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Electromyography (EMG) based signal processing and their Feature Selection using Wavelet Transform

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Abstract: Purpose of this research paper is to identify the Electromyography Signal from muscle activation Signal. Electromyogram (EMG) is a complex signal, which was collected by nervous system depends on the anatomical and physiological properties of the muscles. The EMG signals were collected from the laboratories and experimentally recorded using surface electrode of healthy, myopathic and neuropathic subjects. These signals get corrupted by the noise while travelling through different tissues. The aim of this research is to calculate different features by using the wavelet transform. Wavelet transforms used for training the signal and find the best optimize value. Here we identify time domain and frequency domain features like duration, mean, median frequency, standard deviation etc of the electromyogram (EMG) signal. These features are then utilized on three types of EMG signals like healthy, myopathic and neuropathic signals to classify them. The test results are highly useful for testing purpose in clinical environment.
***Keywords**:* Electromyogram (EMG) signal, Motor Unit Action Potential (MUAP), Wavelet transform, feature extraction, myopathic, neuropathic

Introduction

Electromyogram (EMG) is biomedical signal, measured electrical current which is generated in muscles during the contraction. This contraction of muscles is known as neuromuscular activities of the muscles. EMG signal is directly measured from the muscles by surface electrode and also having a noise. These noises are involved while travelling through different tissues.

For the diagnosis, the measured EMG signal can be decomposed into their constituents Motor Unit action Potentials (MUAPs). MUAPs from the different motor units tends to have different characteristics shapes, while MUAPs recorded by the same electrode from the same motor units and shape depends on where the electrode is located with respect to the fibers and so can appear to the different the electrode moves position. EMG decomposition is non-trivial and many methods have been proposed.

Electromyogram (EMG)

Electromayogram (EMG) is an electrical activity of muscles at rest condition and at contraction. Study of nerve system measures that how fast nerve can send electrical signals. Nerves that control the muscles in the human with electrical signals known as impulses and the muscles react in the specific way because of these impulses. These nerves and muscle problems are identifying under neuromuscular disorders. If you have back pain or numbness, you may have to test to find out how much your nerves are being affected. These tests check how much your spinal cord, nerves and muscles that control your back and their working.

The nerve conduction is used to find damage to the peripheral nervous system that is including all the nerves that lead away from the brain and spinal cord. This test is useful for finding nerve related problem.

To acquire surface electromyogram, electrode is place on the surface of that area muscle, which is wirelessly connected with the software. After placing sensor, the signal is composite of all the muscle fiber action potential occurring in that area muscle. Hence from the blow figure we can see that EMG signal is a very complicated signal, which is controlled by the nervous system and its physiological properties. These EMG signals may be either positive or negative.

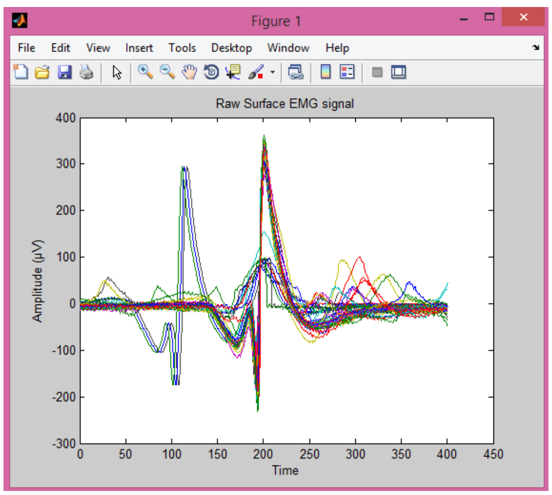

Figure1: Raw surface EMG Signal

I. Noise in Signal

Before calculating features of EMG signal, we have seen that there is unwanted noise is present in the signal. For eliminate the noise first we have to understand that what are the sources of these type of noise. Basically in EMG signal there are two types of noise present:

a. ***Ambient Noise***:

This type of noise is generated mostly by the electromagnetic devices like computer, power supply etc. Initially, a device which is directly plugged into the AC supply (wall outlet) emits ambient noise. This noise is in wide range of frequency component that is 50 Hz to 60 Hz.

b. Transducer Noise:

Transducer noise is generated due to surface electrode and skin junction. Electrodes are used to convert ionic current into the electronic current which can be manipulated by electronic circuit and stored in term of either analog or digital that is known as voltage potentials. These potentials are of two types: DC (Direct current) voltage potential and AC (Alternating Current) voltage potential.

II. Method & Material

a. Types of neuromuscular Disorder

In this research, there are two types of neuromuscular disorder are defined which are myopathy and neuropathy with healthy subjects used as control. These are described as follows:

- **Healthy:**

A person who is not has any muscular disease or we can say who is not affected by a disease nor damaged muscles so that subject can move normally at any time.

- **Neuropathic:**

It can be shown in nerve damage. Neuropathy is damage to a single nerve or a nerve group that is result in loss of movement, sensation or other functions of the nerves.

- **Myopathy:**

It is a muscular disorder in which muscle fiber do not function due to dome reasons, resulting in muscular pain, muscular weakness, stiffness, muscle cramps etc.

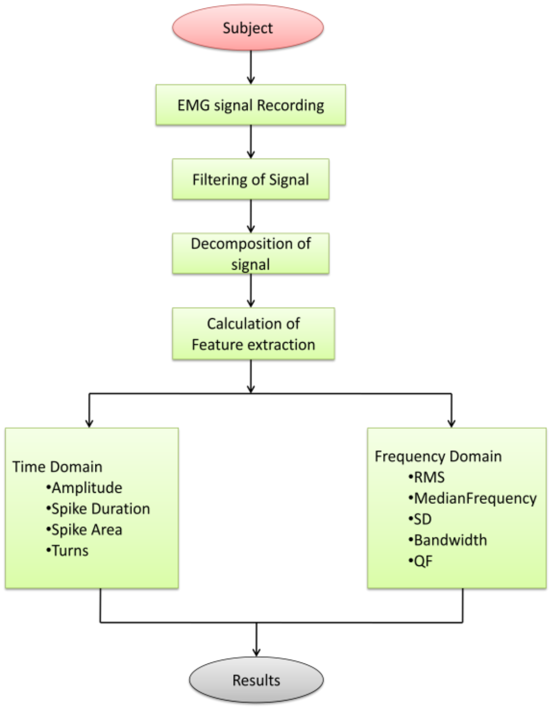

Figure2: Proposed Model for work

b. Database & signal Acquisition:

The data was recorded using wireless Surface EMG electrode with the help of EMGWorks software.

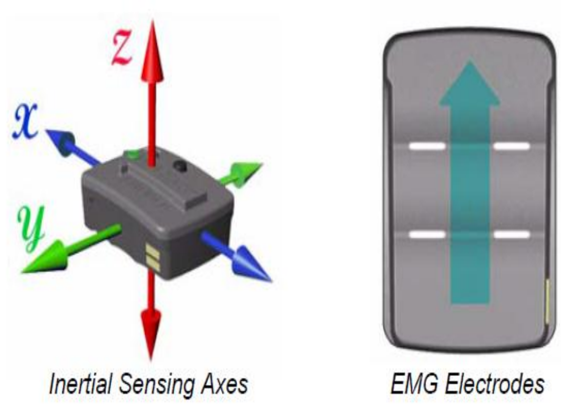

Figure 3: Surface electrode

Here we recorded 30 EMG signals of healthy subjects and 15 EMG signals of myopathic subjects. The length of recorded signal is 10 second. The simulation and programming part is carried out in MATLAB software.

Figure4: Experimental setup for signal recording

We have analyzed the input signal by applying wavelet technique, but before that we have to fulfill some other requirement to make the signal to analyze like data acquisition and filtering. These signals are having noise and muscle artifacts, to remove these noise filters are use like high-pass filter, low-pass filter and notch filter. Thereafter wavelet technique is used to decompose and smoothen the signal. After decomposition feature were extracted by using several feature extraction technique. In this paper we are calculating time domain and frequency domain features of decomposed signal.

c. Wavelet Decomposition:

The wavelet transform is a time-frequency representation. Wavelet transform analysis is the breaking up of a signal into the shifted and scaled type of the original wavelet.

Manual decomposition of the signals is performed from the long time for clinical diagnosis. It has been clearly seen that parameters of the motor unit action potential such as amplitude, spike, shape, number of phases and turns can be calculated manually. However, manual analysis is time consuming and inaccurate because of this decomposition process takes long time. For perfect diagnosis and accurate decomposition of motor unit action potential classification is required.

Wavelet transform is classified in two categories:

1. Continuous wavelet transform (CWT)
2. Discrete wavelet transform (DWT)

Wavelet coefficient calculation is implemented by CWT takes a lot of EMG data. Normally in De-noising point of view, we obtained good results analysis from the discrete transform. The definition of DWT is given as follows:

$$C(a, b) = \sum x(n) g_{j,k}(n)$$

Where, n€Z

Where C(a, b) are dyadic wavelet coefficients, a is dilation or scale ($a=2^{-j}$), b is translation ($b=k*2^{-j}$), x(n) is the input signal, and $g_{j,k}(n)$ is discrete wavelet ($g_{j,k}(n)=2^{j/2}*g(2^{jn-k})$).

When input data is decomposed to a certain level using discrete wavelet transform, a set of wavelet coefficient to the low-scale component while the other wavelet coefficient are correlate to low-frequency.

The De-noising process will be employed when decomposition taken as a whole. If any modification is required, the reconstruction process will be instantaneously done.

In this paper, IIR notch filter and Butterworth was used to reduce the noise in raw MUAP signal which was removed the power line noise of signal.

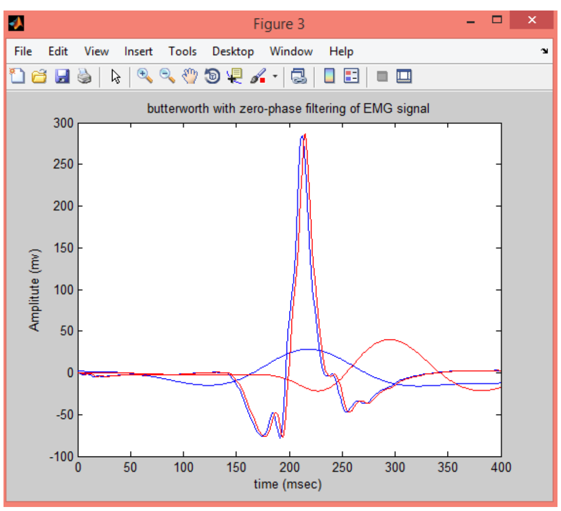

Figure5: Zero-phase filtering with original signal

In above figure red color signal shows the zero-phasing filtering of MUAPs.

After removing these noises wavelet transform is applied on filtered signal. Daubechies wavelets are used to decompose the signal for base line removal.

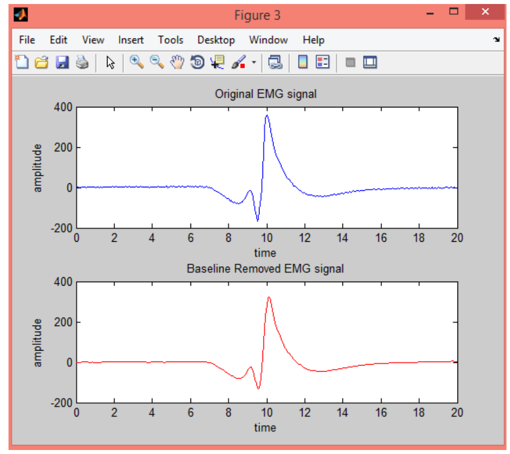

Figure6: Original signal with Wavelet decomposition

III. Results With EMG Signals

In this paper, classification of motor unit action potential involved steps such as EMG signal acquisition, filtering, wavelet decomposition, signal smoothening and feature extraction. The EMG signals was recorded of many subjects (healthy subjects, myopathic subjects and neuropathic subjects) using surface EMG electrode with different mean age that was saved in datasets. After that filters are used to clean the signal such as high-pass filter, low-pass filter and notch filter. Then desecrate wavelet transform is used to decomposed the signal and smoothing the signal. At the end after smoothing the signal features was extracted using several feature extraction technique such as root mean square, autoregressive coefficient etc.

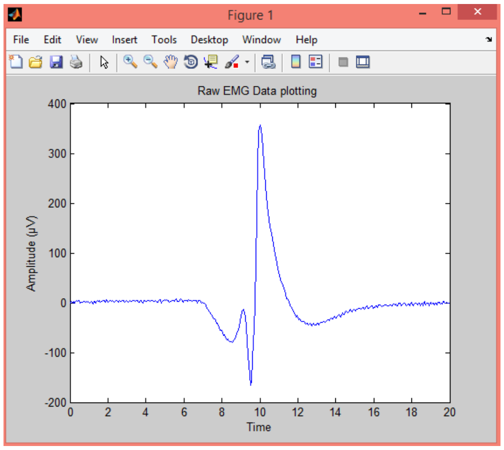

Figure7: Raw EMG signal of Myopathic subject

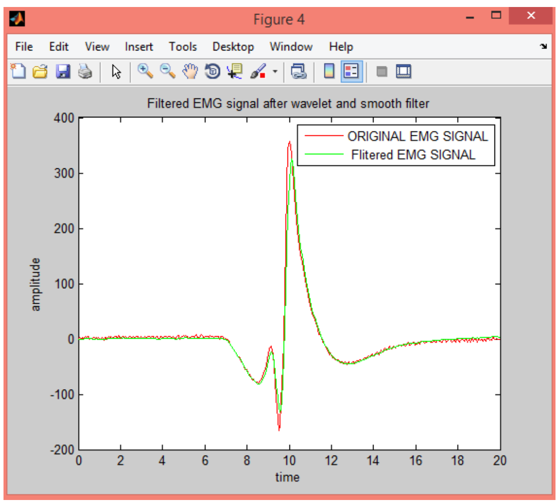

Figure8: Filtered EMG Signal with wavelet Decomposition

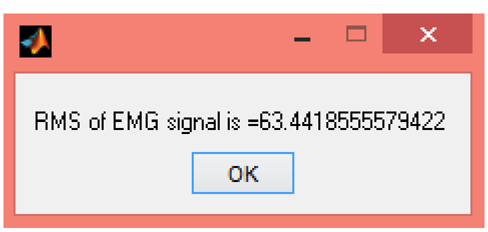

Figure9: RMS value of healthy Subjects

After wavelet implementation, we got decomposed EMG signal which is used to extract the features. Here we calculate time domain and frequency domain parameters using these decomposed signals. Obtaining the frequency spectrum the measurement is assessed by different parameters like mean, median frequency, standard deviation etc. Frequency domain and time domain parameters are given as follows in the table:

TABLE1: Features of Myopathic subjects

Mean	amplitude	Duration	Spike dur.	Spike area	total area	bandwidth	quality factor	RSM
0.599245	448.522412	12.15	19.2	9698.75466	116509.503	130.200397	0.153609363	57.81292078
0.599245	448.522412	12.15	19.2	9698.75466	116509.503	130.200397	0.153609363	57.81292078
-0.77002	444.792994	12.15	18.75	12099.7215	110004.937	130.808724	0.152895001	58.12357355
0.233006	436.066262	12.15	19.15	11379.2611	112620.341	117.166074	0.170697876	55.93716454
-3.01504	166.830554	12.15	19.25	19740.595	90333.0462	66.8646935	0.299111518	33.05190293
0.985723	406.207956	12.15	19.1	8238.345	112101.818	128.659144	0.155449503	55.66914188
-1.26696	96.0801333	12.15	19.4	9814.10246	56555.7286	24.5228414	0.815566176	19.62406134
-1.26696	96.0801333	12.15	19.4	9814.10246	56555.7286	24.5228414	0.815566176	19.62406134
-1.67631	92.1850926	12.15	19.35	9789.99745	56194.9221	35.8479741	0.557911584	19.64353627
-0.5197	438.841184	12.15	19.35	13074.8492	133880.398	161.716538	0.123673189	61.87919806

IV. Conclusion

Research on EMG signal is having a wide area, which is ranging from design of surface electrodes, acquisition techniques, analyzing methods and applications for various clinical diagnosis purposes for clinical purpose. But still there is lot of improvement or research required to optimize the signals for diagnosis of neuromuscular disorders.

In this research paper, signal acquisition, filtering, wavelet implementation and features are calculated for the clinically diagnosis purpose.

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