Detection of Emotion based on Electroencephalogram Signals using DEAP Database

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Abstract - *In past few years, there is a lot of research is ongoing on the Human Machine Interface. In that Emotion is an important aspect of the interaction between humans. There is more interest in detecting emotions automatically. In this paper Electroencephalogram (EEG) signals used to analyze the emotions (Happy, Angry, Sad, and Relax). EEG is a non-invasive method and record electrical pattern in the brain. In the proposed system, raw EEG data taken from DEAP database and identifying the 4 emotions based on valence, arousal model. We used pre-processed EEG data of 32 electrodes. Features are extracted in frequency and time domain. In frequency domain, average power is calculated for alpha, beta, theta and delta band using Discrete Wavelet Transform (DWT). Also, Power Spectral Density is calculated for each emotion. Mean, Variance, Root Mean Square etc. these features are calculated in time domain. A Comparison can be done through the values of valence and arousal. From these values, emotions are detected and classify into 4 different classes based on 2D Russells Plane. Happy emotion define class1 HAHV, Angry emotion define class2 HALV, Sad emotion define class3 LALV, Relax emotion class4 LAHV. The accuracy of each emotion is ranging in between 70% to 90%. We are developing an equivalent algorithm in MATLAB software.*

Key Words: Human Machine Interface, Electroencephalogram (EEG), Emotion Detection, Discrete Wavelet Transform (DWT), PSD, MATLAB

1. INTRODUCTION

An emotion is a physiological and mental state, which contains a bunch of thoughts, behavior and feelings. To identify and study the emotions is very complicated and confused, so therefore this is a most interesting field for researchers in physiology. As we know, the fact that emotion is an important aspect of the interaction between human. Emotion is corresponds to human experience, everyday tasks such as learning, communications and rational decision making. There are many techniques that record the brain signals, like FMRI (Functional Magnetic Resonance Imaging), MEG (Magneto Encephalogram) and NIRS (Near Infrared Spectroscopy) and EEG (Electroencephalogram). In this paper, we used EEG method and this method is advantageous than other method. It is non invasive, having good temporal resolution and simple to record the electrical activity of the brain. EEG technique used in various applications to monitor alertness, coma, and brain death, investigate epilepsy and locate the seizure origin, tumor detection etc.

This paper gives a short survey of emotion detection using EEG signals. DEAP database is used for the proposed system. From this database preprocessed data are used. Features are extracted in frequency and time domain. Comparison is done by calculating valence and arousal values and categorized with the help of dimensional model. Dimensional model as shown in fig -1.the dimensional model described across valence and arousal level. This paper describes in following manner: Introduction in section 1, Literature Survey in section 2, Methodology in section 3, Results and Conclusion are discussed in section 4 and 5.

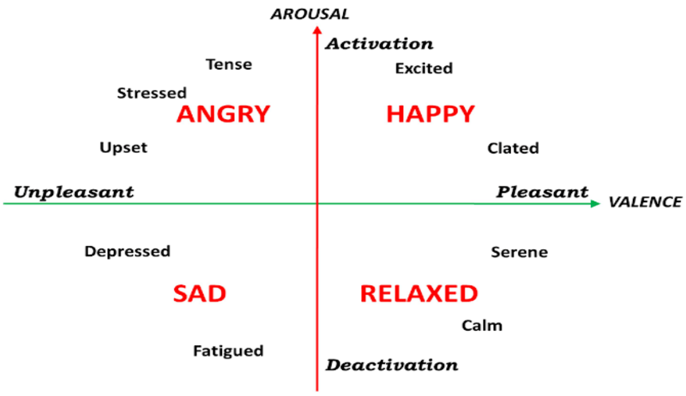

Fig -1: Dimensional Model for Emotion

2. LITERATURE SURVEY

In the following list of papers, the most of the authors used DEAP dataset for detecting emotions. [1] Proposed a method to effect of mediation using EEG signals. Extracted features such as asymmetry of band power for alpha, theta and delta band. Hajorth features also extracted. Used K-nearest classifier, accuracy was decreased after 8 weeks of mediation. [2] In this study, emotion detected from EEG signals based only on 1s of EEG segment. The Asymmetric spatial filtering method used for feature extraction.

Asymmetric spatial features compare time-frequency features and CSP feature for two types valence and arousal. Average accuracy for this feature is 83% and 79%. [3] Extracted time, gabor and IMF features using multiclass classifier for 3 and 7 channels, accuracy obtained 93%. [4] Accuracy obtained for valence and arousal was 83.78% and 80.72% using MCF technique. Features are extracted like frequency, non-linear dynamic and statistical. [5] Used LSTM Recurrent Network and get 85.65% accuracy for arousal, 85.45% accuracy for valence and 87.99% for liking class. [6] Proposed a system using SEED-IV and DEAP databases and calculated statistical features. The Accuracy rate for four classes are 79%, 76%, 77% and 74% for SEED-IV database, and 74%, 86%, 72% and 84% of DEAP database.

From above review of papers, it is clearly seen that many researchers used the various features for developing the different algorithms. In this proposed system, we used DEAP database which online available. Frequency and time domain features are calculated. According to valence and arousal values, emotions are classified into 4 classes. Following table-1 shows the various papers used for the proposed system.

Table -1: List of Research Papers

Sr. No	References	Title	Year	Method
1	Dong Huang, Haihong Zhang, Kaikeng Ang, Cuntai Guan [2].	Fast Emotion Detection From EEG Using Asymmetric Spatial Filtering	2012	Asymmetric Spatial Filtering
2	Yanjia Sun, Husan Ayaz, Ali N. Akansu [7].	Emotion Recognition Based on EEG using LSTM Recurrent Neural Network	2015	EEG and FNIRS both signals used
3	N. Jadhav, Y. Joshi, R. Manthalkar [1].	Effect of meditation on emotional response: An EEG based study	2017	Image processing
4	Thejaswini S., K.M. Ravikumar, Jhenkar L., Aditya Natraj, Abhay K. K. [6].	Analysis of EEG based Emotion Detection of DEAP and SEED-IV Databases using SVM	2019	SEED-IV and DEAP dataset used

3. PROPOSED METHOD

According to the above papers, it is viewed that many researchers used DEAP database for detecting emotions. This system also developed on DEAP database. It consists following steps for identifying emotions using EEG signals: signal acquisition, preprocessing or noise reduction, feature extraction and comparison.

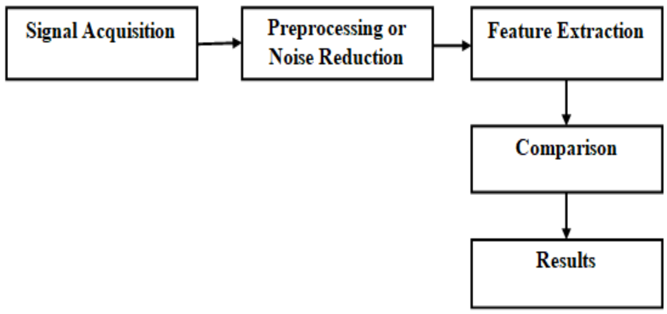

Fig -2: Block Diagram of Proposed Method

3.1 Signal Acquisition

The different systems are available to obtain EEG signals. This system having different sampling rate and used based on the capacity of the system. For EEG signal, the device having sampling rate greater than 150 Hz used. In this method online available DEAP database is used. This data has a combination of EEG and Peripheral physiological data of 32 participants, under the ages of 19 to 37. In that 16 are men and 16 are women. The EEG data available for each participant in the array shape of 40 (trail/video) x 40 (32 EEG electrodes and 8 peripheral electrodes) x 8064 (data samples). Each member or participant watched 1 minute long music videos. Based on length of music video event separation was performed.

3.2 Preprocessing

Before going to preprocessing method, events are separated from the given EEG signal. Based on the database protocol, the number of events per trail and duration of each event are varied. The raw EEG signals passed through three different filters to remove noise. The Following steps are performed to remove artifacts from the given signal.

Step1: To eliminate line frequency artifact, from non-filtered data, 50Hz to 60Hz notch filter used.

Step2: To obtain smooth signal without any spikes, 1D 10^{th} order median filter used.

Step3: Last band pass filter of order 20 used, to limit the output signal in the EEG signal range with cutoff frequency 0.1 and 60.

In the proposed method pre-processed EEG signal was used.

3.3 Feature Extraction of EEG Signal

To get accurate emotion states, some meaningful features are extracted from EEG signal. In the proposed method we load preprocessed EEG signal to extract features in two domains, frequency and time domain. In frequency domain, periodogram and Welch power spectral density for filtered data was calculated by using MATLAB functions. Average power is calculated for alpha, beta, and delta and theta band using discrete wavelet transform. Using inbuilt MATLAB functions, Mean, Root Mean Square, Variance, Standard Deviation, Skewness and Kurtosis are calculated as time domain features.

3.4 Comparison

After extracting necessary features in frequency and time domain, we find valence and arousal values. Depending upon these values, emotions are differentiated into 4 classes based on 2D Russells plane. This plane represents arousal and valence scale from 1 to 9 ranges. Arousal shows high (Excited) value in the range more than 5 to 9 and low (calm) value scale in the range 1 to less than 5. Valence shows a scale from negative (low) to positive (high) value. Negative which means the range is less than 5 and positive means range is greater than 5 to 9. As per these values, emotions are classified as: Happy emotion in class1 (HAHV), Angry emotion in class2 (HALV), Sad emotion in class3 (LALV) and Relax emotion in class4 (LAHV).

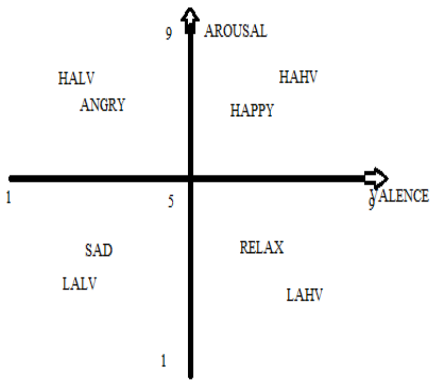

Fig -3: Scale for Valence- Arousal

4. RESULT

Using MATLAB software the entire experiment was simulated. Following figure shows the raw EEG signal for 8064 data samples. This data was taken from DEAP database.

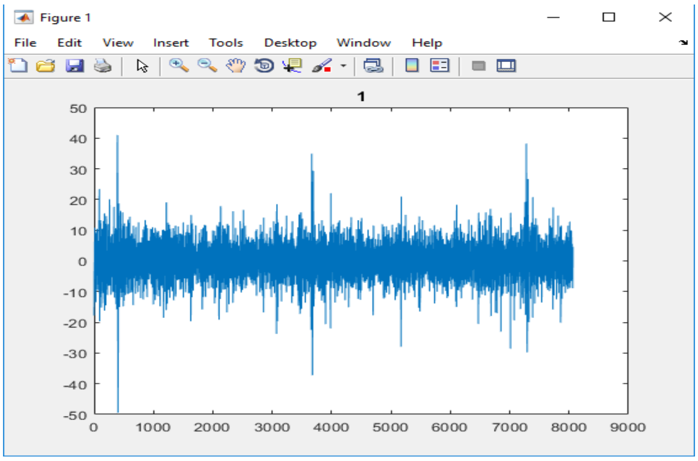

Fig -4: Waveform of Raw EEG Data

Below figure 5(a) and 5(b) shows the periodogram and Welch PSD of filtered data for happy emotion.

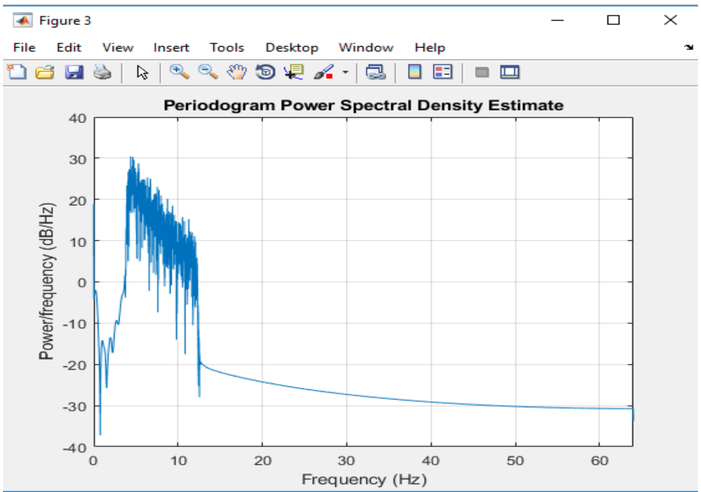

Fig -5(a): Periodogram PSD for Happy Emotion

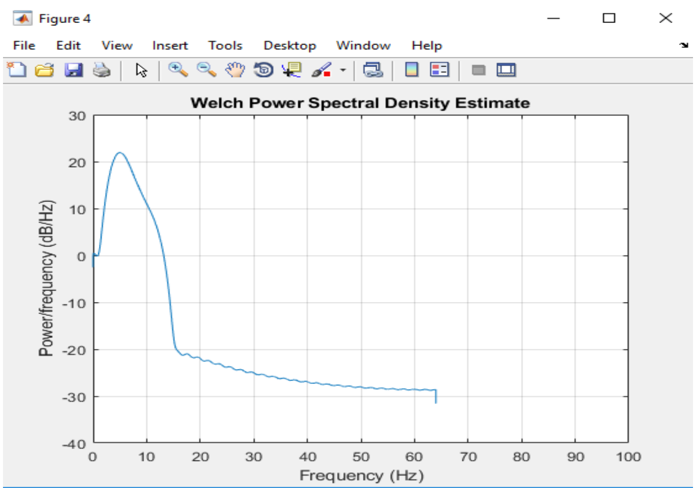

Fig -5(b): Welch PSD for Happy Emotion

Below figure 6(a) and 6(b) shows the periodogram and Welch PSD of filtered data for angry emotion.

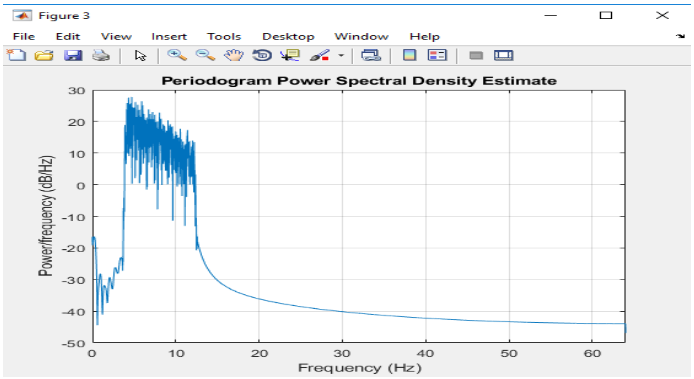

Fig -6(a): Periodogram PSD for Angry Emotion

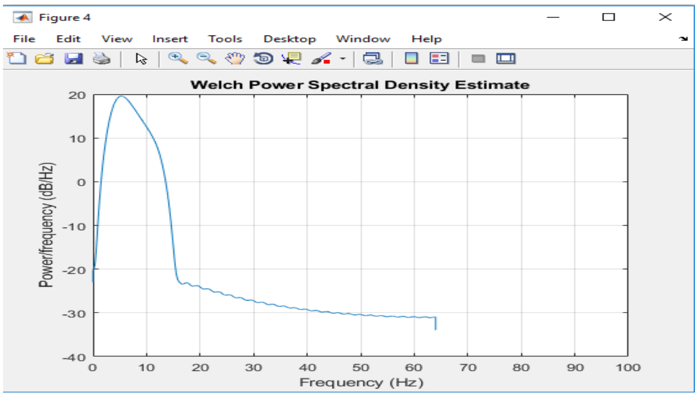

Fig -6(b): Welch PSD for Angry Emotion

Below figure 7(a) and 7(b) shows the periodogram and Welch PSD of filtered data for sad emotion.

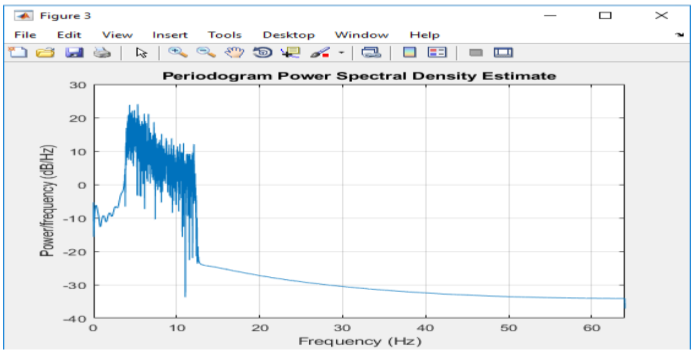

Fig -7(a): Periodogram PSD for Sad Emotion

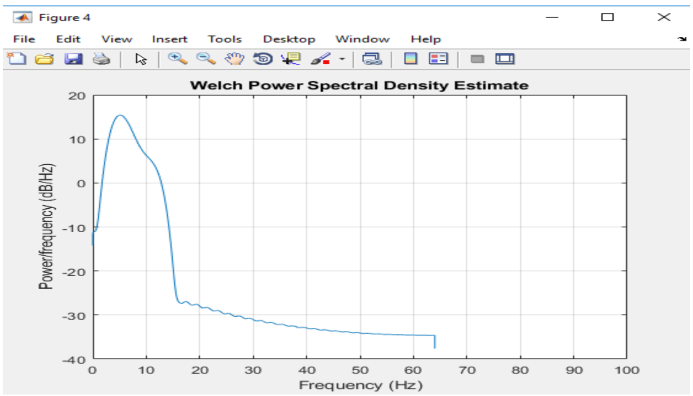

Fig -7(b): Welch PSD for Sad Emotion

Below figure 8(a) and 8(b) shows the periodogram and Welch PSD of filtered data for relax emotion.

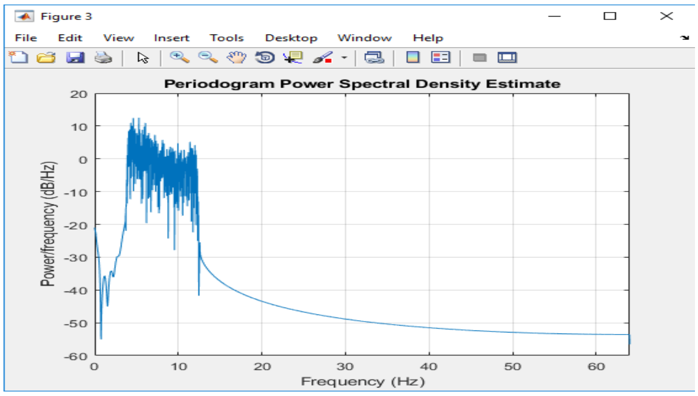

Fig -8(a): Periodogram PSD for Relax Emotion

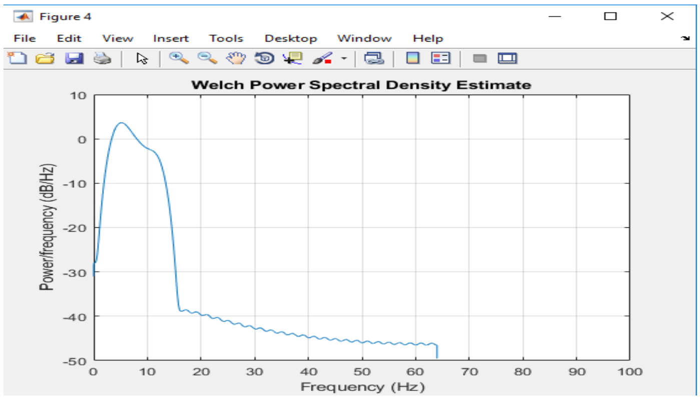

Fig -8(b): Welch PSD for Relax Emotion

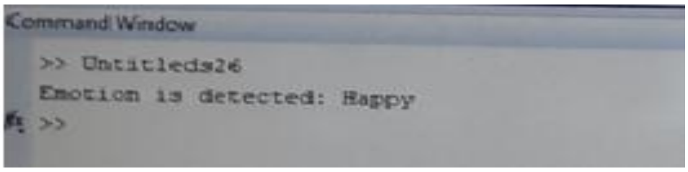

Fig -9: Screenshot of Happy Emotion Detected

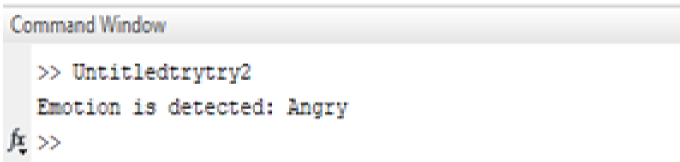

Fig -10: Screenshot of Angry Emotion Detected

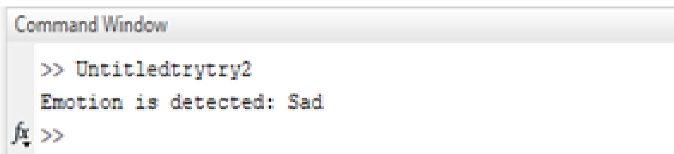

Fig -11: Screenshot of Sad Emotion Detected

Fig -12: Screenshot of Relax Emotion Detected

Below table shows the time domain features results using different parameters.

Table -2: Result of Time Domain Feature

	HAPPY	ANGRY	SAD	RELAX
Mean	1.1271	0.0194	-0.0699	-0.0116
Root Mean Square	24.8718	20.6122	12.2541	3.4536
Variance	617.4140	424.9162	150.1783	11.9285
Standard deviation	24.8478	20.6135	12.2547	3.4536
Kurtosis	23.6674	27.3532	22.4210	14.9137
Skewness	-0.8911	-0.9235	0.2793	-0.4536

Following table 3 shows the accuracy rate for indentifying the emotions and simultaneous compared result to SEED-IV database.

Table -3: Overall Performance Rate

Sr. No	Class	Emotion	Accuracy Rate	SEED-IV Data
1	HAHV	HAPPY	81%	79%
2	HALV	ANGRY	83%	76%
3	LALV	SAD	77%	77%
4	LAHV	RELAX	75%	74%

5. CONCLUSION

By using this method emotions can be detected for each class. Particularly process on signal is done in frequency and time domain. Accuracy for each Emotion is 81%, 83%, 77% and 75%. In future, real time signals can be used to detect facial expression and emotion.

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