim of the feature vector is to classify a new pattern in already defined classes.

The aim of classifier is to divide the feature area into partition of classes. Separation between the regions is known as boundaries of classifiers. If the features of a class are known, individual objects might be identified either belonging or not belonging to that class. A new pattern is assigned to a particular class by patterns of

distinguishing features and comparing it to an already defined class. This task of classification is achieved by feature vector which is obtained as a set of some features. But perfect classification is not possible so we use a more general task of classification which depends on the probability of the possible categories. The difficulty in classification is that it depends on the variation of the feature values of pattern in the same category relative to the difference between feature values for objects in different categories. This variation may be due to complexity or noise in the feature values for objects in the same category. We relate noise to randomness. All the pattern classification problems and decisions related to classification involves noise in some form. .Sometimes it becomes very difficult to find the values of all of the features for a particular input. If there are any missing values of feature then we assume these value as zero or as the average value of all the features.

When some features are missing then it becomes too difficult to train the classifier.

1. SUPPORT VECTOR MACHINE

Analysis of data for classification can be easily done by supervised learning models which have associated learning algorithms such as SVM (Support Vector Machine). It is a probabilistic nonlinear classifier as if we have known it classifies a new object to one class to other. SVM model classifies by representing an object as points in space and mapping is done so that objects of different objects are classified by a gap which is as wide as possible. This gap is known as hyper plane .New object to be classified is mapped to the same space and the class to which they belong is classified according to the side of the hyper plane they fall.

Suppose we are given with some data points belonging to two different classes and we need to classify where a new objet needs to be classified. In that case we view that data-point as a n-dimensional vector i.e. a list of n numbers and then we need to

think if we can find a n-1 dimensional hyper-plane to separate such n points. This is known as linear classifier. The selection of best hyper-plane is that which can classify the two classes by a margin which has largest separation. That hyper-plane is selected which can easily classify such that distance from the object to be classified and the nearest point is maximized. Such a hyper-plane is known as maximum margin hyper-plane and the linear classifier is known as maximum margin classifier.

LINEAR CLASSIFIER

If we are given a set of n points such as (x_1, y_1)….. (x_n, y_n) where y_I represents either positive one or negative one depending on the class of which x_i belongs where x_i -is a n-dimensional vector. Thus we find the maximum margin hyper-plane which divides the x points from region for which y=1 from that region for which y=-1.

Any hyper-plane can be represented by set of x points as

w.x-b=0

Where w is the normal vector to the hyper-plane where b\||w|| represents the offset of hyper-plane from origin along the normal vector w. To maximize the distance between the two classes to the maximum margin hyper-plane two parallel lines are selected to separate the two classes of data which are linearly separable. The region bounded by the hyper-planes is called as margin and the maximum margin hyper-plane lies in exactly middle. These hyper-planes can be described as

w.x-b=1

and

w.x-b=-1

And geometrically the distance between the hyper-planes is 2/ ||w|| so the distance between the hyper-planes can be maximized by minimizing the width |w| which gives value of x as sgn {w.x-b} . This shows that maximum margin hyper-plane is determined by those which lie close to x_i and they are known as support vectors.

2. KNN

Classification is simply a matter of locating the nearest neighbor in feature space and labelling an unknown object with the same class label as the nearest neighbor of the known class. This is known as nearest neighbor classifier. But there may be lack of robustness that characterizes the classifiers but it is highly affected by noise in the training data. So more robustness is achieves by k>1 where a class is labelled depending on the distance and the majority voting of these distances decide the class labelling. Thus the nearest neighbor is a special case of k nearest neighbor with value of k=1.

K-nearest neighbor algorithm is used for classification and it is a non-parametric method .In feature space for classification purpose k training examples are taken. In k classification method the output is membership of a class. An object is classified as belonging to a class by calculating majority vote of its k neighbors and object is classified as belonging to that class which is most common among its neighbors. An object is classified as belonging to single class if value of k=1. It is the simplest form of classification method of machine learning. It is also a non-parametric method of classification. It is a lazy algorithm as the training phase is minimal and it does not lead to any generalization. Lack of generalization means it takes all training data.

The training phase involves storing of feature vectors and class label of training sample. For classification phase an object is assigned a label which is the most frequent among the k training samples nearest to that point. Mostly Eucledian distance is used for distance metric. The value of K selected depends on data if its value is high it reduces the effect of noise but at the same time reduces distinction between the classes. The performance is affected by presence of noise and if the features used for classification are not consistent with their performance

CHAPTER 4

RESULTS

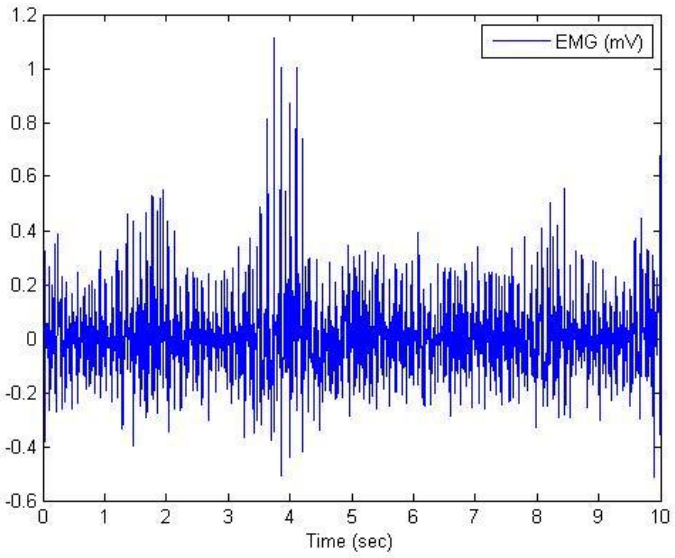


Figure4.1 Healthy person signal

The above figure shows the EMG signal of a person with no disease backlog. The signal is taken for a duration of ten seconds.

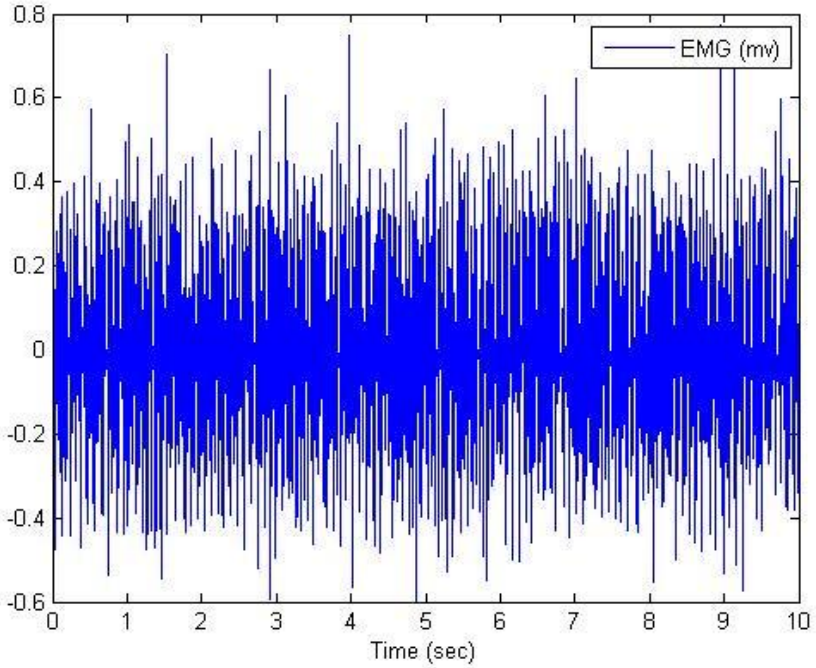


Figure4.2 Myopathy person signal

The above figure shows a person who has a myopathy disease and here for the comparison purpose the signal is again taken for the same duration.

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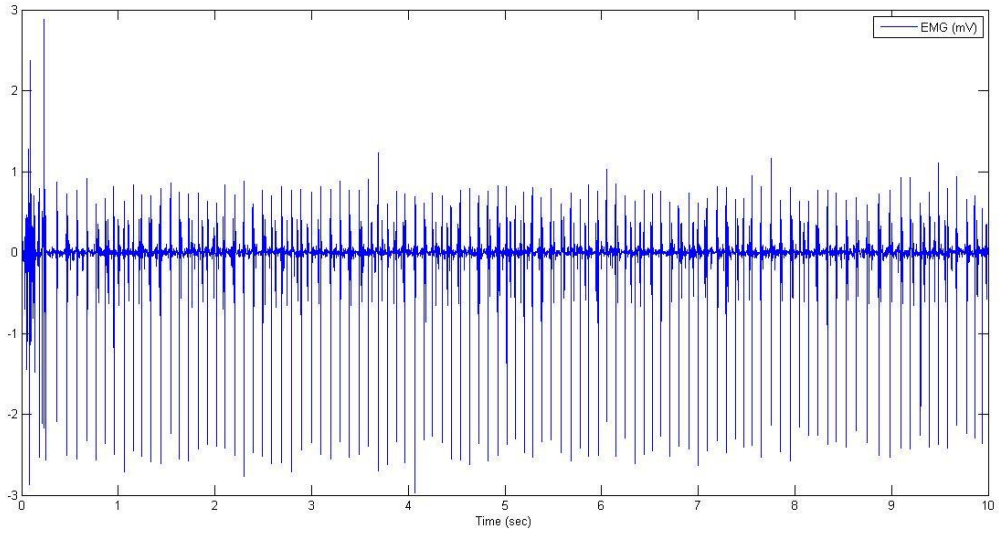

Figure4.3 Neuropathy signal person

The above figure shoes a signal of a person who has neuropathy disease and here also the signal is taken for the same duration for comparison purpose.

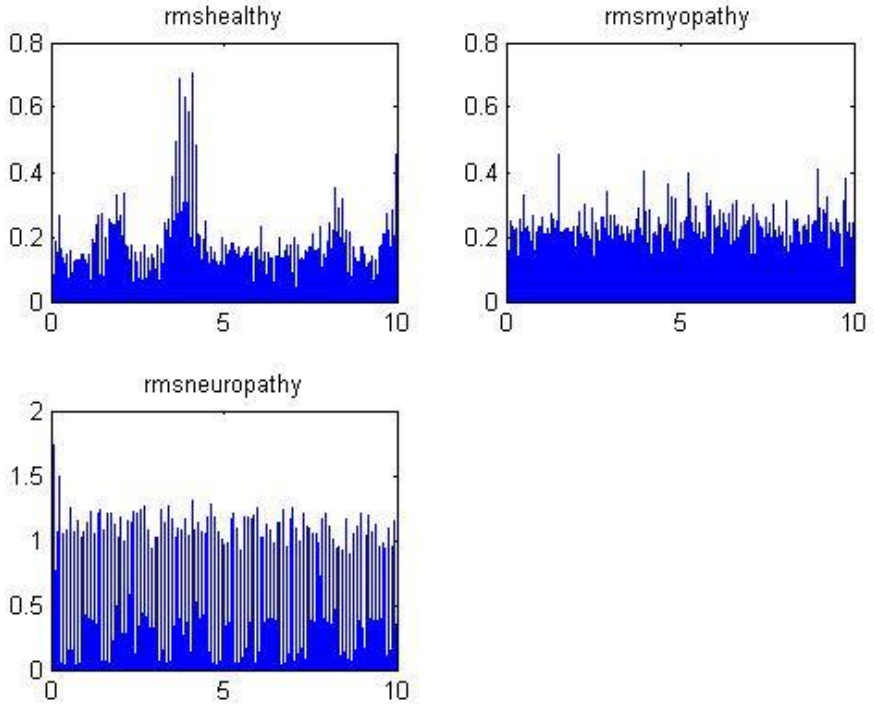

Figure 4.4 RMS Value of signals

The above figure shows the distinction among signals when only root mean square value is taken into consideration.

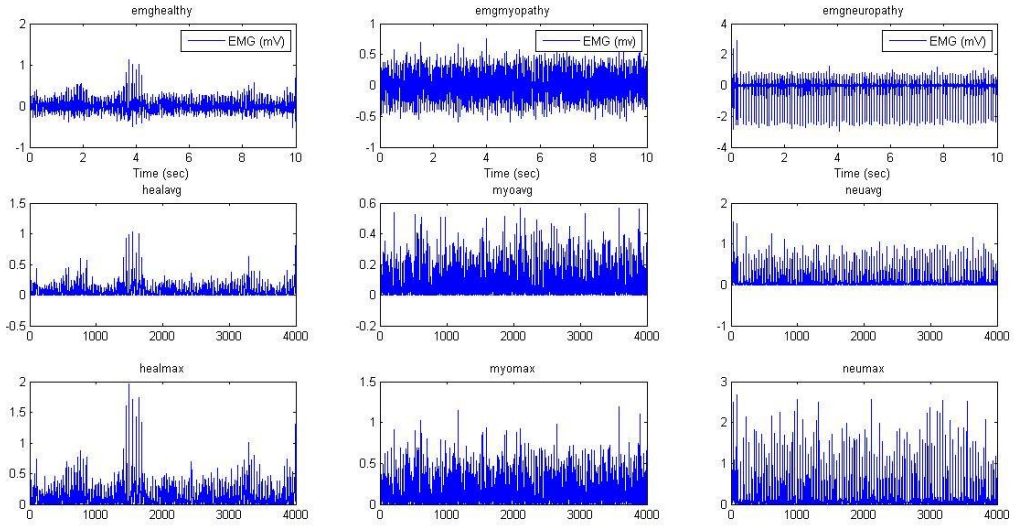

Figure 4.5 Wavelet analysis of signals

The above figure shows the distinction when discrete wavelet transform is applied and then dimensions are reduced by taking only few coefficients from the wavelet transform.

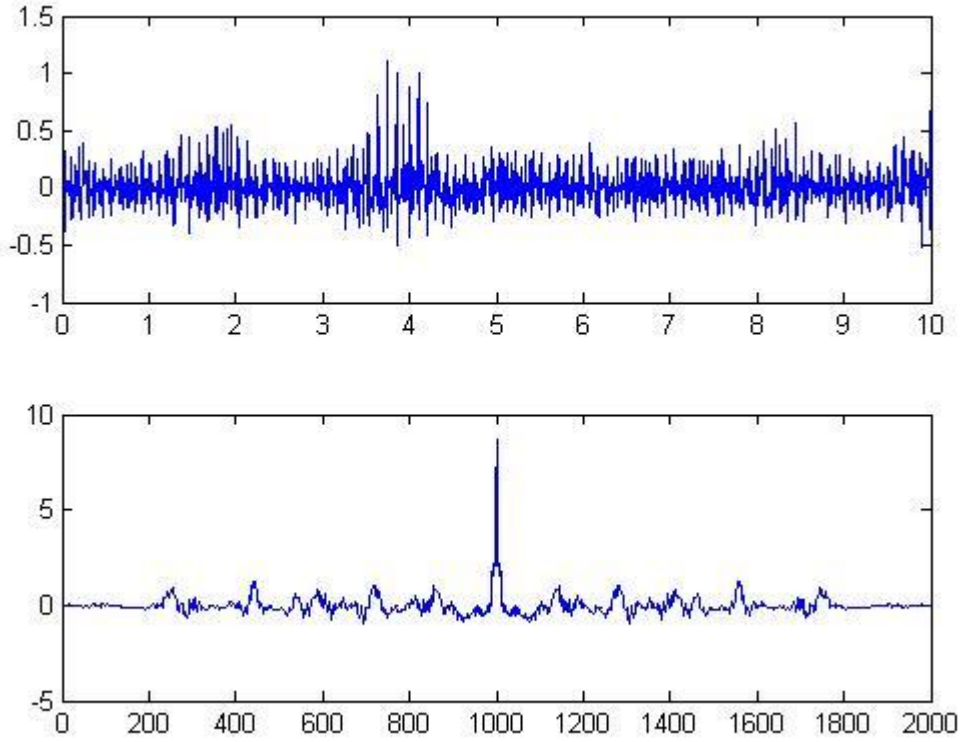

Figure 4.6 Healthy cross correlation data

The above figure is obtained by the cross co-relation of healthy person signal with itself i.e. an auto co-related signal.

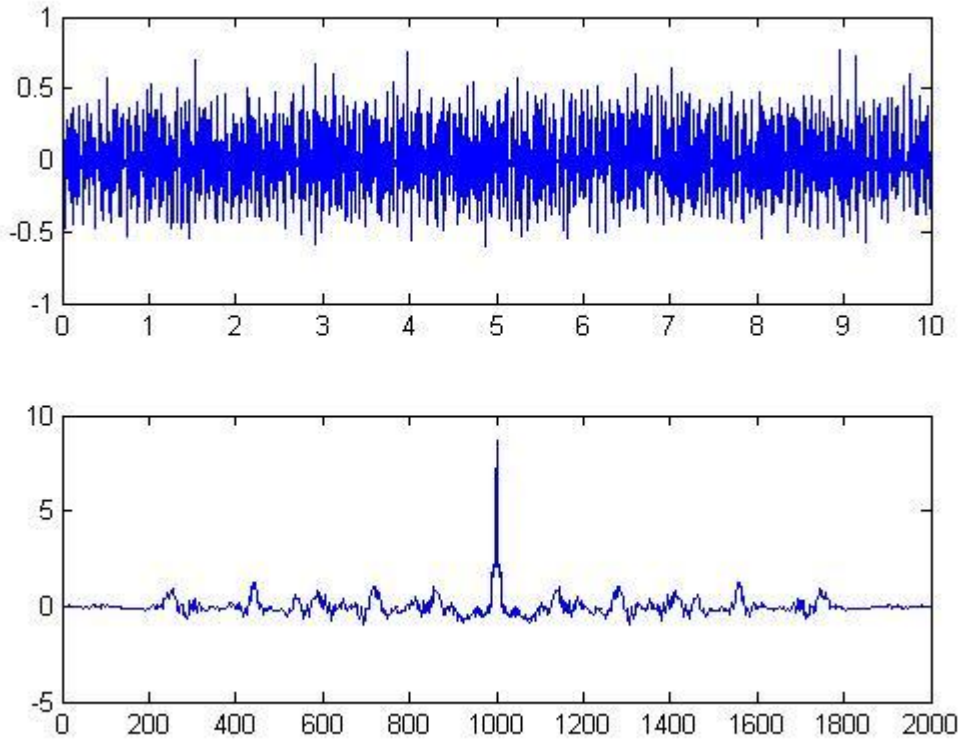

Figure 4.7 Myopathy person cross correlation data

The above figure is obtained by the cross co-relation of healthy person signal with the myopathy person signal and the time duration so obtained is 2N-1.

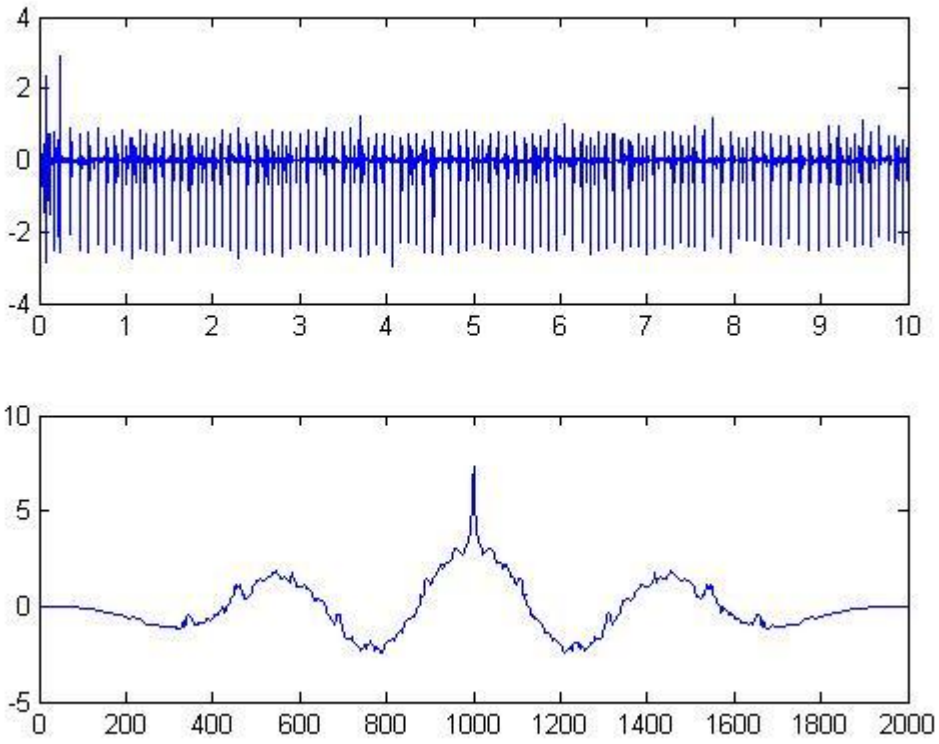

Figure 4.8 neuropathy cross correlation data

The above figure is obtained by the cross co-relation of healthy person signal with the neuropathy person signal and the time duration so obtained is 2N-1.

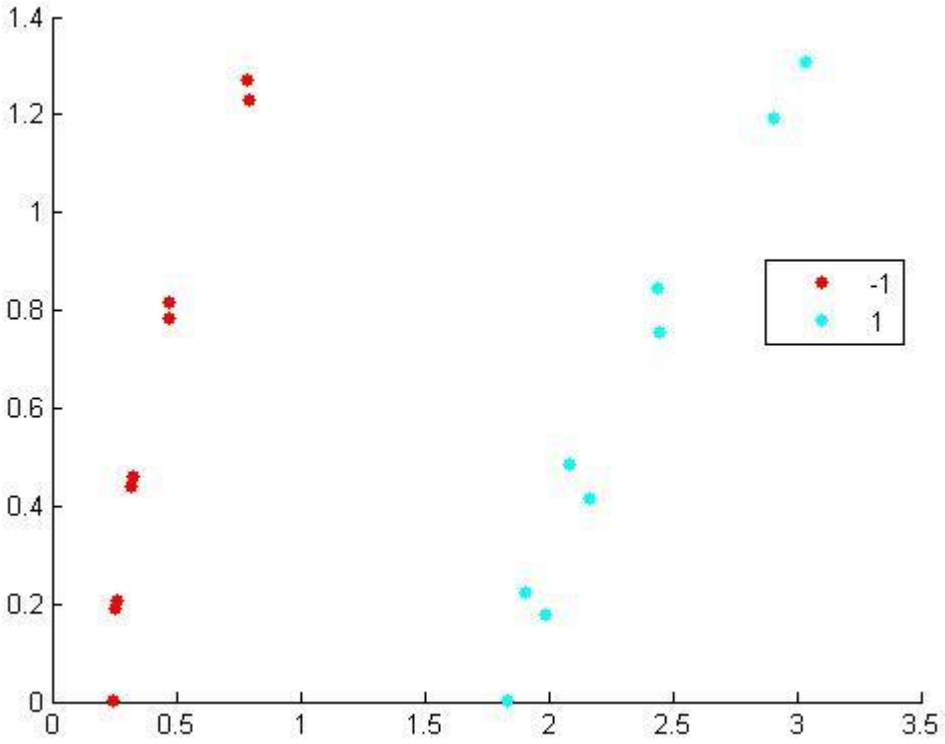

Figure 4.9 Healthy vs. Myopathy KNN classification

The above figure classifies healthy and myopathy signals by obtaining some features from the cross co-related data and classify them by KNN with k=2.

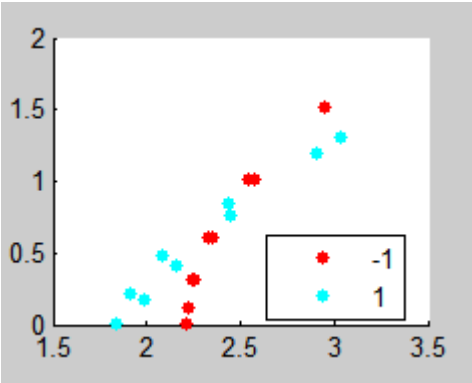

Figure 4.10Healthy vs. Neuropathy KNN classification

The above figure classifies healthy and neuropathy signals by obtaining some features from the cross co-related data and classify them by KNN with k=2.

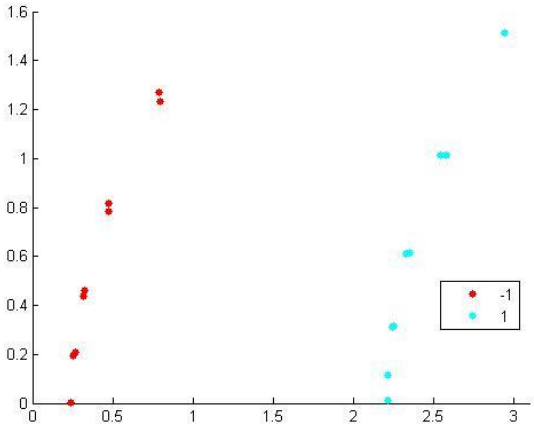

Figure 4.11Neuropathy vs. Myopathy KNN

The above figure classifies myopathy and neuropathy signals by obtaining some features from the cross co-related data and classify them by KNN with k=2.

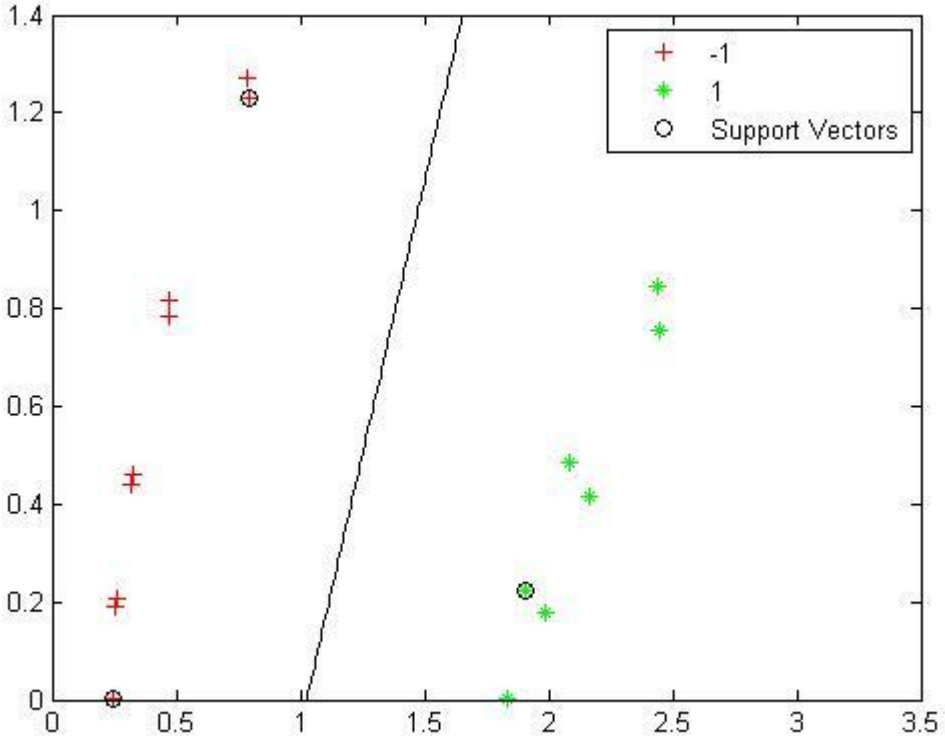

Figure4.12 Healthy vs. Myopathy SVM

The above figure classifies healthy and myopathy signals by obtaining some features from the cross co-related data and classify them by SVM.

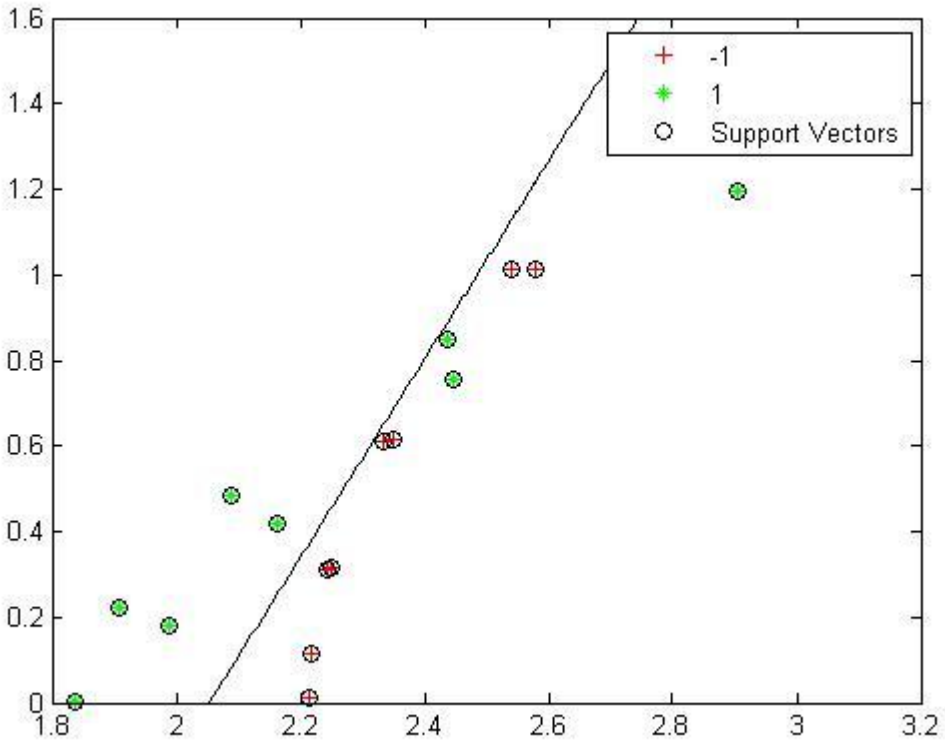

Figure 4.13 Healthy vs. Neuropathy SVM

The above figure classifies healthy and neuropathy signals by obtaining some features from the cross co-related data and classify them by SVM.

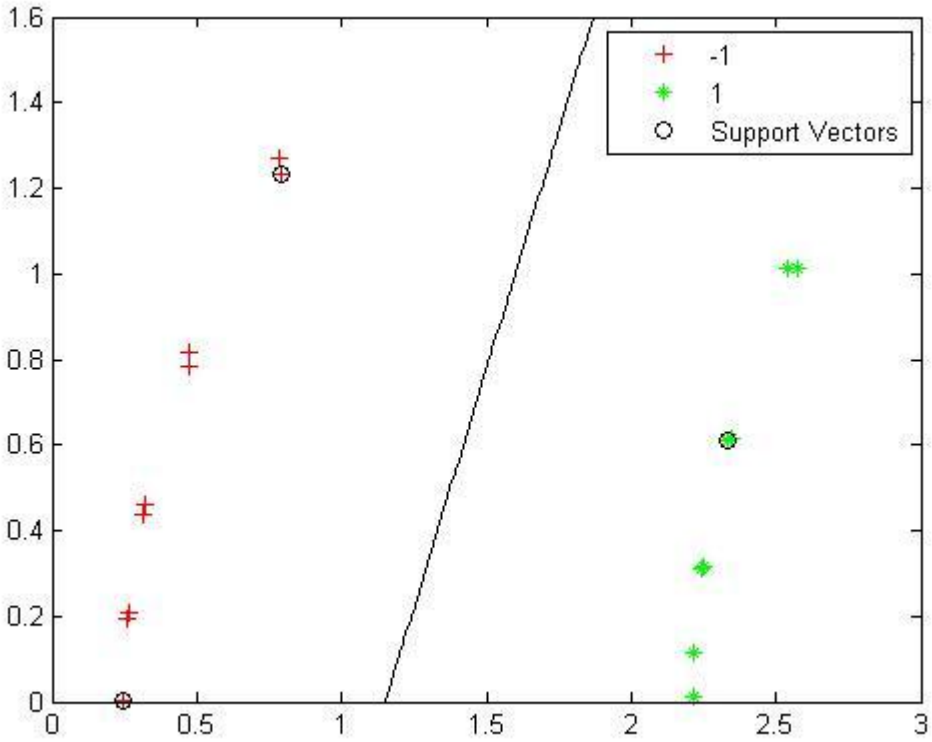

Figure 4.14Neuropathy vs. Myopathy SVM

The above figure classifies neuropathy and myopathy signals by obtaining some features from the cross co-related data and classify them by SVM.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

In this chapter the overall process and results of Electromyogram (EMG) Analysis for Neuromuscular Disease detection using DWT and Cross-correlation function including classifiers such as KNN and SVM and the problems faced and limitations of the project is discussed.

The Thesis is an endeavor which discusses the methods of neuromuscular disease classification through EMG in biomedical field. Although there are various instruments for detection but still there is always some gap existing between the existing things and the needs in biomedical field.

The analysis part is composed into three stages. First stage involves the collection of EMG data for healthy, neuropathy and myopathy patients. Then the collected data is evaluated and preprocessed through filters so that it can be used in MATLAB software.

The second stage involves methods application on processed EMG data.

Earlier the neuromuscular disease classification was done by RMS method but due its disadvantages DWT method was used. But it too didn't give perfect results

So further we had used cross co-relation method for neuromuscular classification in our second stage and through cross co-relation function statistical features such as mean, power and standard deviation and Hjorth parameters were found out. Finally last stage includes application of classifiers such as KNN and Smith was clear from the above results that SVM gives better classification as compared to KNN in healthy, neuropathy myopathy, healthy and neuropathy and myopathy.

5.2 LIMITATIONS

While classifying the healthy, neuropathy and myopathy disease we had observed that through RMS method we could easily differentiate between the neuropathy and normal person but differentiation between myopathy and normal person was difficult

as they both had same RMS value. So we used DWT which although could classify up to some level but not accurately hence SVM and KNN based classifiers gave results in which SVM though gave better performance than KNN but still data of 2 to 3 points were not exactly differentiated due to the features value which were very close.

5.3 FUTURE WORK

Less accuracy was obtained with SVM and KNN so other higher classifiers such as Artificial Neural Network, Fuzzy Logic or a combination of the above could be used to obtain higher accuracies.

For DWT based classification it can be classified using dominant action motor potential based on energy criterion.

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CHAPTER 6

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