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Multichannel EEG Signal Acquisition and Multiwavelet Based Emotion Recognition using BCI

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Abstract—**This paper aims to recognize emotion through EEG. The EEG signals are acquired from the wireless wearable 8-channel Enobio device for the emotions such as smile and anger. The acquired EEG signals are processed to recognize selected emotions. The features like mean, standard deviation, median, entropy, variance, minimum, maximum and skewness have been extracted from sub-signals obtained by multiwavelet decomposition of EEG signals. These features are used as an input to support vector machine (SVM) for classification of human emotions. The proposed method has provided classification accuracy of 87.5% using SVM.**

Keywords— **EEG, Multi-wavelet, SVM, BCI**

I. Introduction

Brain-computer interface (BCI) is a new technology which aims to communicate people's intentions directly from their thoughts to the outside world. It is especially useful for severely paralyzed patients, since motor ability is no longer a necessity for this communication. The normal people can enhance their communication with computers using this technology. Many researchers are examining the possible uses of such applications. BCI desires to give an alternative way of communication for the disabled persons. [1].

Emotion plays a very important role in human life. Emotion classification aims to develop and improve the intellectual brain computer interface (BCI) system. The emotion classification is applicable in many areas of medical sciences like neurology and psychology. The neurology related disorders can be recognized by using emotion recognition system using biomedical signals like electromyogram, electrocardiogram and facial expressions. The common strategy for classification of emotion is through speech and facial expression. This strategy can lead to false classification of emotion since face expression and speech can be intentionally changed to mislead. Due to this reason it is helpful to use physiological signals like electroencephalogram (EEG) signal to study human emotions.

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The emotions from EEG signal are more useful since it is difficult to intentionally influence the brain activity. The features extracted from EEG signals are useful for recognition and classification of human emotions. Non-linear dynamic complexity can be used which measures complexity of different emotional signals. Another measure can be correlation dimension which measures the complexity of EEG signals and analyzes human emotions. The statistical and energy based features extracted by using discrete wavelet transform of EEG signal can used for classification of human emotions [2].

This paper proposes a new method based on multiwavelet decomposition for classification of emotions from EEG signals. The multiwavelet transform is used to decompose the EEG signals into sub-signals. The features like mean, standard deviation, median, entropy, variance, minimum, maximum and skewness have been extracted from sub-signals obtained by multiwavelet decomposition of EEG signals. The extracted features used as an input to support vector machine (SVM) for classification of emotions from EEG signals. The paper is structured as follows: Section 2 shows the details of data collection, pre-processing and feature extraction, SVM classifier. The experimental results and discussion are shown in section 3. Finally, Section 4 concludes the paper.

II. Methodology

A. *Data Collection*

The EEG signals were collected from 14 healthy subjects by using the EEG headset shown in figure 1. All the subjects were undergraduate students of age 20-23. They did not have any physiological problems and psychological disorders. An 8-channel ENOBIO device was used to acquire the EEG signals via NIC software as shown in figure 2. The sampling rate was 500SPS. The electrode positions are F3, F4, C3, C4, T7, T8, F8 and Pz. The right (A2) and left (A1) earlobes used for ground and reference electrodes, respectively. Subjects were told not to make any hand or leg movements to avoid artifacts and eyes were closed.

Figure 1: 8-Channel Enobio EEG Headset

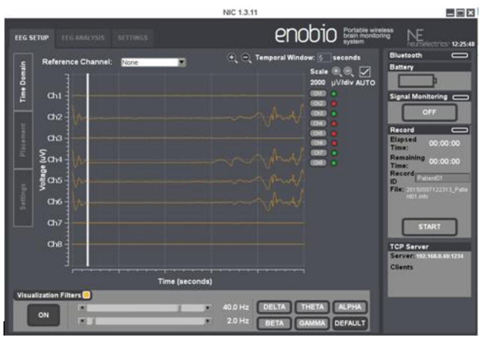

Figure 2: NIC software

The flowchart of the proposed method is as shown in the figure 3.

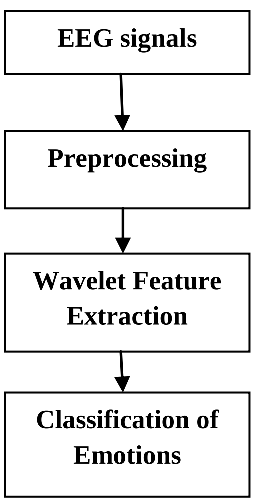

Figure 3: Flowchart of Proposed Method

B. *Preprocessing and Feature Extraction*

Some pre-processing techniques are to be applied to the raw EEG signals to reduce error as well as computational complexity.

i) Filtering:

Parks-McClellan optimal FIR filter of range 1-40 Hz is used. We are interested only in delta, theta, alpha, beta and lower gamma band signals, which have actionable information [3]. Figure 4 shows filtered EEG signal and figure 5 shows spectrogram and filtered signal of signal channel.

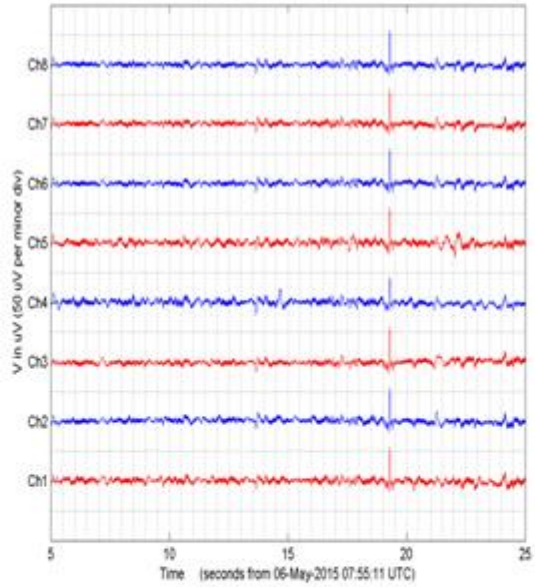

Figure 4: Filtered 8 channel EEG signal of one subject

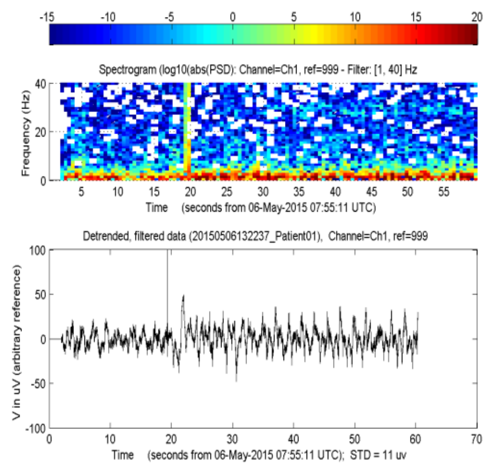

Figure 5: Spectrogram and filtered signal of single channel.

Histogram of the filtered data is obtained which is shown in figure 6.

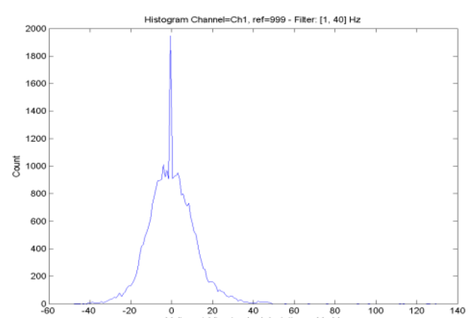

Figure 6: Histogram of single filtered EEG signal

ii) *Feature Extraction*

The filtered signal is wavelet decomposed into 6 levels using Daubechies 14 wavelet. The names of the Daubechies family wavelets are written as dbN, where N is the order. Wavelets divide the signal into different frequency components in a multi-resolution manner. As the EEG signals are non-stationary, Fourier Transform may not be a good choice. For given a signal of length N, the WT consists of log2 N stages at most. The first step is to produce starting from s, two sets of coefficients namely approximation coefficients CA1, and detail coefficients CD1. These vectors are obtained by convolving s with the low-pass filter Lo_D for approximation, and with the high-pass filter Hi_D for detail, followed by dyadic decimation (down sampling). Figure 7 shows decomposition signals using multilevel transform and figure 8 shows MWT decomposition structure.

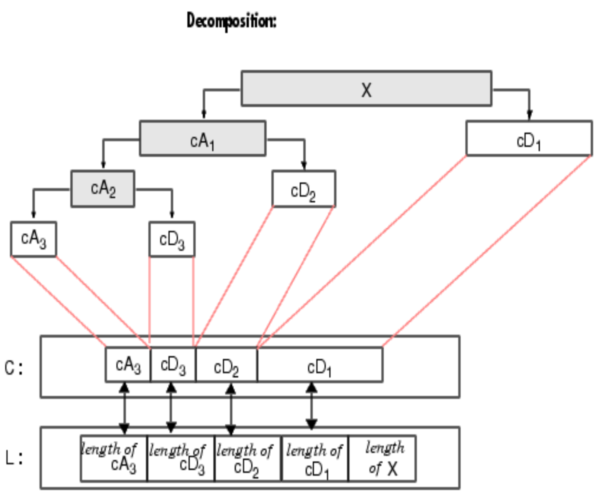

Figure 7: Image of decomposition signals using multilevel transform.

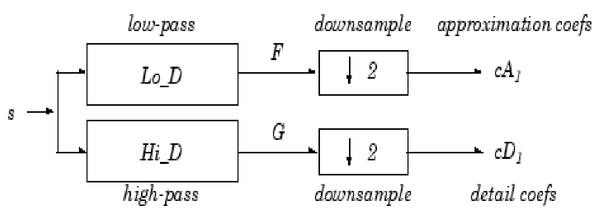

Figure 8: MWT decomposition structure

The statistical features are extracted from the decomposed sub-signal obtained from multiwavlet transform. The different statistical features considered are mean, standard deviation, median, entropy, variance, minimum, maximum and skewness.

1) Mean: It is commonly used to determine the normally distributed numerical data.

$$\bar{X} = \frac{\Sigma X}{N} \qquad (1)$$

2) Standard Deviation: It is a measure that is used to quantify the amount of variation or dispersion of a set of data values [4].

$$\sigma_x = \left(\frac{1}{N-1}\right) \sum_{n-1}^{N} (X_n - \mu_x) \qquad (2)$$

3) Median**:** It is the number separating the higher half of a data sample, a population, or a probability distribution, from the lower half [5].

$$\text{Median} = (n+1)/2 \qquad (3)$$

4) Entropy: The entropy is a measure of the level of disorder in a closed but changing system or it is a measure of randomness of a signal.

$$e = -\sum_1^n -\log(x^2) \qquad (4)$$

5) Variance: Variance measures how far a set of numbers is spread out [6].

$$\text{Var}(X) = \text{Cov}(X, X) = E[(X - \mu)^2] \qquad (5)$$

6) Minimum: The minimum block identifies the value and position of the smallest element in each row or column of the input, along vectors of a specified dimension of the input, or of the entire input.

(7) Maximum: The maximum block identifies the value and position of the largest element in each row or column of the input, along vectors of a specified dimension of the input, or of the entire input.

8) Skewness: It is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean [7].

$$\text{Skewness} = \frac{\Sigma (X_i - \bar{X})^3}{(n-1)^3} \qquad (6)$$

C. Classification

The classification of two emotions smile and anger is done using support vector machine (SVM) classifier.

i) Support Vector Machine (SVM)

The support vector machine is a learning algorithm which addresses the general problem of learning to discriminate between positive & negative members of given n-dimensional vectors. The SVM is used for classification & regression purpose. The main idea of SVM classification is to transform the original input set to a high dimensional feature space by using kernel function.

In Classification, training examples are used to learn a model that can classify the data samples into known classes. The Classification process involves following steps:

a. Create training data set.
b. Identify class attribute and classes.
c. Identify useful attributes for classification (Relevance analysis).
d. Learn a model using training examples in Training set.
e. Use the model to classify the unknown data samples.

SVM is a supervised learning process comprising of two steps:

i. Learning (Training): Learn a model using the training data.
ii. Testing: Test the model using unseen test data to assess the model accuracy.

The standard SVM takes a set of input data and predicts, for each given input, which of two possible classes the input is a member of, which makes the SVM a non-probabilistic binary linear classifier. Given a set of training examples, each marked as belonging to one of four categories, SVM testing algorithm builds a model that assigns new examples into one category or the other. An SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on. SVM constructs a hyper plane or set of hyper planes in a high- or infinite- dimensional space, which can be used for classification. A good separation is achieved by the hyper plane that has the largest distance to the nearest training data points of any class, since larger the margin the lower the generalization error of the classifier [8]. Figure 9 shows working of SVM.

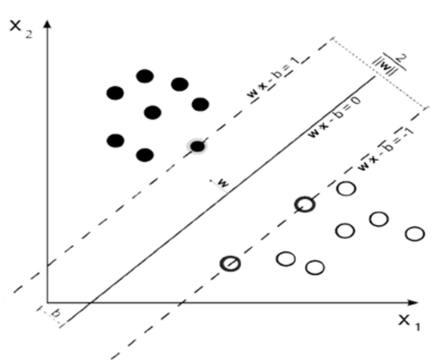

Figure 9: Working of SVM

III. Experimental Results and Discussion

In training phase 10 samples are used and those are pre-processed and features are extracted from those samples and they are used for testing phase for classification. In the testing each remaining samples are tested one at a time, the testing samples are also pre-processed and features are extracted. We calculate the total accuracy based on the following formula,

a = (no of correct output/ total no of testing samples) * 100

In the table 1 we have taken 8 samples for testing and got 7 correct outputs and the total accuracy obtained is 87.5% for SVM classifier.

Table 1: Accuracy

Classifier	Tested samples	Correct Output	Total accuracy
SVM Classifier	8	7	87.5%

IV. CONCLUSION AND FUTURE WORK

The use of EEG signals as a vector of communication between man and machines represents one of the current challenges in signal theory research. The principal element of such a communication system is known as “Brain Computer Interface”. The emotion recognition by computers is becoming very popular. It attempts to present various techniques that can be used to recognize emotions using speech and EEG brain signals. The signals are recorded from EEG headset and they are pre-processed using filtering process. The wavelet transform decomposed the EEG signals for feature extraction and based on the calculated parameters values the classification takes place. The SVM classifier classifies the smile and anger emotions with different accuracies. The total accuracy achieved for SVM is 87.5 % when we classified EEG signals into the emotions smile and anger. Therefore, we could conclude that the combination of wavelets and SVM classifier is a good choice for classifying emotions by emotion recognition systems using EEG signals based on BCI interface

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