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Human Emotion Classification From EEG using SVM and K-NN Classifier For BCI

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***Abstract*— Electroencephalogram (EEG) is one of the most reliable physiological signals used for detecting the emotional states of human brain. In this work the decomposition and automatic classification is achieved for two human emotions obtained from Electroencephalograph signals. Emotion is a natural communication in human life, the emotional state of a person defines their interaction with other people or objects. The EEG signals are most widely used in the medical field to analyse the patient condition, because it contains more information about human brain task. The subjects were described for different emotions such as smile and anger. The EEG signals are recorded by using ENOBIO 8 device, and pre-processing of the signal is done by designing the FIR filter. For the feature extraction the multi-wavelet transform is observed and for classification purpose KNN classifier, SVM classifiers are observed. In multi-wavelet Transform method we extract 8 statistical parameters for each sample. The comparision of the performance of both classifiers is achieved by calculating classification accuracy. The result shows 87.5% accuracy achieved by SVM and 75% by KNN classifier. SVM classifier reaches high efficiency.**

***Index Terms*— Electroencephalogram (EEG), Wavelet decomposition, 10-20 electrode system, KNN classifier, SVM classifier**

I. Introduction

The Electroencephalography is a type of simple, non-invasive brain-computer interfacing technique (BCI), it is used to measure the electrical activity of the human brain. Brain Computer-Interfacing is a popular technology that provides a way for communication with the outside environment using the brain thoughts. The success of this technology depends on the selection of methods to process the brain signals in each phase. Brain Computer Interface is a process that makes use of the brain's output path way for conveying the commands and messages to the external world [1]. There are various different brain computer interface technologies have been developed at different times, through different methods. In BCI technology there are three types.

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They are Invasive BCI, Semi Invasive BCI and Non Invasive BCI. Invasive Brain Computer Interface devices are those inserted directly into the brain and have the highest quality signals. Partially invasive BCI or semi invasive BCI devices are inserted inside the skull but rest outside the brain rather than within the grey matter.

The non-invasive brain computer interface has the least signal quality when it comes to communicating with the brain (skull distorts signal) but it is considered to be very safest when compared to other types. This type of device has been found to be successful in giving a patient the ability to move muscle implants and restore partial movement. One of the most popular devices under this category is the EEG or electroencephalography capable of providing a fine temporal resolution. It is easy to use, cheap and portable. The electric potential measured at the scalp through a set of electrodes (channels) are rich in information about the brain activity. Most of the useful information about the functional state of human brain lies in the frequency range of DC-30 Hz. EEG signals are discern as: delta band (0 to 4 Hz), theta band (4 to 8 Hz), alpha band (8 12 Hz), beta band (12-16 Hz), and gamma band (16- 30 Hz). The primary research on emotion recognition depends on alpha band [2].

EEG measurement is one of the most challenging tasks in emotion detection. Since the signals also contain a huge quantity of unwanted signals therefore care must be taken for a proper EEG recording. After signal acquisition phase, signals are to be pre-processed. Signal pre-processing is also called as Signal Enhancement. The acquired brain signals are contaminated by noise and artifacts (unwanted signals). The artifacts are eye blinks, eye movements (EOG), heart beat (ECG). In addition to these, muscular movements and power line interferences are also mingled with brain signals. The goal of this preprocessing step is to reconstruct the original brain activity. Artifact removal can be done using Common Average Referencing, Surface Laplacian, Independent Component Analysis, Common Spatial Patterns, Principal Component Analysis, Single Value Decomposition, Common Spatio-Spatial Patterns etc. The most frequently used methods are ICA, CAR, SL, PCA, CSP and Adaptive Filtering [3].

After obtaining the noise-free signals from the signal enhancement phase, essential features from the brain signals were extracted. For feature extraction from EEG signals use methods like Adaptive Auto Regressive parameters, bilinear AAR, multivariate AAR, Fast Fourier Transformations, PCA, ICA, Genetic Algorithms, Wavelet Transformations, Wavelet Packet Decomposition. Among these ICA, PCA, WT, AR, WPD, FFT are mostly used [4]. After feature extraction the signals are classified into various classes using various

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classifiers. Different types of classifiers include linear classifiers, Artificial Neural Networks (ANN) based classifiers, nonlinear Bayesian classifiers and, nearest neighbour classifiers [5]. Of these classifiers linear classifiers and non-linear Bayesian classifiers are mostly used in BCI design [4].

II. Materials and Methods

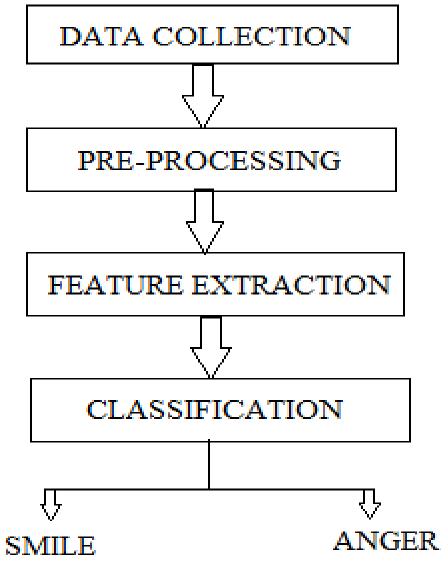

Figure-1 Flowchart of emotion classification process

2.1 Data Collection

The Data Collection starts with collecting the EEG signals from 14 subjects by using the EEG headset. In that 10 samples are taken for training phase to train the system and other samples are used for testing phase. A 8-channel ENOBIO device used for recording the EEG signals and later these signals are collected from NIC software via Bluetooth. The subjects are all right-handed between the age of 20-23 years. Firstly, for the subjects we give some instructions to think about smile and anger emotions then place the EEG headset device to record the EEG brain signals. These signals are then used to classify the emotions. The recorded signals are saved in '.easy' format in the system. These signals loaded into MATALB and they are processed by using MATLAB coding.

2.2 Pre-Processing

It includes filtering the EEG data which taken from the electrodes F3, F4, C3, C4, T7, T8, F8 and Pz. For filtering the Parks-McClellan optimal FIR filter of band range 1-40 Hz is used and a sampling frequency 250Hz is designed using NE_viewer tool in MATLAB. The recorded signal is passed through this filter and the ne_viewer tool describes the histogram, PSD, spectrogram for each channel of each EEG samples. The Parks-McClellan algorithm is an iterative algorithm for finding the optimal Chebyshev finite impulse response (FIR) filter. This algorithm is utilized to design and implement efficient and optimal FIR filters. It uses an indirect method for finding the optimal filter coefficients [6]. The goal of the algorithm is to minimize the error in the pass and stop bands by utilizing the Chebyshev approximation. The Parks–McClellan design is a variation of the Remez exchange algorithm, with the change that it is specifically designed for FIR filters.

2.3 Feature Extraction

The filtered signal is wavelet decomposed into 6 levels using Daubechies 14 wavelet for feature extraction purpose. The names of the Daubechies family wavelets are written as dbN, where N is the order and db is the 'surname' of the wavelet. Wavelets divide the signal into different frequency components in a multi-resolution manner[7]. As the EEG signals are non-stationary, Fourier Transform may not be a good choice. For given a signal s 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). The step is shown in figure 2.

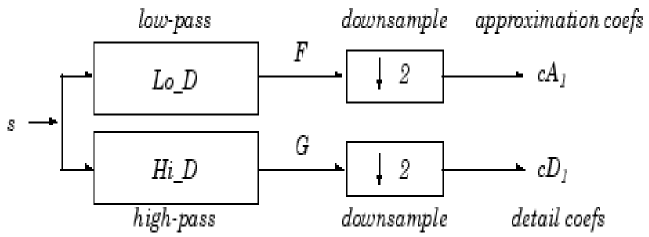

Figure-2 MWT decomposition structure

Then 8 statistical parameters are calculated for wavelet decomposed coefficients. They are as follows.

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

$$\mu_x = \frac{1}{N}\sum_{N}^{1} X_n \qquad (1)$$

2)Standard deviation: It normalizes the data and it gives us an idea of how far apart our data is from the mean. If X is a variable with mean μ_x, then the standard deviation is given

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

3)Variance: The variance is a determinant of measure of how far a set of numbers is spread out.

$$\mathrm{Var}(X) = \mathrm{Cov}(X,X) = E[(X-\mu)^2] \qquad (3)$$

4)Entropy: It is a measure of randomness of a signal.

$$e = -\sum_{1}^{n} -\log(x^2) \qquad (4)$$

5)Median: The median is the number separating the higher half of a data sample, a probability distribution from the lower half.

6)Minimum: The value and/or position of the smallest element in each row or column of the entire input.

7) Maximum: The value and/or position of the largest element in each row or column of the entire input.

8)Skewness: Skewness is a measure of symmetry, or more precisely, the lack of symmetry.

$$\text{Skewness} = \frac{\sum(X_i - X)^3}{(n-1)^3} \qquad (5)$$

2.4 Classification

For classification KNN and SVM classifiers are observed.

2.4.1 KNN classifier

The KNN classifier is a non-linear classifier it classifying the discrete emotions. This classifier makes a decision on comparing a new sample or testing data with the baseline data or training data. The training data set includes classes, it classifies the rows of the data matrix sample into groups, based on the grouping of the rows of training. Sample and Training must be matrices with the same number of columns. Group is a vector whose distinct values define the grouping of the rows in training. Each row of training belongs to the group whose value is the corresponding entry of group. The function 'knnclassify' assigns each row of sample to the group for the closest row of training. Group can be a numeric vector, a string array, or a cell array of strings. Training and group must have the same number of rows. The knnclassify treats NaNs or empty strings in group as missing values, and ignores the corresponding rows of training.

The Class indicates which group each row of sample has been assigned to, and is of the same type as group. This class enables us to specify k, the number of nearest neighbors used in the classification default is 1. The k-NN finds the 'k' (closest neighbourhood) for a given set of values in training data set and assigns a class which appears frequently in its neighbourhood. For each row of the test set, the K nearest (in Euclidean distance) training set objects are found, and the classification is determined by majority vote with ties broken at random. If there are ties for the k^{th} nearest vector, all candidates are included in the vote[8]. In KNN classifier an any instance is given, whose attributes will refer to as q and we wish to know its class. In KNN, the class of q is found as follows.

- Find the k instances in the dataset that are closest to q.
- These k instances then vote to determine the class of q.

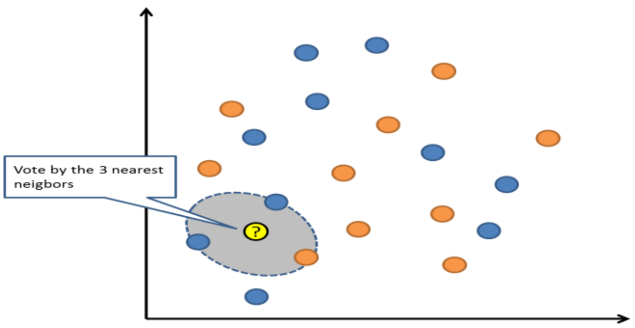

Figure-3 Query q is here being classified by its 3 nearest neighbours

2.4.2 SVM classifier

Support Vector Machine classifiers are based on the concept of decision planes that define decision boundaries. A decision plane is one that separates between a set of objects having different class memberships and it has capable of separating highly dimensional data. A SVM separates the data from two classes by constructing a hyperplane between the data points from both classes with the highest margin. The data points closest to the separating plane are called support vectors. This process is depicted in fig 4. SVM is a linear classifier that is used by most of the BCI applications. SVM was developed by Vapnik and was driven by statistical learning theory following the principle of structural risk minimization. SVM finds a hyper plane to separate the data sets. It separates data sets with clear gap that is as wide as possible to classify them into their relevant category. The hyper plane maximizes the margin that is the distance between the hyper plane and the nearest points from each class that are called as support vectors. The objective of this method is to provide good generalization by maximizing the performance of machine while minimizing the complexity of learned model[9]. By using a kernel-based SVM approach a mean classification accuracy of 87% was obtained. SVM has more performance and has high computational complexity.

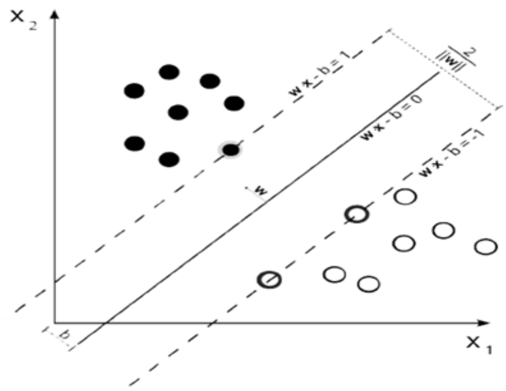

Figure-4 Working of SVM.

III. RESULTS AND DISCUSSSION

In training phase 10 samples are selected and those are pre-processed and features are extracted from those samples and they are stored in the training variable which is used for testing phase for classification. In the testing each remaining samples are tested one at a time, the testing sample also pre-processed and extracted feature from that.

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 output and the total accuracy obtained is 87.5% for SVM classifier. And in out of 8 samples for testing we got 6 correct output and the total accuracy obtained is 75% for KNN classifier.

Classifier	Training samples	Testing samples	Correct output	Total accuracy
KNN Classfier	10	8	6	75%
SVM Classifier	10	8	7	87.5%

Table-1 Comparision of accuracies

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 KNN and SVM classifiers are classifies the smile and anger emotions with different accuracies. K- Nearest neighbor is a simplest classification technique is based on distance function therefore for different value of 'k' different accuracies are obtained. The total accuracy achieved for KNN classifier is 75% and that for SVM is 87.5 % when we classified EEG signals into the emotions into smile and anger. Therefore, we could conclude that the combination of wavelets and neural SVM classifier is a good choice for classifying emotions by emotion recognition systems using EEG signals based on BCI interface.

The future work includes a further research on EEG for different and more number of emotions. And Cognitive response can also be thought of as future work using EEG signals and understanding the different stages of how the brain processes on every situation according to environment. And use large number of samples to get high accuracy to improve the system efficiency.

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