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Surface Electromyography (sEMG) Feature Extraction based on Daubechies Wavelets

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Abstract— **Wavelet transform feature extraction has become one of the most powerful techniques to improve the classification accuracy. In this paper, we are investigating the multi-level Daubechies wavelet reconstruction parameters. The EMG signal after performing the Daubechies wavelet was further processed by using one of the most successful features which is MAV. RES index statistical measurement was used to evaluate the class reparability of the features. The optimal results are obtained by using the seventh order of Daubechies with the level 1 and level 2 details components after performing wavelet reconstruction.**

Keywords-component: Daubechies wavelet, feature extraction, Electromyography signal, EMG.

I. INTRODUCTION

Electrical signal which is acquired from any organ of human body which represents the physical variable of interest is known as biomedical signal. Electromyography (EMG) signal is a biomedical signal derived from neuromuscular activities of skeletal muscle [1]. EMG signal measures electrical currents generated in the muscle fibers and can be observed at the surface of the skin. EMG signal has become one of the most important physiological signals, which has been widely used in clinical and engineering applications [2].

EMG signal is controlled by the nervous system and it is dependent on the physiological properties of muscle. EMG signal is a complicated signal, and noise is acquired while travelling through different tissues [3]. Muscle tissue conducts electrical current and these electrical signals are the muscle action potential. Surface EMG (sEMG) is a method of recording the information present in these muscle action potentials. The surface EMG is the summation of the entire muscle action unit potential (MUAP) underneath the sensors that placed on the skin surface. The electrical signal generated during muscle activation which is the EMG signal can be measured by placing the EMG sensors on the surface of the skin at the desired muscle [4].

EMG feature extraction is an important step to improve classification results. Feature extraction is needed in order to extract the useful information from the signal [2]. EMG signals can be represented in both time domain and frequency domain [5]. Time domain features are amplitude versus time representation of the signals. Signal processing application requires additional information that is not present in the time domain representation, thus signals are usually analyzed in frequency domain. Wavelet is recently developed signal processing tool enabling the analysis on several timescales of the local properties of complex signal that can present non-stationary zones. Wavelet Transform is a time-frequency representation which is useful in the analysis of non-stationary signals such as EMG signal. Wavelet transform possesses the characteristics of multi-resolution parameters and these features have overcome the weakness of a single resolution of the short-time Fourier transform [6]. By using wavelet transform method for feature extraction, unwanted noise was eliminated effectively through the selection of the different techniques of wavelet transform.

In previous work, wavelet transform has become an important technique to extract the features from the filtered EMG signal. An investigation on usefulness of EMG feature extraction from the multiple-level wavelet reconstruction of the wavelet coefficients for improving the EMG classification has been widely introduced [2, 7-10]. In this work, Daubechies wavelets similar to work in [11] have been used to find the optimal wavelet reconstruction which gives the best result for EMG feature extraction. Different levels and orders of Daubechies wavelet were evaluated in this research.

II. MATERIAL & METHODS

A. sEMG Signal Acquisition

The experiment was carried out after obtaining the clearance from university ethics committe. The sEMG signals were recorded by using Delsys Trigno Wireless System [12]. The EMG signals were extracted from six daily life upper limb movements. The experiment was conducted on 5 different subjects with 3 males and 2 females. Each subject were asked to perform the six different movements which are wrist flexion (wf), wrist extension(we), forearm pronation (fp), forearm supination (fs), hand close (hc) and hand open(ho) as shown in Fig 1. Recordings of sEMG were recorded from two different muscles which are flexor Capri radialis and extensor capriradialis by using patented parallel bar of the Delsys Trigno Wireless sensors as shown in Fig 2. The sensors were placed in the parallel position with the muscle for accurate recordings. Each subject was asked to hold for 5 seconds for each

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movement with a rest of 5 seconds in between the changes of the movements. Butterworth band pass filter of 10-500Hz bandwidth were used to filter the excessive noise of the raw EMG data by using the Delsys EMGWorks 4.0 software [12]. The sampling frequency was set to 450Hz using a 16bit resolution for this experiment.

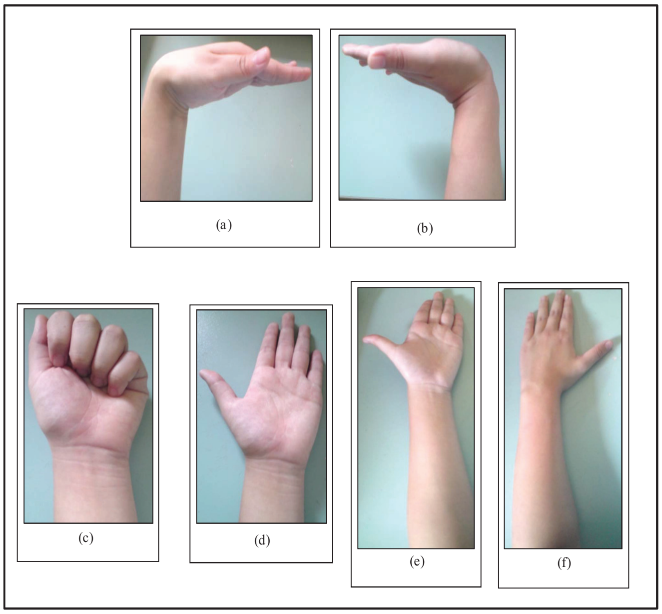


Fig.1. Six daily life hand motions (a) wrist extension (b) wrist flexion (c) hand close (d) hand open (e) forearm supination (f) forearm pronation

Fig.2. DelsysTrigo Wireless sensors placement on subject's hand for flexor capri radialis muscle and extensor capri radilis muscle.

B. *sEMG Feature ExtractionTtechniques*

Feature extraction techniques can be divided into time domain and frequency domain representation. Time domain methods such as Zero Crossing (ZC), Slope Sign Change (SSC), Willison Amplitude (WAMP), Root Mean Square(RMS), Mean Absolute Value (MAV) and other techniques has been investigated by many researchers for extracting the useful information from the raw EMG signal [5,13]. In this work, two successful methods for time domain feature extraction, i.e., RMS and MAV have been identified. The raw EMG signal was initially filtered and subsequently feature extraction was applied to highlight the information and, finally, evaluated by using statistical measurement method.

Mean absolute value was calculated by taking the average of the absolute value of the raw EMG signal. It is defined as:

$$MAV = \frac{1}{N}\sum_{n=1}^{N}|x_n| \quad (1)$$

Root mean square is calculated by squaring each data point, summing the square, dividing the sum by taking the number of samples and taking the square root. It is defined as:

$$RMS = \sqrt{\frac{1}{N}\sum_{n=1}^{N} {x_n}^2} \quad (2)$$

In this work, it was found that the MAV and RMS method yielded almost the same result but MAV features gives a better quality in class separability viewpoint. This findings is consistent with findings of other researchers as reported in [13].

Wavelet transform techniques are representation in time-frequency domain. Wavelet transform are generally divided into discrete and continuous wavelet transform [14]. Continuous wavelet transform is used to divide a continuous time function into wavelet. Large amount of data will be produced by using the continuous wavelet transform while this can affect the efficiency of the feature extraction. Discrete wavelet transform is used to overcome the redundancy of continuous wavelet transform by scaling and translating function in discrete wavelet [15].

Daubechies wavelet has been widely in used for its effectiveness in giving a better feature extraction result [2, 11]. Thus, in this research, the Daubechies wavelet in various levels and orders was investigated. DB4, DB7 and DB10 were used with level 1, 2, 5, and 9 for highlighting the features in EMG. Daubechies wavelet also acts as a filter where it can be able to remove more unnecessary noise in the EMG signal since Butterworth filtering techniques alone does not remove the extra noises in the EMG signal effectively.

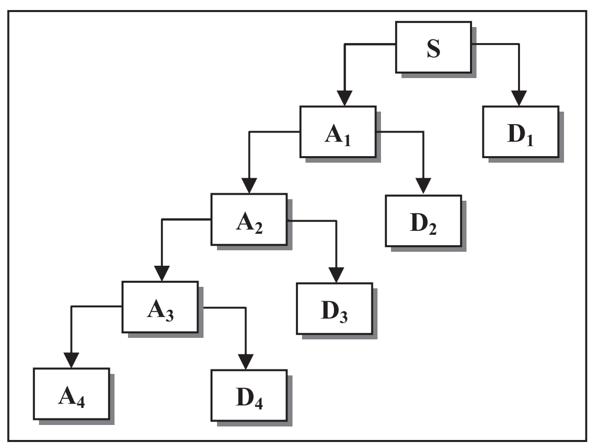


Fig.3. Daubechies level 4 reconstruction tree

The filtered raw EMG signal was then processed by using Daubechies wavelet to obtain details components (D1) at level 1. The data was processed by passing through various level of wavelet reconstruction until the results of the expected levels are obtained (D1, D2, D5 and D9) as shown in Fig 3. Daubechies wavelet can be divided into decomposition and reconstruction techniques. Literature has shown that reconstruction techniques of wavelet transform gives a better classification performance [2]. The inverse wavelet transform techniques were used for obtaining the reconstructed Daubechies wavelet. After obtaining the reconstructed signal, the details of subset (D1, D2, D5 and D9) was extracted by using the MAV features to gives a better feature extraction results.

C. Feature Extraction Evaluation

A better class separability viewpoint will give a better performance in feature extraction [2, 13]. The separation between the motions was measured and the minimum variation in the subject would yield a better results. In this context, the statistical measurement criterion which is known as RES index method [13] was used. The performance of the feature extraction was measured using this statistical measurement index. Euclidean Distance (ED) was used for the separation index and Standard Deviation (SD) is used to measure the variability which is also used as a compactness index [10]. ED is defined as:

$$ED = \sqrt{(a_{ch1} - b_{ch1})^2 + (a_{ch2} - b_{ch2})^2} \qquad (3)$$

where, a and b are the feature mean of two motions from the six daily upper limb motions with two muscles, ch1 is flexor capri radialis muscle and ch2 is extensor capri radialis muscle. The SD equation is given by

$$SD = \sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_1 - \bar{x})^2} \qquad (4)$$

where, N is the number of samples, x_1 is the MAV features and $\bar{x}$ is the mean of the MAV features. The ratio between ED and SD is known as RES index [10].

$$RES = \frac{ED}{\bar{\sigma}} \qquad (5)$$

The higher the RES index value, the better the class separability performance which can lead to a better classification performance.

III. RESULT & DISCUSSIONS

The example of the EMG signals feature extraction by using MAV and RMS techniques are shown in Fig. 4. It can be observed that MAV and RMS features yield almost the same result but MAV gives slightly better result as compared to RMS features. The tabulated RES index for both techniques is shown in Fig.5. We can see that MAV RES index is slightly higher than RMS. As the MAV techniques would lead to better class separability performance, we are using MAV to further perform the feature extraction for the Daubechies wavelet.

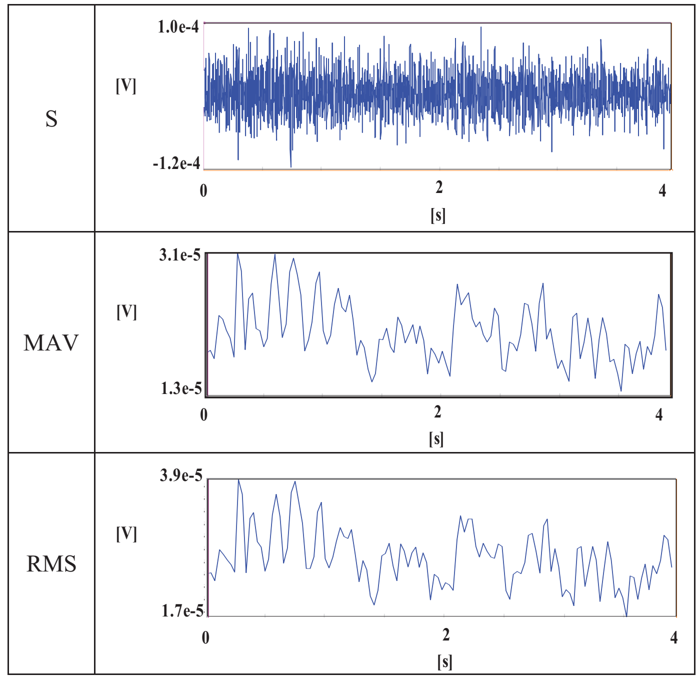


Fig. 4. Comparison of EMG signals using MAV and RMS feature extraction from the raw signal (S)

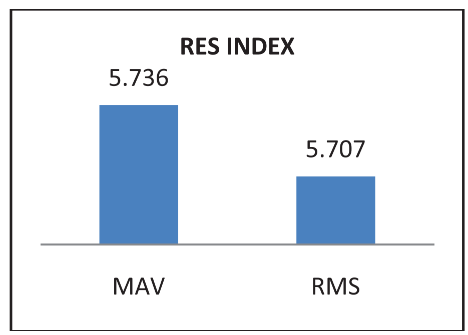
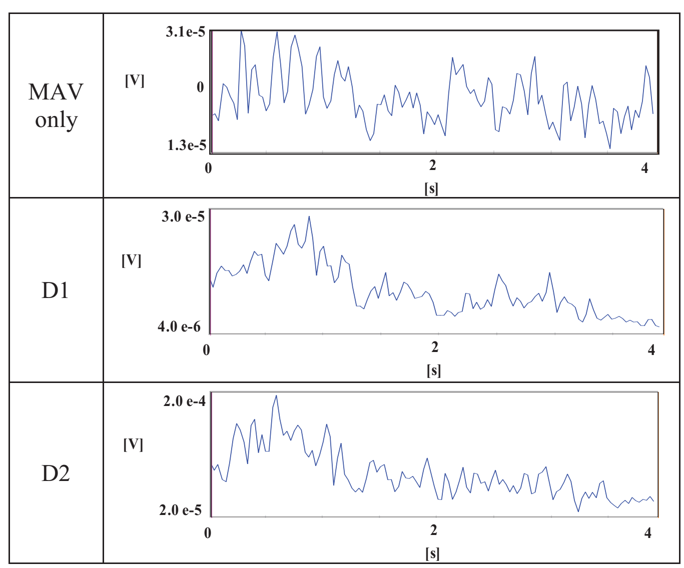


Fig. 5. Bar chart for MAV and RMS RES index



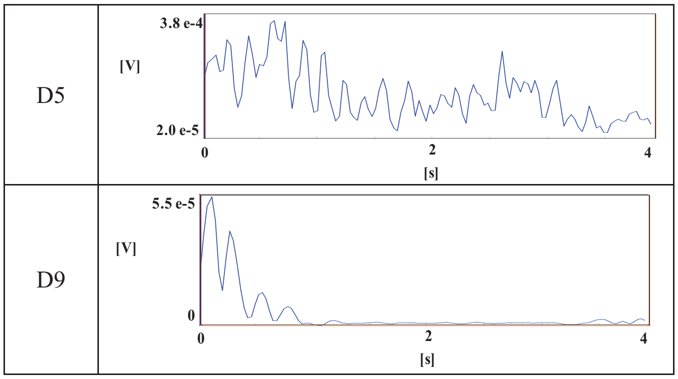


Fig.6. The MAV features of EMG signals after using Daubechies DB7 reconstruction signal (D1, D2, D5 and D9)

Fig.6 shows the MAV features of EMG signals after using the Daubechies DB7 reconstruction techniques. It can be seen that D1 and D2 levels resemble the original MAV features without any further filtering techniques. Meanwhile, D5 and D9 levels are slowly losing its information as the levels of Daubechies wavelet are increased. This shows that there are more information loss as the Daubechies wavelet levels are increased.

The results of RES index for Daubechies wavelet was achieved from DB4, DB7 and DB10. The bar chart in Fig. 7 shows that the RES index gives a better performance from the detail signal in the first and second level (D1 and D2) compared to the signal with the MAV feature extraction only. It was found that DB7 shows a better performance in terms of the detail component in the first and second level (D1 and D2) compared to DB4 and DB10. From the bar chart, it can also be observed that Daubechies wavelet reconstruction in the first level, D1 shows better results than D2, D5, and D9 level. In this context, the feature extraction using Daubechies wavelet reconstruction from the first level and second level in DB7 shows a better class separability performance.

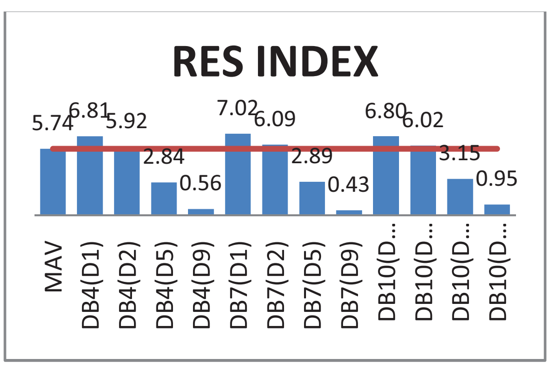


Fig.7.Bar Chart for D1, D2, D5, and D9 (DB4, DB7 and DB10) RES index

IV. CONCLUSION

The performance of Daubechies wavelet with multi-level reconstruction has been investigated in this research. The most successful feature extraction techniques were chosen by using MAV and also wavelet transform for EMG signal processing. The results show that EMG signals feature extraction gives a better performance in term of class separability by using Daubechies detail component in level 1 and level 2. The RES index has been used to evaluate the performance of the EMG feature extraction. Good feature extraction techniques can lead to higher classification accuracy. In this paper, it shows that DB7 are suitable for EMG feature extraction.

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