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Emotion Recognition Using EEG Signals

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Abstract: This paper introduces an emotion recognition system based on electroencephalogram (EEG) signals. EEG signals are classified into four emotional states happy, relax, sad and fear. We have used pre-processed dataset of EEG signals to build an emotion recognition system. To evaluate classification performance, Support Vector Machines is used and for feature extraction AR (Auto Regression) and FFT (Fast Fourier Transform) is used. This paper provides a methodology which is easy to understand and perceive emotion recognition process.

Keywords: EEG, FFT, AR, SVM.

I. INTRODUCTION

In the past decades, most of emotion recognition researches have only focused on using facial expressions and speech. Information about the emotional state of users has become more and more important in human-machine interaction and brain-computer interface.

However, it is easy to fake facial expressions or change tone of speech and these signals are not continuously available, and they differ from using physiological signals, which occur continuously and are hard to conceal, Electroencephalogram (EEG) is the recording of electrical activity on the scalp.

EEG measures voltage changes resulting from ionic current flows within the neurons of the brain.

Emotion is related with a group of structures in the centre of the brain called limbic system, which includes amygdala, thalamus, hypothalamus, and hippocampus [5, 6].

There are five major brain waves distinguished by their different frequency bands.

These frequency bands from low to high frequencies, respectively, are called Delta (1–3 Hz), Theta (4–7 Hz), Alpha (8–13 Hz), Beta (14–30 Hz), and Gamma (31–50 Hz).

II. METHODOLOGY

The work is presented for making a system which is able to detect human emotion through brain signals. Many experiments have been performed till now by just Chopping analysed EEG signals and using neural networks to classify six emotions based on emotional valence and arousal.

But these results have only 64 percent success rate. Our system aims to achieve 89 percent success rate [6]. Basic steps used are Feature extraction and Classification.

For feature extraction we have used a combination of AR and FFT and for classification SVM.

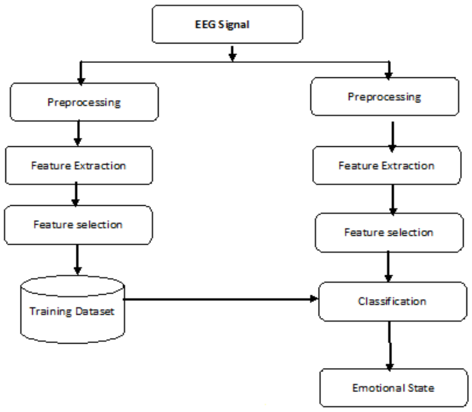

Fig. 1 Methodology

A. Feature extraction

The artifact free pre-processed data is used for feature extraction process. We have used two methods for feature extraction:

1) FFT (Fast Fourier Transform)
2) AR (Auto Regression)

To analyse the brain signals correctly, Fast Fourier Transform (FFT) is the best method as it is the fastest method and resulted signals are in frequency domain.

A.1 Fast Fourier Transform (FFT) Method:

We have used power spectral density (PSD) to calculate features of EEG signal. PSD represents the EEG signals selectively. There are five frequency bands which contains the major characteristics of EEG signal. The five frequency bands are: delta (δ: 1–3 Hz), theta (θ: 4–7 Hz), alpha (α: 8–13 Hz), beta (β: 14–30 Hz), and gamma (γ: 31–50 Hz).

By applying the data sequence to data windowing, we get modified periodograms. The information sequence is represented as xi(n).

Where, xi(n) is represented as follows :

$x_i(n)=x(n+iD), \quad n=0,1,2,\ldots,M-1 \text{ while } i=0,1,2,\ldots,L-1;$

The starting point of the ith sequence is iD. The data segments that are formed are represented by

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L of length 2M.The periodogram is given by:

P≈(i)xx(f)=1MU||∑M−1n=0xi(n)w(n)e−j2πfn||2

U: normalization factor of the power

U=1M∑M−1n=0w2(n),
w (n) :window function.

By calculating the average of these modified period grams, we get power spectrum as:
PWxx=1L∑L−1i=0P≈(i)xx(f) [1].

A.2 Auto Regression (AR) Method:
AR method works in time, frequency and spatial domain. This method calculates power spectrum density (PSD) of the EEG.AR method gives better frequency resolution as there is no issue of spectral leakage. By calculating the AR coefficient estimation of PSD is achieved. We have used Yule walker method to estimate AR model.

Yule Walker method:
In Yule walker method, by exploiting the resulted biased approximate of the autocorrelation data function we can estimate AR coefficients. We get the AR coefficient by finding the minimization of the least squares of the forward prediction error as[2].

$$\gamma_m = \sum_{k=1}^{p} \varphi_k \gamma_{m-k} + \sigma_\varepsilon^2 \delta_{m,0},$$

Where,

m=0, -------------- p. It gives p+1 equation.
γm = the auto covariance function of Xt.
σε = standard deviation f the input noise process.
The above set of equation can be solved by representing the equations for m>0 in matrix form as:

$$\begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \vdots \\ \gamma_p \end{bmatrix} = \begin{bmatrix} \gamma_0 & \gamma_{-1} & \gamma_{-2} & \cdots \\ \gamma_1 & \gamma_0 & \gamma_{-1} & \cdots \\ \gamma_2 & \gamma_1 & \gamma_0 & \cdots \\ \vdots & \vdots & \vdots & \ddots \\ \gamma_{p-1} & \gamma_{p-2} & \gamma_{p-3} & \cdots \end{bmatrix} \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \vdots \\ \varphi_p \end{bmatrix}$$

The above equation can be solved for all φ_m ; m=1,2,……p.
The equation for m=0 is

$$\gamma_0 = \sum_{k=1}^{p} \varphi_k \gamma_{-k} + \sigma_\varepsilon^2,$$

Finally, the full autocorrelation can be calculated by recursively calculating equation given below [2]

$$\rho(\tau) = \sum_{k=1}^{p} \varphi_k \rho(k-\tau)$$

B. Classification
Classification is done after features are extracted to get the resulting output as one particular emotional state from happy, sad, angry, neutral states. We have used support vector machine (SVM) classifier.SVM is a statistical learning theory. It uses a hyper plane to separate the datasets. The datasets are separated out to classify them in their relevant category. For two dimensional data, the data is separated out in two groups as +1 or -1.Whereas two hyper planes will be required to separate the data points in three dimensional data. Hyper planes will be constructed by SVM based on the target categories. In SVM optimal hyperplane is an area which has maximum margin width [3].The two lines H1 and H2 are drawn parallel to hyper plane. Then the distance between hyper plane and data points is marked.AC is called as margin which is the distance between dotted lines. In SVM support vectors are the sample data points on plane H1 and H2.Margin width is calculated by these support vectors.

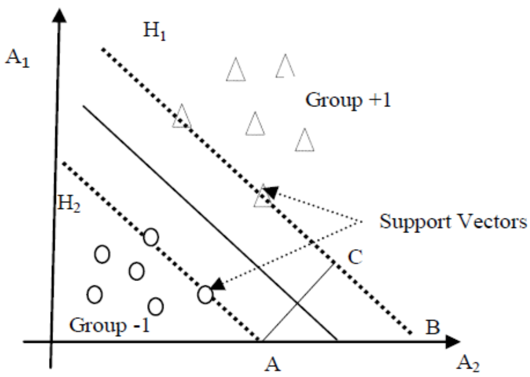

Fig.2 Linearly separable [3]

The equation of optimal hyper plane is:
w1x1+w2x2-b=0……………… (1)
The hyperplane H1 and H2 is as:
w1x1+w2x2-b=1……………… (2)
w1x1+w2x2-b=-1……………… (3)

Where,
w1, w2= positions of the hyper plane H1 and H2 respectively.

x1 , x2= data points, b= it takes values of +1,0,-1 shows the distance of hyper planes from origin.

Optimal decision function of classifier is given as [4]:

$$f(y) = sign(\sum_{i=1}^{sv} \alpha_i y_i (x_i, x_{sv}) + b)$$

Where αi is the Lagrangian multiplier

Fractal dimension (FD) values of EEG signals are extracted from both hemisphere and allow recognizing emotions with different levels of arousal and valence values. Support vector machine kernel classifier is used to classify the emotions based on positive and negative values of arousal and valence features [5]

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III. RESULTS

Feature extraction with combination of AR and FFT gives features more accurate and precise from classification point of view. SVM used for classification has provided good generalization and its performance is more as compared to other classifiers. SVM has given 89% accuracy in emotion detection. Other classifiers like ANN are difficult to build and runtime performance is poor if training set is large. Experimental results indicate that an average test accuracy of 88.51% for classifying emotion states can be obtained by using frequency domain features and support vector machines

IV. CONCLUSION

In this paper, the focus is on emotion detection by analyzing the EEG signals. The paper has tried to show how EEG can be used for the emotion detection since it is direct result of the electric activity inside the brain. The valuable information lies between the frequencies 2Hz to 40Hz. various parameters are to be used to judge the features for effective emotion classification and detection. SVM can be used for classification because of its capabilities to classify the complex features also. We are using the multiclass SVM, to classify the user in different emotions such as happy, angry, sad, fear, surprise etc. The system can be used for a wide range of purposes.

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