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DWTBASEDIDENTIFICATIONOFAMYOTROPHICLATERALSCLEROSISUSINGSURFACEEMGSIGNAL

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DWT based Identification of Amyotrophic Lateral Sclerosis using Surface EMG Signal

Dr. Suvarna. S. Chorage [α] & Archana Bhaskarrao Sonone [σ]

Abstract- In the process of identification of Amyotrophic Lateral Sclerosis (ALS) which is a motor neuron disorder, extraction of feature is the most important step. In this work normal and ALS class for identification and monitoring have been included. Analysis of surface electromyography (sEMG) signal for ALS identification using discrete wavelet transform is most simple and powerful method being used all over the world. Time domain parameters, like Zero Crossing Rate (ZCR) and Root Mean Square (RMS) and frequency domain parameters like Mean Frequency (MF) and Waveform Length (WL) are considered. Threshold values for the above mentioned parameters are calculated for both the normal and ALS classes. Discrete Wavelet Transform (DWT) parameters are considered and their threshold values are also calculated for both normal and ALS classes. Surface EMG (sEMG) signal database of normal and ALS patients for both male and female is considered.

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I. Introduction

Human body is made up of large number of different bundles of muscle fibers. These all bundles of fibers are arranged functionally into different motor unit which are activated by nerve impulse which is very minute electrical pulse provided by the brain's nervous systems. These electrical impulses travel through the whole length of muscle fiber spread throughout in the body. Hence very small electric currents are generated by these bundles of muscle fibers during muscle force production [1]. The electromyography (EMG) signal is an electrical responses generated by the nerve cells of the brain in the form of electrical pulses from the contraction and relaxation of bundles of muscles throughout the body. sEMG is an electrical signals associated with the uppermost layer of muscles which are the electrical impulses generated and controlled by motor nerve unit of brain [2]. sEMG consists of the information in the form of electrical impulses about the various muscle activities in the body. Obtaining sEMG signals are of two different types [3]. First method of recording sEMG is with a surface electrodes and second method is insertion needle electrode which is called as intra electrode. By applying conductive solution to the skin surface and placing the electrodes on it, sEMG recording is done. It contains important information about the activity of muscles, status of its health, and its characteristics. There are two types of EMG signals are 1) Surface EMG (sEMG) 2) Intramuscular EMG (iEMG) [1]. In sEMG collection of muscle contraction or expansion information from the uppermost layer of muscle .Whereas in the case of iEMG collection of information is done from the deep inside the muscles in the body. To extract information from surface EMG signal, there are different methods of different time domain, frequency domain and time-frequency domain methods have been used. EMG is very important to diagnose many nervous disorders [1]. ALS is one among those Motor Nerve Disorder (MND).ALS, which is a progressive neurodegenerative disorder that affects the muscular activities of the body because of changes in the muscle configuration [1]. The EMG represents electrical activities inside the body. As EMG signal plays very important role as diagnostic tool for the MND patients, hence extracting important information from it is very important and having vast scope in it its analysis process. To classify different MND diseases, feature extraction of sEMG is very important. Here one of those feature extraction techniques are presented based on wavelet transforms [1][3]. The rest of the paper has been arranged as, in the next section which is section II, the related work is stated. Section III explains the methodology of the identification using feature extraction. The section IV explains about the results obtained in the process and its analysis which is in the terms of discussion. In the last section V conclusion is stated.

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II. Related Work

Work proposed by Shaikh Anowarul Fattah et.al [1], is based on feature extraction of EMG using discrete wavelet transform. The time domain and frequency domain features have been discussed along with discrete wavelet transform features. The time domain feature discussed in this paper is zero crossing rate and the frequency domain feature discussed is mean frequency. Wavelet transform coefficients are explained in detail. Wavelet transform used is three level decomposition coiflet transform. Accuracy of the time and frequency domain feature extraction methods are compared with wavelet transformation method.

Work done by A. B. M. Sayeed Ud Doulah et.al [2], EMG signal is studies and examined in short time fourier transform for the detection of the ALS disease.

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Shapes and firing rates of motor nerve unit are the important features analyzed for the detection of neuromuscular disease. For the same study, time-frequency domain method has been considered. Use of spectrum analysis for the extraction of features has been done. The Short Time Fourier Transform method for the classification of EMG signals to detect the ALS patients and distinguish normal group.

Work done by Amol Lolure and V. R. Thool [3], is on the extraction of features from EMG and it has been evaluated in scatter graph. Extraction techniques have been applied for the recognition of hand movements. Scatter graphs which are actually mathematical diagram tool for evaluating the performance of EMG features. Mean absolute value is the key parameter has been considered which has been obtained from coefficients has shown the better performance in EMG signal analysis for hand and finger movement recognition.

Work done by Hossein Parsaei et.al [4], is the decomposition of EMG signal using the supervised technique of feature extraction. Signal decomposition techniques are discussed. Fisher discriminant analysis and supervised principal component analysis have been explored. The work proposed by the author is most beneficial in the decomposition of more complex signals. This work is quite useful for the decomposition of biomedical complex signals such as EMG in order to extract important information from them in order to detect the particular disease using the threshold values of the features.

Work done by P. Pal et.al [5], is the feature extraction for the detection of muscular atrophy. Knowledge-based expert system design and disease diagnosis is explored for the classification of EMG signal which is very hard to classify because of non stationary nature of the signal. Here on-line and off-line classification of EMG signal focusing mainly on disease diagnosis based on muscular atrophy approach.

III. Methodologies

a) Discrete Wavelet Transform

Wavelet transform has been proved to be very powerful mathematical tool for biomedical signal processing as it can process non stationary time varying complex signals. Wavelet transform techniques are of two types. 1) Discrete wavelet transformation (DWT) 2) Continuous wavelet transformation (CWT). In this paper DWT has been chosen because the application is in real time engineering signal application and the biomedical signal involved here is in complex nature. In discrete wavelet transform method, it iteratively transforms interested real time signals into multi-resolution two domain subsets of coefficients of wavelet transform which contains the information about the non stationary signal which can be used to analyze the complicated signal. Coiflet wavelet transform has been used for the decomposition of EMG signal in order to detect the neuromuscular disorder ALS.4level decomposition of wavelet transform has been used. Hence 5wavelet transform coefficients are used as characteristic parameters.4level decomposition means signal undergoes low pass and high pass filtering 4 times to give 4 low pass filter coefficients and 1 coefficient from last stage high pass filter.

b) Different Features

1) Root Mean Square (RMS): Time domain parameter considered is RMS which is one of the well known features in time domain for analysis of the EMG. It is defined as the square root of the arithmetic mean of the squares of a set of values. It shows the power contain in the signal. It is the most common mathematical tool for defining the effective voltage and current of a non stationary signal. Mathematically it is represented as,

$$RMS = \sqrt{[\frac{1}{N}\sum_{i=1}^{N} y_i^2]} \quad (1)$$

2) Waveform length (WL): WL describes the complexity of non stationary EMG signal. It is defined as the cumulative length of the EMG waveform over the particular focused time period segment N where n is the number of signal samples being considered. Mathematically it is expressed as,

$$W_l = \sum_{n=1}^{N} |z_{n+1} - z_n| \quad (2)$$

3) Mean Frequency (MF): It is defined as a pitch measure which shows the center of the distribution of power across the all frequencies in the spectrum. It represents the smooth estimation of the concentration of spectral power contain. It is a summation of all the frequencies under consideration divided by total frequencies present over the particular time segment. Mathematically it is expressed,

$$M_f = \frac{\sum f_x}{\sum f} \quad (3)$$

4) Zero Crossing Rate (ZCR): Rate of sign-changes in any signal is called as ZCR. It refers the rate at which the signal crosses from positive amplitude to negative amplitude or vice a versa. In some applications only the "positive-going" or "negative-going" crossings are counted, rather than counting all the crossings. It is a summation of difference of all the present signal sample $x(n)$ and previous signal sample $x(n-1)$ over the particular time segment K. Mathematically it is expressed as,

$$zcr = \frac{1}{2K}\{\sum_{n=1}^{K-1} |sgn[x(n)] - sgn[x(n-1)]|\} \quad (4)$$

5) DWT Coefficients: 4 level decomposition is been used in coiflet wavelet transformation for feature extraction to get 5 coefficients in all, 4 from 4level low pass filter and 1 from last stage high pass filter such as

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cd1,cd2,cd3,cd4 and ca4. The energy contain in the above said coefficients is been used in order to use them as features for detecting the neuromuscular disorder.

6) KNN Classifier: It is k-nearest neighborhood algorithm (KNN). It is used for classification of objects in pattern recognition which is based on closest training examples. It is an instant based learning or lazy learning. In this paper for the classification of sEMG into two classes normal and defected i.e. ALS KNN is used.

IV. Results and Discussions

EMG database of 30 normal male and 15 normal females of age between 22 to 35 and 40 to 67 having normal body shape is been considered. For ALS patients also 30 male and 15 female EMG database is been considered. The features on the basis of which detection of ALS and classifying them into two group of normal class and ALS class are considered as follow. Mean frequency which is the frequency domain feature showing the comparison between normal and ALS class. Here the bubbled line shows the graph for normal person and plain line shows the graph for ALS patient. Following graph shows the MF in normal person is more stable as compares to ALS person. MF is more for ALS patient than normal. But this frequency domain parameter does not give us accuracy in every case. Hence for more accurate results we are exploring the other techniques.

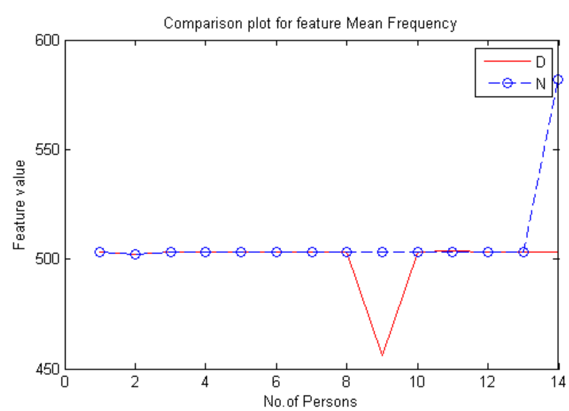

Fig. No. 1: Comparison graph for Mean Frequency in normal (Bubbled line) and ALS patient (Plain line).

Another frequency domain feature we considered is waveform length which is denoted as WL and which refers the complexity of the waveform in the particular time segment. Following graph shows the graph of WL for both normal and ALS person. WL is more in ALS than that of normal persons.

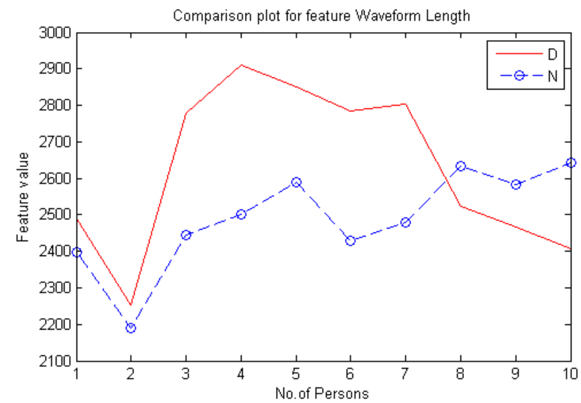

Fig. No. 2: Comparison graph for Waveform Length in normal (Bubbled line) and ALS patients (Plain).

Time domain feature Root Mean Square has been considered to show the time domain parameter in normal and ALS patients. Following graph shows the comparison between normal and ALS patient. RMS value is always greater in ALS than normal person.

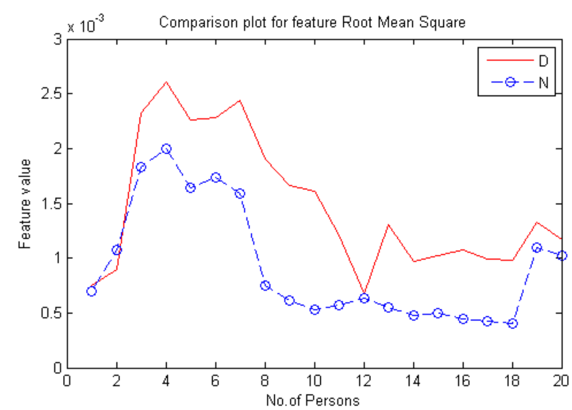

Fig. No. 3: Comparison graph for RMS in normal (Bubbled line) and ALS patients (Plain line)

Another time domain parameter we considered here is Zero crossing rate for both the class. ZCR is greater in ALS than that of in normal persons. Following graph shows the comparison for ZCR between normal and ALS patients.

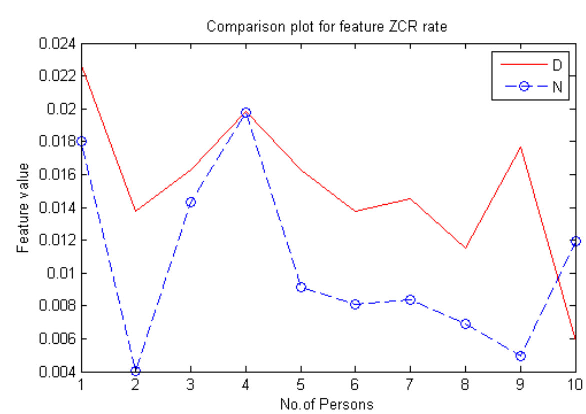

Fig. No.4: Comparison graph for Zero Crossing Rate in normal (Bubbled line) and ALS patients (plain line).

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As only frequency domain or time domain parameter does not give accurate identification of ALS. Hence we exploring the other techniques which give the multi-dimensional parameter to get the more accurate results. Following graphs show the energy of wavelet transform coefficients for 4level decomposition which gives us 5 coefficients are as follows. D1,D2,D3,D4 and C4 these are wavelet transform coefficients obtained from 4level decomposition wavelet transform from which D1,D2,D3 and D4 are obtained from low pass filter and last coefficient C4 is obtained from last stage high pass filter.

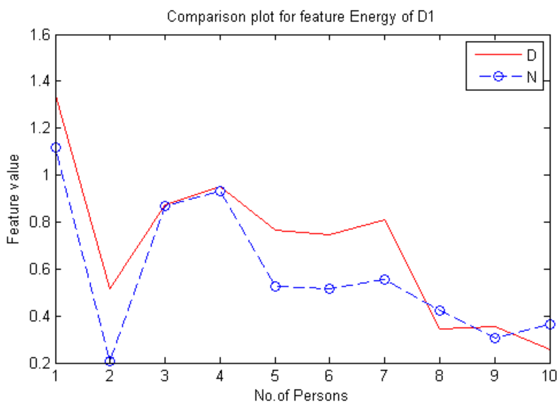

Fig. No. 5: Comparison of energy of D1 coefficient in normal (Bubbled line) and ALS patients (Plain line).

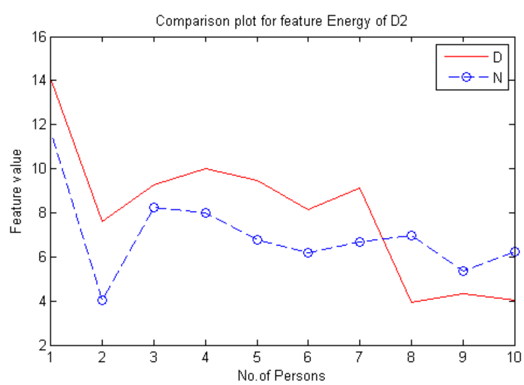

Fig. No. 6: Comparison of energy of D2 coefficient in normal (Bubbled line) and ALS patients (Plain line).

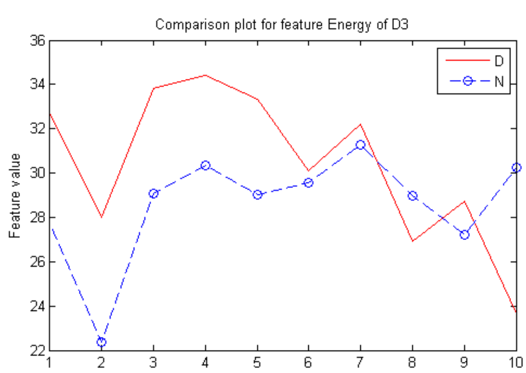

Fig. No. 7: Comparison of energy of D3 coefficient in normal (Bubbled line) and ALS patients (Plain line).

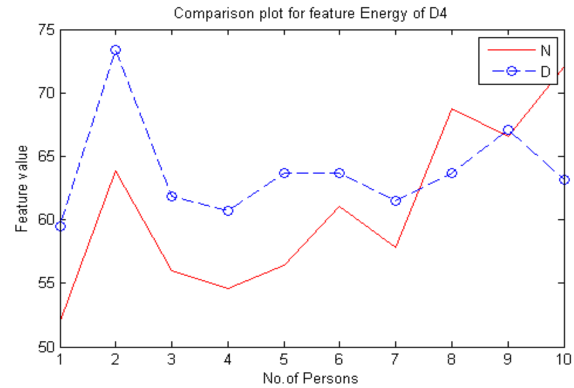

Fig. No. 8: Comparison of energy of D4 coefficient in normal (Plain line) and ALS patients (Bubbled line).

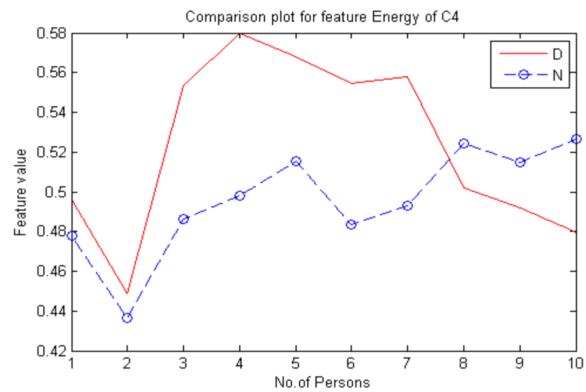

Fig. No. 9: Comparison of energy of C4 coefficient in normal (Bubbled line) and ALS patients (Plain line).

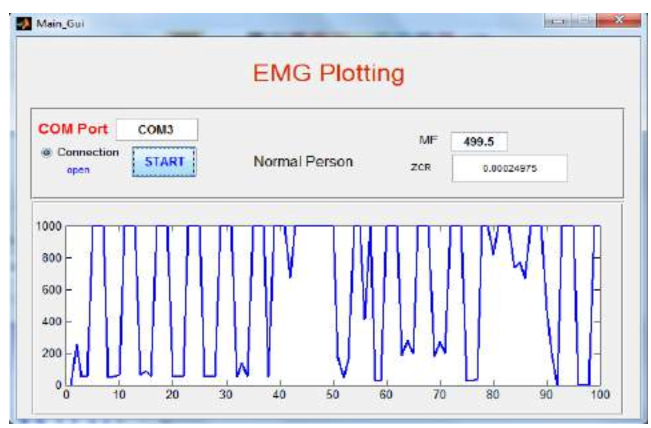

Fig. No. 10: GUI showing the result of normal person EMG taken from EMG sensor of hardware part of the project along with its mean frequency (MF) and zero crossing rate (ZCR).

In figure No.10 mean frequency of normal person's EMG is less than 500 and zero crossing rate is 0.002464 which is nearly to the values obtained from the signals of database used for normal persons. In figure No.11 MF and ZCR are zero as no signal is detected by the EMG sensor. This case can be obtained in two different ways first when the person whose EMG is to be taken is dead and secondly when EMG sensor is not connected.

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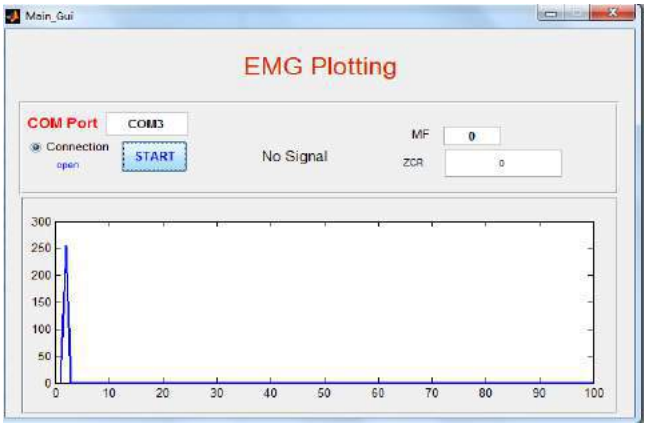

Fig. No. 11: GUI showing the results when there is no signal is detected by the EMG sensor and value of both MF and ZCR are zero.

V. Conclusion

To identify the ALS disease on the basis of feature extraction from the sEMG database we have used the 4level decomposition wavelet transform to get the multi-dimensional resolution of higher accuracy than the conventional time and frequency domain analysis. From the time domain, frequency domain and wavelet domain feature extraction, we compare the threshold values for the different parameters in above mentioned domains to identify the ALS patient with more accuracy. Characteristic table of features in different domains and their values in normal and ALS are shown as follows.

Table No. 1: Threshold values for the normal and ALS patients

Sr. No.	Parameter Name	Threshold Values in normal	Threshold Values in ALS
1.	Mean Frequency	502	503
2.	Waveform Length	2535	2750
3.	Root Mean Square	1.525	2.575
4.	Zero Crossing Rate	0.010	0.0114
5.	Energy of D1	0.5125	0.875
6.	Energy of D2	7.120	9.70
7.	Energy of D3	30.5	31.6
8.	Energy of D4	59.9	63.2
9.	Energy of C4	0.496	0.483

VI. Acknowledgment

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