CLASSIFICATION OF EMOTIONS FROM EEG USING K-NN CLASSIFIER

1VAISHNAVI L. KAUNDANYA, 2ANITA PATIL, 3ASHISH PANAT

1PG Student, Cummins College of Engineering for Women, Pune,
2Research Scholar, Priyadarshani College of Engineering, Nagpur,
3Research Guide, Priyadarshani College of Engineering, Nagpur
Email: vaishnavikaundanya33@gmail.com, anita.patil@cumminscollege.in, ashish.panat@gmail.com

Abstract— This paper describes a method for automatic classification of different human emotions obtained using Electroencephalograph (EEG) signals. The human brain is a complex system. The superimposition of the diverse processes in the brain is recognized through EEG signals. Electroencephalographic measurements are commonly used in medical applications and in the research areas to study and analyse different disorders in the brain functioning. EEG signals indicate changes in the state of brain. Data acquisition is done for different emotions with the help of ADinstruments’ power lab instrument. In this research work, we have collected real life EEG signals using Ground Truth Method. Our proposed system consists of four steps, viz., Data Acquisition, Pre-processing, Feature extraction and Classification. The subjects were stimulated for different emotions such as Sad and Happy. The signals are pre-processed and used to calculate statistical features which will be given to the classifier. The system has been tested on number of subjects who were stimulated for invoking various emotions.

Keywords— Brain Computer Interfacing, EEG signals Electroencephalography, Emotions, k-NN classifier, Statistical Features

I. INTRODUCTION

The brain is one of the nonlinear systems. It is a formidable complex structure, comprising a network of roughly a hundred billion neurons. The organization of the brain is obviously far too sophisticated for any discussion in numeric terms. Human brain is a superimposition of many diverse processes. Human emotions play very important role to recognize, identify and study the brain signals. Emotion assessment is very much essential to determine the brain signals.

Emotions are part of any natural communication involving human. There are various ways to express the emotions. Verbal, non-verbal, facial expressions and gestures are some of the ways to show the emotions. In this research work, the aim is to classify the emotions into two classes such as Sad and Happy. Emotion is a complex psychological and physiological behavior of mind which is associated with mood, temperament, personality, disposition and motivation.

In this research work, brain signals are captured using Brain Computer Interfacing (BCI) technique. BCI is designed to do some tasks to restore sensory function, to transmit the information to brain as well as to get information from brain, i.e. the information of human emotions is gathered from a subject using various methods such as CT-SCAN, fMRI (functional Magnetic Resonance Imaging), MEG (Magneto Electroencephalography), PET (Positron Emission Tomography) and EEG (Electroencephalograph). EEG is used to record information of human brain activities in the form of measurement indicates the emotional state. The EEG has few advantages that enable it to be chosen in the study of human emotions such as it is high speed, non-invasive method and causes no pain to human subjects. The EEG recordings are obtained in both the emotions, processed and used for calculating statistical parameters. These statistical parameters (features) are given to classifier.

k-NN classification of different human emotions with the help of real dataset of emotions is used in this research. K-Nearest Neighbor (k-NN) classification technique conceptually and computationally provides good classification accuracy. In the paper, “Classification of Human Emotions from EEG Signals using Statistical Features and Neural Network”, Chai Tong Yuen, San San and Tan Ching Seong have discussed about the statistical based system for human emotions classification by using back-propagation algorithm is applied for classification.

In the paper, “Weighted K-Nearest Neighbor Classification on Feature Projections”, H.Altay Guvenir and Aynur Akkus from Bilkent University have discussed about the method which is extension to K-nearest Neighbor on feature projections called k-NNFP. k-NNFP has very low time complexity than k-NN. In the paper, “Automatic Medical Image Classification and Abnormality Detection Using K-Nearest Neighbor”, Dr. R. J. Ramteke and Khachane Monali have discussed about the method of k-NN as a classifier. They have discussed about the multivariate approach based on mutual information estimated by nearest neighbour.
II. DATA ACQUISITION

This section describes the acquisition of physiological signals from EEG under some emotion stimuli. Various ways of elicitation emotions in human subjects have been employed in order to develop datasets of brain waves for different emotions. The basic method is known as Ground Truth Method. In this method subject is asked to invoke a particular emotion by remembering some of his life incidents or by providing some audio and visual stimuli. Another approach is to provide the combination of visual and audio stimuli. This method is capable of producing responses that are closer to real life. After providing the visual stimuli, subject is allowed to stabilize so as to invoke particular emotion and then the EEG is captured with the closed eyes. An ADInstruments’ power lab instrument is used to capture the signals. For each emotion, the signal is captured using a sampling rate of 400 samples per second as the range of EEG signal is up to 100Hz. So according to Nyquist criterion this rate fulfills the requirement. Acquired signal is band passed with the range from 3Hz to 35Hz. The reason behind keeping this particular range is to get the alpha waves of brain where maximum emotions are present. The single channel bio amplifier is used. Subject is seated comfortably and calmly. A supporting IDE (Integrated Development Environment), named as Lab chart is used to capture the signals and to store the signals in the form of instantaneous values for each emotion.

III. METHODOLOGY

For emotion classification, significant features need to be extracted from EEG data. In this study, seven statistical parameters are calculated after pre-processing the signal. So the methodology contains following steps:

1. Pre-processing
2. Feature Extraction
3. Mean
4. Standard Deviation
5. Variance
6. RMS value
7. Skewness
8. Power
9. Entropy

A. Pre-processing
After receiving all the EEG signals, they are filtered using band pass filter. EEG wave contains delta (0-3Hz), theta (3-7Hz), alpha (8-13Hz), beta (13-30Hz) and gamma (above 30Hz). Therefore, a band pass filter of 3-35Hz is applied to signal using Lab Chart software.

This filter removes the DC offset of each electrode, drifts due to electrode impedance over time and power lines 50Hz noise. It also allows preserving frequency bands of interest for study of emotional processes. Also after capturing the EEG for emotion, the part containing artifacts can be trimmed manually.

B. Feature Extraction
Different statistical parameters are calculated using wavelet transform. Calculating four level of decomposition, we have extracted some features. Coefficients are calculated and using those coefficients, the features Mean, Variance, Standard Deviation, RMS, Skewness, Entropy and Power are calculated.

1. Mean
It is commonly used to describe numerical data that is normally distributed. Mean is average of all values. It is referred to a central value of discrete set of values. If the values are considered to be numbers like \( X_1, X_2, \ldots, X_n \), then

\[
\mu_x = \frac{1}{N} \sum_{n=1}^{N} X_n
\]  

2. Standard Deviation
This normalizes the data and gives us an idea of how far apart our data is from the mean. If we have large standard deviation, it means that data is farther from our mean. If we have small standard deviation, it means that data is closer to mean. It is a measure of the spread of a set of values from the average value. If \( X \) is a variable with mean \( \mu_X \), standard deviation is given as,

\[
\sigma_x = \left( \frac{1}{N-1} \sum_{n=1}^{N} (X_n - \mu_x) \right)^{1/2}
\]  

3. Variance
It is a determinant of measure of how far a set of numbers is spread out. It is specially a raw material of statistics and it is important since it helps and allows you to compute the dispersion...
of a set of variables around their mean. If a random variable is \( X \), its expected value is \( E(X) \), then the variance of \( X \) (1) is the covariance of \( X \) with itself, it is given as

\[
\text{Var}(X) = E[(X - \mu)^2] = E[X^2] - (E[X])^2
\]

4. **Skewness**

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. It is a third moment of distribution of data.

5. **Entropy**

It is a measure of the level of disorder in a closed but changing system. Or we can say, it is a measure of randomness of a signal. It is a statistical feature which can be used in representation of an EEG signal. Higher the entropy, higher disorder and vice versa. It can be represented as,

\[
\epsilon = - \sum_{i=1}^{n} \log(X^i)
\]

6. **Power**

Estimation of power is one of the most frequently used methods of EEG analysis. It provides information about the basic rhythms present in the signal and can be easily and rapidly calculated by means of fast Fourier transform i.e., FFT. It can be calculated as

\[
\text{Power} = \frac{\sum X^2}{L(X)}
\]

Where, \( X \) = signal values

\( L(X) \) = Length of signal

7. **RMS Value**

It is also known as quadratic mean. It is a statistical measure of the magnitude of a varying quantity. It is useful when variates are positive and negative. In case of a set of values, \( X1, X2, X3...Xn \) the RMS value is given by,

\[
X_{\text{rms}} = \sqrt{\frac{1}{n}(X_1^2 + X_2^2 + ... + X_n^2)}
\]

It can be calculated for discrete values. Various Engineering fields use RMS value.

**IV. CLASSIFICATION USING K-NN CLASSIFIER**

k-NN is a simple and intuitive method of classification used by researchers for classifying signals. This classifier makes a decision on comparing a newly labelled sample (testing data) with the baseline data (training data). Training data set includes classes. For given set of values, k-NN finds the k (closest neighbourhood) in training data set and assigns a class which appears frequently in its neighbourhood. Therefore, the algorithm for k-NN can be given as:

1. The k-nearest neighbour classification is performed by using a training data set which contains both the input and the target variables.
2. Then test data which only contains input variables is compared with reference set.
3. k-NN classifier works with k patterns, the distance of unknown ‘k’ determines the class, by considering nearest neighbour points.
4. Majority voting scheme where class gets one vote for each instance in neighbourhood samples.
5. The given target data is classified.

In training and testing, k-NN needs to specify value of k. In this work, the value of ‘k’ varied k=1 to k=10. And at the end the classification performance is checked for different values of ‘k’ to evaluate its accuracy.

**V. RESULTS OF FEATURE EXTRACTION**

Feature Extraction includes the different statistical parameter calculation. Features are important because, original EEG signal is a time domain signal where signal energy distribution is scattered. The signals’ features can get diminished behind the noise. Therefore, to extract features from EEG signal they should be represented in time or/and frequency domain.

Mental tasks can be recognized in frequency domain i.e. by using a Fast Fourier Transform (FFT). But as EEG signal is non stationary and its spectrum changes with time. Fourier Transform does not adequately represent non stationary signals.

So it is better to use wavelet transform which is a type of Time-Frequency representation. And using this transform, different features or statistical parameters are calculated.

The results obtained after feature extraction give the features such as, Mean, Variance, Standard Deviation, RMS, Skewness, Entropy and Power as explained in section III of this paper. Out of these features, Mean & Skewness give much overlapped plot for Sad and Happy emotion. But Variance, Standard deviation, RMS and Power gives accurate separation for both emotions. That is, they show that values for Happy emotions are higher than values for Sad emotion. Entropy is also a good parameter for classification of both emotions but only difference is it gives opposite results, i.e. it shows higher values for Sad and Lower values for Happy emotion. But it gives a noticeable discrimination between emotions. This is how features are helpful to classify the emotions.
VI. RESULTS FOR K-NN CLASSIFIER

k-NN used as a classifier, for two emotions viz., Sad and Happy. So from the total database some values of emotions are selected for classification and accuracy is obtained.

\[
\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \times 100\%
\]

Where,
- \(TP\) = True Positive: Sad people correctly identified
- \(FP\) = False Positive: Happy people incorrectly identified as sad
- \(TN\) = True Negative: Happy people correctly identified
- \(FN\) = False Negative: Sad people incorrectly identified as happy

Table I: Accuracy and Execution Time for different values of \(k\)

<table>
<thead>
<tr>
<th>Ratio of Training:Testing Samples</th>
<th>Value of (k)</th>
<th>Accuracy [%]</th>
<th>Execution Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNN_70_30</td>
<td>(k=3)</td>
<td>100</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>(k=5)</td>
<td>87.5</td>
<td>1.87</td>
</tr>
<tr>
<td></td>
<td>(k=7)</td>
<td>86.66</td>
<td>1.82</td>
</tr>
<tr>
<td></td>
<td>(k=8)</td>
<td>75</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>(k=10)</td>
<td>50</td>
<td>1.98</td>
</tr>
<tr>
<td>KNN_80_20</td>
<td>(k=3)</td>
<td>100</td>
<td>1.82</td>
</tr>
<tr>
<td></td>
<td>(k=5)</td>
<td>80</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td>(k=7)</td>
<td>100</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>(k=8)</td>
<td>80</td>
<td>1.87</td>
</tr>
<tr>
<td></td>
<td>(k=10)</td>
<td>80</td>
<td>1.88</td>
</tr>
<tr>
<td>KNN_90_10</td>
<td>(k=3)</td>
<td>100</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>(k=5)</td>
<td>87.5</td>
<td>1.95</td>
</tr>
<tr>
<td></td>
<td>(k=7)</td>
<td>100</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>(k=8)</td>
<td>87.5</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>(k=10)</td>
<td>75</td>
<td>1.9</td>
</tr>
</tbody>
</table>

From the Table I, it is observed that for different values of \(k\) different accuracies are obtained. As shown in above table, for three different combinations i.e. when training samples are 80% and training samples are 20%. Similarly 70_30 and 90_10 training and testing samples are chosen.

Accuracy is calculated by selecting values of \(k\) for 3, 6, 7, 8 and 10. Maximum accuracy is obtained for the value of \(k=3\). For the value of \(k=7\), which is actually in between all the values, it shows good accuracy.

Accuracy has been obtained using formula given above.

Above results proved that optimized value for \(k\) is obtained to be 3 only where k-NN gives maximum accuracy. Further the accuracy for the 90_10 combination of training and testing samples is compared with standard results of k-NN and it is observed to be giving correct accuracy here also.

CONCLUSION

K-Nearest neighbor is a simplest classification technique which provides computationally good classification. K-NN algorithm is based on distance function therefore for different value of \(k\) different accuracies are obtained. The method used to capture the emotions, which is known as Ground Truth method also proven to be efficient enough.

From the results of K-NN classification, it is observed that for \(k=3\), maximum accuracy is obtained. Further for the \(k=7\), maximum accuracy as well as appropriate computational time is obtained. For three different configurations of training and testing samples accuracy is calculated.

Result of K-NN with 90_10 (90% training and 10% testing) combination gives better accuracy as compared to 70_30 (70% Training and 30% testing) combination and 80_20 (80% Training and 20% training) combination.

REFERENCES

[7] H.Altay Guvenir and Ayur Akkus, “Weighted k Nearest Neighbour Classification on feature Projections”, Department of Computer Engineering and Information Science, Bilkent University, Turkey