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Bio-medical (EMG) Signal Analysis and Feature Extraction Using Wavelet Transform

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ABSTRACT
In this paper, the multi-channel electromyogram acquisition system is being developed using programmable system on chip (PSOC) microcontroller to obtain the surface of EMG signal. The two pairs of single-channel surface electrodes are utilized to measure the EMG signal obtained from forearm muscles. Then different levels of Wavelet family are used to analyze the EMG signal. Later features in terms of root mean square, logarithm of root mean square, centroid of frequency, as well as standard deviation were used to extract the EMG signal. The proposed method of feature extraction for extracting EMG signal states that root means square feature extraction method gives better performance as compared to the other features. In the near future, this method can be used to control a mechanical arm as well as robotic arm in field of real-time processing.
***Keywords* -** EMG Signal, Feature Extraction, Wavelet Transform.

I. INTRODUCTION

Electromyography (EMG) is the study of muscular electrical signals. EMG is sometimes referred to a myoelectric activity. Many muscular undergo some abnormalities such as muscular dystrophy, inflammation of muscle, peripheral nerve damages which may result into an abnormal electromyogram. EMG signals can be recorded basically by two types of electrodes which are an invasive electrode also-called wire electrodes or needle electrodes and the second type is a non-invasive electrode also-called surface electrode. The Wire or needle electrode records the potentials of individual muscle fibre which is an ideal choice to evaluate the various muscle activities [1].

In this paper, we propose that the features extracted from acquired raw EMG contribute to the different muscular contraction classification. The features which we using are based on the Wavelet Transform approach. A surface electrodes array is being used as a data acquisition system to acquire EMG raw data. The data acquisition system which we are using to extract EMG provides us to extract some features such as Root Mean Square (RMS), Logarithm of Root Mean Square (log RMS), Centred of Frequency, and Standard Deviation methods to extract the features [2].

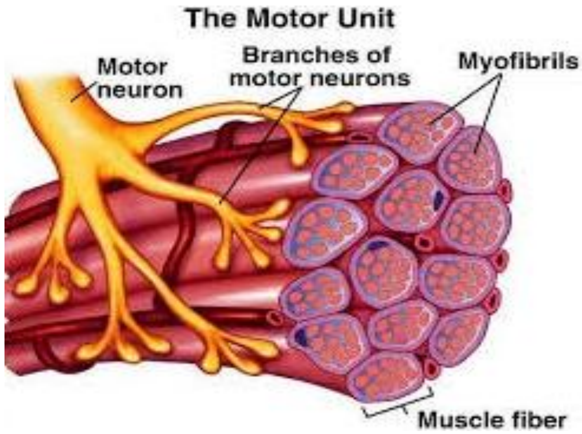

Fig. (1) Cross-sectional view of muscles

The proposed features which are extracted from acquired EMG are serving for muscular contraction. As shown in Fig. 1 these signals are in two different forms and are conducted via two different types of nerves. The signals which are moving from the limbs towards the spinal cord are conducted via sensory nerves, and the signals which are moving from the spinal cord towards the limbs are conducted via motor nerves. And this is an unchangeable process hence the waves are termed as F-waves and H-reflexes. EMG signals are recorded in form of NCV i.e. nerve conduction velocity. Thus this NCV measures the ability of the motor nerve as well as the sensor nerve to conduct the electrical impulses [4]. Our features are based on the Wavelet Transforms approach. A two single-channel surface electrodes array can be used as a data acquisition system to acquire EMG data by the best level of Wavelet family.

II. WAVELET ANALYSIS OF EMG DATA

The signal that consist of the EMG data has to be initially pre processed using three stages of pre processing which are EMG data acquisition, data segmentation and EMG feature extraction [2]. Two pairs of single-channel surface electrodes are used to measure and record the EMG signal on forearm muscles. Then different levels of Daubechies Wavelet family are used to analyze the EMG signal. Finally these features are in terms of root mean square, logarithm of root mean square, centroid of frequency, and standard deviation are extracted from the EMG signal. The main frame GUI format is as shown in Fig. 2.

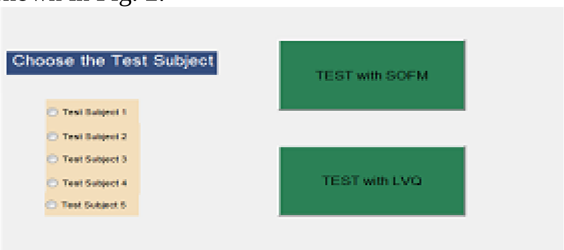

Fig. 2 GUI main frame screen using matlab

2.2MULTI-CHANNEL EMG ACQUISITION

EMG measurement is defined by the instrument called electromyogram. The acquisition system generally consists of an instrumentation amplifier, a notch filter, an offset adjustment, an isolator, a main amplification circuit, and the cathode ray tube (CRT) display. An instrument amplifier is a high common mode rejection ratio (CMRR) differential amplifier which works to acquire a weak signals or low amplitude signal included in the high-frequency noise signal. The notch filter gets rid of the 50Hz noise while keeping the EMG signal data intact [5]. The offset adjustment maintains the baseline level during the subject's motion. The function of isolator is to separate front-end section from the rear-end section to protect the EMG signal from possible electrical shock to the patient. The main amplification circuit conditions the EMG prior to be display on the CRT display. The complexity of the electronic circuit becomes realized with the necessity to monitor the multi-channel of EMG. Such complicate designs, are made generally possible by the creation of entirely reconfigurable and programmable components. In this research, we acquire two EMG signal from the surface electrodes placed at the forearm [8].

An EMG control system based on pattern recognition includes three significant stages, respectively data acquisition, data segmentation and feature extraction [7].

2.2 DATA SEGMENTATION

The EMG signal obtained from the acquisition system is further de-noised using wavelet Transformation method. As the wavelet transform can localize both time and frequency components. Whereas the Fourier transform gives only the frequency components hence the wavelet transform is more preferable over Fourier Transform. More over the wavelet transform gives very high frequency resolution even at high frequency ranges, so the noise components in the desired signal can be isolated farther. The discrete wavelet transform with four levels of decomposition is proposed; the Daubechies (db2) mother wavelet transform family is selected and is made applicable as shown in Fig 3.

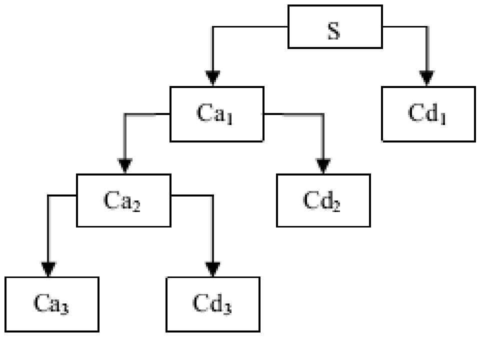

Fig. 3 Multi-resolution decomposition tree of EMG signal at third stage.

The window size of Daubechies Family mother Wavelet Transform can be modified by using the frequency analysis. Consequently, the signal analysis can be performed at the high frequency signals resulting into the same consequences as of the analysis at the low frequency. Combination of different wavelet windowing technique can be used to describe the signal characteristics. Each wavelet is based on the same function called "mother wavelet". These wavelets are the subset of mother wavelet operated with scaling and translation as shown in equation (1).

$$S = Ca_3 + Cd_1 + Cd_2 + Cd_3 \quad ..... (1)$$

From the equation, the scaling and translation are represented as 'a' and 'b', respectively one for approximation and second for standard deviation from those of real values. The scaling is a process of compression or dilation of mother wavelet window resulting into the variation in its resultant frequency. The scaled wavelet is then normalized so as to maintain its energy level to be equal to meet the energy level of mother wavelet window. Therefore, if the φ (t) is the function of mother wavelet, a general term of wavelet with the position of 'a' and 'b' can be written as following by equation (2).

$$\varphi_{a,b}(t) = \frac{1}{\sqrt{a}}\varphi\left[\frac{t-b}{a}\right] = \varphi(scale, position, t) \quad ...... (2)$$

2.3 FEATURE EXTRACTION

2.3.1 RMS and logRMS

The root mean square (RMS) value of each channel was calculated to create a 2-D feature vector. It has been argued that the response time of the control system should not introduce a perceivable delay [9]. In the same set of data if the signal functions in a continuous f (t), which is set in the T1 ≤t ≤T_2can measure RMS of continuous functions from the equation (3)

$$X_{RMS} = \sqrt{\frac{1}{T2-T1}\int_{T1}^{T2}[F(t)]DT_1^2} \qquad \text{........ (3)}$$

Similarly, the log-transformed feature space, demonstrates a more uniform scattering of points compared to the untransformed RMS features of an able-bodied participant [12]. That shown by equation (4)

$$X_{RMS} = \log x_{RMS} \qquad \text{......... (4)}$$

2.3.2 Centroid of Frequency

The frequency centroid is a measure used in digital signal processing to characterise a spectrum. It indicates where the centre of mass of the spectrum. The spectral centroid is the barycentre of the spectrum. It is computed considering the spectrum as a distribution which values are the frequencies and the spectrum of frequency [10].That shown by equation (5)

$$\mu = \int x.p(x)\delta x \qquad \text{....... (5)}$$

2.3.3 Standard Deviation

The standard deviation of EMG signal can calculate by the sample of signal that shown by equation (6)

$$SD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \qquad \text{......... (6)}$$

III. CONCLUSION

The usefulness of the EMG features extracted from multiple-level decompositions of the EMG signal has been described in this paper. The optimal EMG resolution components are selected to obtain the features with a minimum effect of noise. By means of an efficient acquisition system the various features are extracted from EMG data renders to be an effective means that can estimate the various detail coefficients of the EMG for a prosthetic hand. It can also ensure that the result of the feature extraction will give accuracy will be as high as possible. The suitable mother wavelet and decomposition level of Daubechies wavelet can be utilised for various human robot interfacing. This method can be used in a wide class of clinical and engineering applications.

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