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Extracting the Features of Emotion from EEG Signals and Classify Using Affective Computing

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***Abstract*—The extraction of features, for the recognition of affective states through various means such as gestures of the body, facial images and electroencephalogram (EEG), is very important in affective computing. The brain-machine interface (BMI) using emotions, are used in medical robots, neuroergonomics, and auto-navigation and security systems. Emotions can be identified using analysis of scalp EEGs. The EEG data with audio-visual stimulus is collected and analyzed to extract the features of five emotions viz., happy, sad, fear, neutral and disgust. The raw EEG data is used to create the database, EEG_Amrita_emote. Features of EEG data are extracted using independent component analysis (ICA), and are classified using K Nearest Neighbor (KNN) algorithm. Cluster centroids are identified using k-Mean Clustering. The spectral energy of emotional activities in the brain is taken as one of the features. The EEG data is collected from male subjects of age group between 20 and 30. The locations of high intensity spectral energy is calculated for every emotion. The primary centroids of emotions are happy at (26.58, -99.97), neutral at (-69.18, 12.89), sad at (66.45, 29.52), fear at (74.22, -9.65) and disgust at (63.05, 38.68) respectively.**

***Index Terms*—EEG, affective computing, feature extraction, ICA, BMI, KNN, clustering, brain lobes, total energy, topographic plots, cortex, emotion.**

I. INTRODUCTION

Emotions are fundamental to human experience in day to day learning, social behavior, perception and communication. Emotions differentiate man from machines. Every individual is characterized by divergent emotions. Paul Ekman describes happiness, sadness, fear, anger, surprise, and disgust as the basic emotions [1]. He created an Atlas of emotions which is a collection of about ten thousand facial expressions [1]. The intensity and nature of the emotions can be classified as arousal and valence. There are different schools of thinking regarding origin of emotions; one which believes that emotions are created inside the brain while the other school hypothesizes that, they are not originating within the brain [2]. However both schools assume that, emotions originate from the mind.

Affective computing is an interdisciplinary field that includes the study and development of devices that work on the interaction with human emotions. Traditional means of emotion detection are EEG, image analysis and speech signal processing. Monitoring of EEG by keeping the electrodes on the scalp is a non-invasive method of recording the electrical activity of the brain. The electric potential distributions on the scalp are a direct consequence of internal electric currents associated with firing of neurons and can be measured at discrete points on the scalp over a period of time [3]. Interpretation of EEG recordings helps in detecting patients undergoing schizophrenia, drowsiness, alzheimers and various mental and neurological disorders [1]. In gesture recognition the hand gestures can be incorporated with their corresponding EEG data for better performance [5]. Similar to EEG, Magneto Encephalogram (MEG) may also be used to measure the neuronal discharge activity. The brain waves, thus tapped are used in various applications like BMI's, medical diagnosis of epileptic foci detection and prediction of onset of epilepsy [4]. The frequency of the brain waves vary from 0.01 Hz to 60 Hz. These waves are mainly classified as delta, theta, alpha, beta and gamma. The range of frequencies of different brain waves are as follows: delta waves vary from 0 to 3 Hz, theta waves from 3 to 8 Hz, alpha waves from 8 to 12 Hz, beta waves from 12 to 38 Hz and gamma waves from 38 to 45 Hz. Delta waves correspond to deep sleep state, while gamma has frequencies corresponding to the enhancement of mental activities. Alpha waves are the ones stimulated when a person is relaxed. Theta waves and beta waves lie between the mental states alpha-delta and alpha-gamma respectively.

A novel method for emotion recognition from the EEG data is presented in the subsequent sections. The method uses ICA for feature extraction, KNN for classification of extracted features and k-Mean Clustering locates each cluster centroid. The data is recorded using EMOTIV EPOC+ EEG head set. Section II of the paper briefs the brain lobes, characteristics of EEG signals, procedure of data collection and description of the device used for data collection. Section III discusses on preprocessing techniques and analysis involved in locating the response centers. This explains feature extraction and classification methods. Section IV discusses the results of the analysis. Scatter plots are fit on the scalp plots to identify the response centers. Section V concludes with the results and discussions.

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II. Measurement of Scalp EEG

A. EEG Data Acquisition System and Data Collection Methods

The EEG is the electric potential on the scalp, which is 10–100 mV and this signal is amplified to 1–2 mV in-order to digitize and transmit the data. EEG waveforms are defined and described by their frequency, amplitude, and location [6]. The frequency band of EEG is 1–64 Hz.

Frequency is the key characteristic which defines EEG rhythms. In healthy awake adult, frequencies of 8 Hz and higher values determine the normal functioning of the brain. Even though, brain waves of frequencies 7 Hz or below appear in children during relax or sleeping state, they are considered to be abnormal in an awake adult. Under certain circumstances, EEG waveforms of appropriate frequency for particular age and state of alertness are considered to be abnormal because they occur at an inappropriate scalp location or demonstrate irregularities in rhythm or amplitude [7].

The data is further filtered in the range of 0.2–40 Hz to locate the major activities and features present. The other reason for choosing the frequency range is to avoid power line pickup and to satisfy the Nyquist criterion. Butterworth filter of order 1800 is used to extract the required frequency components from the EEG.

For data acquisition, the subjects are shown the video clips of all the five emotions in a random sequence and their EEG signals are simultaneously recorded. Relaxation video clips are shown in between the switching of emotion clips. Virtual reality (VR) set is used to create a realistic environment for the subjects. All the subjects are nonprofessional actors in the age group 18–22. A data base of 300 waveforms, EEG_Amrita_emote, is created and this data is used for preprocessing.

B. Data Acquisition and Transmission

The head set EMOTIV EPOC+ is used to acquire the data which has a sampling rate of 128 Hz and 14 bit EEG resolution. The montage used for acquisition is AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8 and AF4. The electrodes are named in accordance to their position on the scalp. Odd numbered electrodes represent their position on the left side of the brain and even numbered electrodes represent the right side. The head-set has an analog filter of bandwidth 0.2 to 43 Hz followed by digital notch filters of 50 Hz and 60 Hz. The head set uses a fifth order Sinc filter. The dynamic range of input referred is 84 dB. The digitized data is packetized and transmitted in wireless Bluetooth over 2.4 GHz band. The data is encrypted at the transmitting end, and is decrypted and used in a Windows based PC system, for recording and analysis, at the receiving end.

C. Brain Lobes and their Functions

Brain has four lobes: frontal, parietal, occipital and temporal as shown in Fig. 1. The frontal lobe is associated with reasoning, motor skills, higher cognitive thinking, and expression. Parietal lobe has many functions including sensory functions, visual perception and reasoning. Temporal lobe is the locale of primary auditory functions, formation of verbal and visual memories. Occipital lobe is to the posterior, near the back of the skull. It is the primary center of visual stimuli and information.

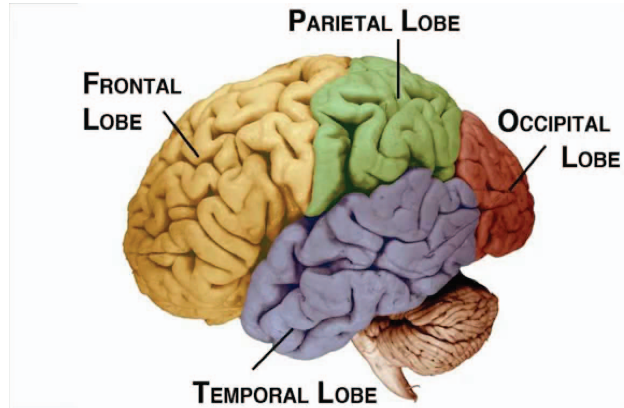

Fig. 1. Lobes of the brain.

The limbic system, which consists of thalamus, amygdala and hypothalamus, has a major contribution in the creation of emotional response. Thalamus sends the motor and sensory signals to the cerebral cortex. Amygdala which is situated in front of hippocampi, near the temporal lobe, detects the negative emotions. Hypothalamus is responsible for producing the output as a physical response.

III. Preprocessing and Analysis

Five emotions are taken from the created data base EEG_Amrita_emote and ICA is performed on the data in order to separate the various sources present in the brain waves of each emotions. The acquired digital EEG data is preprocessed, sources are extracted and classification is done using KNN algorithm. The details of analysis are given below:

A. Preprocessing

In order to remove the baseline and unwanted noise the signal is filtered in the frequency range 0.2–40 Hz using basic FIR filter of order 1800. The data is segmented into non-overlapping windows of duration 45–120 s corresponding to each emotions. If the data segments containing large pick-ups, which cannot be removed by pre-filtering, are omitted. The main noises observed are power line pickups, eye artifacts and muscle movements like chewing. The subjects are instructed to reduce the eye-blinks, avoid posture changes and chewing once the video starts. The EEG waveforms are visually monitored and only good quality waveforms are selected for analysis.

B. Feature Extraction

The feature extraction of EEG data set is done by using Independent Component Decomposition (ICD) [3]. For finding the features, the topographic plots are used. These plots give the spatial distribution of spectral components. The point corresponding to the maximum spectral energy is identified

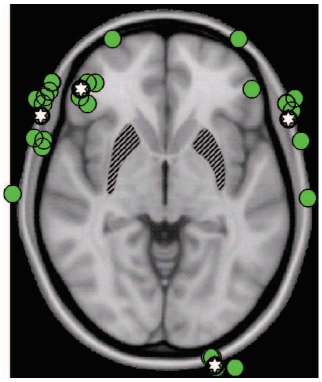

Fig. 2. Happy.

and the corresponding x and y co-ordinates are taken as two features. The cumulative energy is also considered as another feature. Thus there are 3 features corresponding to each component of ICA. The first four of the fourteen components are considered, contributing to twelve feature vectors. The total number of trials for each emotion is twenty five. The feature matrix is constructed using the features as columns and trials as rows. The dimension of the feature matrix is 125×12.

C. Classification

Classification involves minimizing the basic (1) under different classifiers.

$$Ax = S \tag{1}$$

where A is the feature matrix, x is the predictor, S is the target. The equation is iteratively solved for x. The analysis takes the number of features as columns and the number of trials as rows. The row of the matrix multiplied with the predicted values gives the target value S.

The purpose of the classifier is to locate the response centers of each emotion. The K-nearest-neighbor algorithm estimates how likely a data point is to be a member of one group, depending on the location of the data points nearest to it.

IV. Results and Discussions

The response centers of emotions and centroids are obtained. The prominent centroids are the centroids with more number of samples present in the cluster. The details of emotions and characteristics are given below.

A. Happy

The response centers of happy are present in left thalamus at a depth of 83.61, frontal cortex at a depth 41.36 and right hypo-thalamus at a depth of 84. Frontal cortex is found to be active when subjects are happy. The scatter plot over the scalp plot, which depicts the response centers and centroids of the emotion, is shown in Fig. 2. In the figure, the response centers lie on the left frontal region which validates arousal emotions. The analysis of this emotion shows four clusters whose centroids are given in Table I.

TABLE I
Centroids of Activities on Each Emotion.

Emotions	Centroid	
	X	Y
Happy	−65.4531 26.5784 −44.1557 65.3483	38.1455 −99.9688 52.6086 36.1966
Neutral	45.424 65.5957 −69.1767 66.4525 −50.8583 26.3913	58.1 −65.4086 12.8933 33.6079 48.566 −99.5404
Sad	27.3627 −62.6487 66.4481 −43.3639	−100.5909 48.5171 29.5178 48.9221
Fear	23.1074 62.351 74.2242 −47.6074	−98.3645 35.0941 −9.6528 52.4389
Disgust	31.0892 63.0479 −50.2684	−94.6092 38.68 49.7547

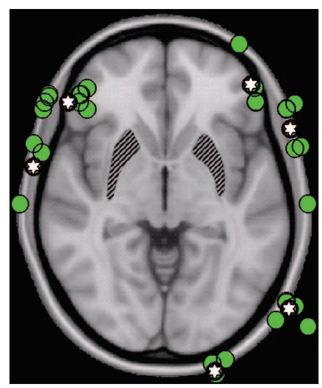

Fig. 3. Neutral.

B. Neutral

Neutral depicts six response centers which include right parietal, right occipital, right and left frontal and right and left temporal regions. This emotion relaxes all the regions of the brain, slowing all the brain activities. In emotion neutral, almost all the regions of the brain get affected. The left of the brain is prominently affected, showing its characteristics towards the category of arousal emotions. The scatter plot over the scalp plot, which depicts the active centers of the emotion, is given in Fig. 3. The analysis of this emotion shows six clusters whose centroids are shown in Table I.

C. Sad

The emotion sad, shows spread of regions of activity and has the response centers on the right occipital and left frontal temporal linked to the limbic system. The EEG activity is seen in amygdala and stroked thalamus at a depth of 86.73

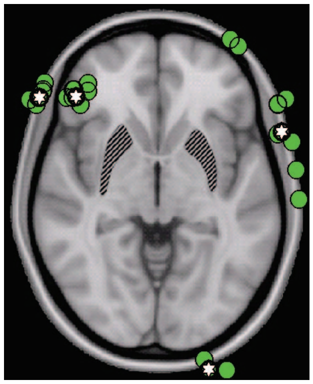

Fig. 4. Sad.

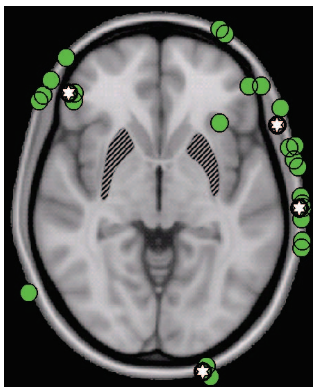

Fig. 5. Fear.

and in hypothalamus at a depth of 86.65. The centers of clusters are shown in the Table I. The prominent centroid in the response cluster is on the right prefrontal temporal region as in valence emotion. The scatter plot over the scalp plot, which depicts the active centers of the emotion, is seen in Fig. 4. The analysis of this emotion shows four clusters whose centroids are given in Table I.

D. Fear

The emotion fear, has response centers at left hypothalamus, frontal cortex, right amygdala and left pre-frontal temporal regions. The data is clustered into three clusters, located respectively, at left pre-frontal temporal, temporal amygdala and right pre-frontal stroke temporal regions. This emotion in temporal central limbic system has a depth of 54. The temporal amygdala is linked to the limbic system at a depth of 78.5. Left pre-frontal temporal is at a depth of 42. One of the prominent centroids of the fear emotion and its response center is on the right frontal region. The scatter plot over the scalp plot, which depicts the active centers of the emotion, is shown in Fig. 5. The analysis of this emotion shows four clusters whose centroids are listed in Table I.

E. Disgust

The emotion disgust has three response centers. The time scroll plot of ICA shows that the response starts on the right

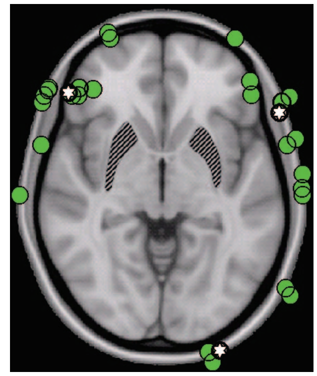

Fig. 6. Disgust.

occipital region with the prominent centroid value -50.2684 as x coordinate, 49.7547 as y coordinate. The left side of the prefrontal temporal region has a prominent centroid value (31.0892, -94.6092). The left prefrontal temporal region can probably be linked to the limbic system with a depth varying from 42 to 87.12 implying the presence of cluster in that region. The third region is the right prefrontal/temporal region linked with the limbic system's hypothalamus at a depth of 40. The centroids and the response centers of the emotion disgust are shown in Fig. 5. It can be inferred that response centers and the prominent centroid lie in the right occipital region proving the results of the valence emotions. The scatter plot over the scalp plot which depict the active centers of the emotion is given in Fig. 6. The analysis of this emotion shows three clusters whose centroids are included in Table I.

V. Conclusion

The analysis of EEG data of five emotions, from a group of non-professional actors using ICD, gives the location co-ordinates as the features. These are used for clustering and finding the emotional response centers. The prominent cluster centers for happiness, neutral, sadness, fear and disgust are on the left temporal, left frontal, right frontal-temporal, right temporal and left frontal regions respectively. In addition to these prominent centers, each emotion has additional three more local centers. The corresponding location co-ordinates of the prominent centers are: (26.58, -99.97), (-69.18, 12.89), (66.45, 29.52), (74.22, -9.65) and (63.05, 38.68). The features obtained from ICD of the EEG data is used to classify using KNN classifier. The total percentage of error for KNN classification is less than 20. Most of the researchers feel emotion center is unique and localized, but the analysis shows that there is a distribution of centers in the brain. Though, this is similar to constructionist approach, the results show that they are not universal. As a future step, the data of female subjects is to be collected in order to make a comparative study.

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