Implementation of Image Processing and Classification Techniques on EEG Images for Emotion Recognition System

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Abstract— The target paper aims at recognizing emotions using miscellaneous stimulus domains such as Electroencephalography (EEG) Images. The present study focuses on the recognition of emotions and extracting active regions, by using image processing and classification techniques. The study was performed using the data from 10 volunteers experiencing three emotional states relax, happy and sad. By applying thresholding and Sobel Edge detection technique, active regions were extracted. The Principle Component Analysis (PCA) and Linear Discriminate Analysis (LDA) classification techniques were enforced on the results respectively. The techniques resulted in effective outcomes, which can further be used for compelling Emotion Recognition System.

Keywords- *Emotion Recognition, EEG, Sobel Edge Detection, Thresholding, EEG images, LDA*

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I. INTRODUCTION

Emotion recognition has become apparent research topic in the field of Human Computer Interface. Emotions can be shaped by culture and learning, but all humans possess the capacity to experience and perceive the same core set of emotion recognition. Emotions emerge when people make meaning out of sensory input from the body and from the world using knowledge of prior experiences. Sometimes sensations from the body are experienced as physical symptoms, but more often they are experienced as states that have some hedonic tone and level of arousal. [1] There also exists a broader range of techniques used for automatic emotion recognition of affective states. Emotion recognition is drawn on two foundational emotion conceptualization. The first type focus on the basic emotions made up of a finite array of emotional constructs such as anger, fear, sadness, happiness etc. The second approach focuses on the arousal ranging from calm to excitement and valence ranging from unpleasant to positive. The study of neurophysiological aimed to identify the two primary aroused affective states which are related to positive and negative emotions, these emotions are further used in classification for each second [2]. The ability to understand human emotions is fascinating the computer in varieties of applications, the basic research and the recent advances in emotion recognition can be seen in facial, voice, pshysiological signals[3].The affirmation indicates that the emotions are laterized in both the right and left hemisphere. The literature describes the injury to the left hemisphere results in feelings like anxiety, anger while the injury to the right hemisphere can cause problems resulting in emotional stillness[4].The study of fMRI is also used for laterization of brain region, basically the positive and negative emotions in music. The results for EEG and fMRI are studied and seen different in different brain activities [5]. When analyzing the emotions with respect to waves, the alpha wave significantly decreased towards the left temporal lobe for negative emotions, the increase in beta waves was observed only at the left temporal lobe for fear emotions, on the other hand the alpha wave decreased at C4 in happy emotions, for peaceful the gamma wave increases in T5[6].

A) EEG

Electroencephalography (EEG) is a technique which measures the electric fields that are produced by the activity in the brain. The brain is divided into five main lobes; frontal lobe, central lobe, parietal lobe, occipital lobe, temporal lobe;

- The Prefrontal lobe regulates emotion and emotionally attuned communications
- The Frontal lobe regulates thinking and planning.
- The parietal lobe seen active in movement, orientation, calculation and emotion recognition.
- The Temporal lobe includes sound and speech processing, aspects of memory.
- The Occipital lobe deals with visual processing of memory [7].

For acquiring the data RMS EEG 32 channel 19 electrodes data monitoring equipment is used, includes 19 electrodes

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which are placed on the scalp of the subject with the help of gel, using 10-20 international system.

The standard placement has been recommended by American EEG Society. The standard numbering system places, odd numbered electrodes at the left of the scalp and even numbered electrodes are placed at the right side of the scalp. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals. In this system 21 electrodes are located on the surface of the scalp, as shown in Figure 1 [8].

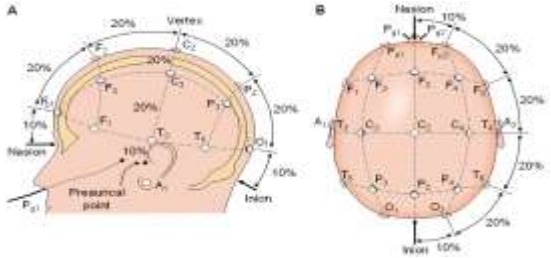

Figure 1: The international 10-20 system

EEG signals arise due to electrical potential produced by the brain, the EEG signals are classified into four different frequency bands; Delta (<4) , Theta (4-8 Hz), Alpha (8-12 Hz), Beta (13-30 Hz) seen in figure 2.

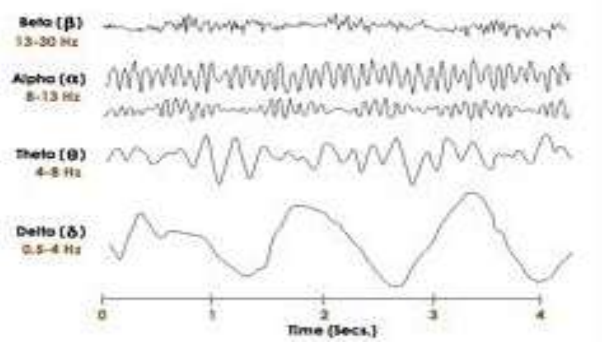

Figure 2: EEG waveforms for different signals

Figure 2: EEG waveforms for different signals

- Delta (δ) wave ranges from 0.5 to 4 Hz. Delta brainwaves are the slowest, but loudest brainwaves. They are generated in deepest meditation and dreamless sleep, also in infants.
- Theta (θ) wave ranges from 4 to 8 Hz. Light sleep or extreme relaxation. Theta is seen in mental state that has proven useful for hypnotherapy.
- Alpha (α) wave ranges from 8 to 13 Hz. In alpha wave the person is awake but relaxed. Alpha activity has also been connected to the ability to recall memories, lessened discomfort and pain, and reductions in stress and anxiety.
- Beta (β) wave ranges from 13 to 30 Hz. In Beta waves the person is wide awake. People lacking sufficient beta activity, can cause mental or emotional disorders such as depression. Stimulating beta activity can improve emotional stability, energy levels, attentiveness and concentration[9].

B) EEG images

Besides EEG signals, images are also incorporated in the software we have considered EEG images for the experimentation.EEG images are examined in cognitive neuroscience. For assembling EEG images, RMS EEG 32 channel 19 electrodes data monitoring equipment was used, data monitoring equipment is used for acquiring and analyzing the images. There are 19 electrodes which are placed on the scalp with the help of gel, according to the international 10-20 system. The machine also provides Brain mapping color coding as per international standard. RMS EEG machine also provides two software i.e. "Acquire" and "Analysis".

- Acquire software: The software is used to acquire the recordings of the subject. Features like patient info, impendence check, start/stop EEG buttons, record EEG and so on is provided by the software.

- Analysis software: There are different tools provided by the software like split screen, single map, tri map, frequency map, frequency spectrum, amplitude progressive, frequency progressive and frequency table, for frequency domain analysis the software provides 2 sec data, from which every frequency domain tool can be used, on the other hand the software gives a tool called Amplitude Progressive which provides 12 amplitude maps at consecutive time difference of 7.8125 ms, is used for experimentation. For analyzing the brain images, full spectra is provided as shown in figure 3;

Figure 3: Full Color spectra for EEG images

The spectra ranges from +60µV to -60µV. According to literature the +60µV give the intense higher activity, and -60µV give the indistinct lesser activity. There are in all 16 color shades in the spectra provided.

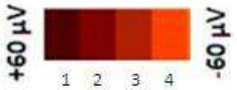

Figure 4: Selected Color spectra for EEG images

For this target experiment, we have concentrated on first 4 shades as seen in figure 4, to analyze the emotional activity in the brain[10].

The flow for detecting the active regions from the EEG images is described in figure 5.The EEG recording were acquired in silent environment for relax state, whereas an interactive talk with the subject was done to acquire the

images for happy and sad mental state. The images with highest activity were sorted for all affective states. Thresholding was applied on images for extracting active regions from EEG images. The Sobel Edge detection technique was also applied on the images to get the active regions of the image. Further these active regions were considered to calculate the actual active size using nonzero function.

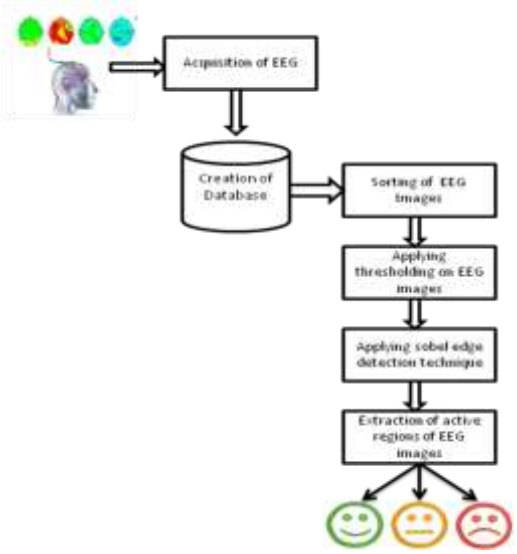

Figure 5: Flowchart for Emotion Recognition using EEG images.

The data is acquired from the subjects for three different mental states, for relax state the recording was done for 5 min, whereas for happy and sad it is done for 15 min. Overall 20 images were selected for each state, for the sake of space in this article, from 20 images three representative images are considered they are image 3, 7 and 14 respectively.

II. METHODOLOGY

A. *Emotion Intelligence Test (EII)*

The psychological aspect was also considered at the first stage of the experiment, Emotional Intelligence Inventory (EII) Test was conducted to analyse the emotional quotient of the volunteers. The participants have gone through the test by which we were able to select the subject more easily. For experimental purpose 10 volunteers with efficient emotion were considered.

B. *Image Processing techniques applied on EEG images*

Image processing involves handling the images as a 2 dimensional signal and using standard signal processing techniques. The techniques used for EEG image processing are:

A) Threshold

It is a non-linear operation that converts a gray-scale image into a binary image where the two levels are assigned to pixels that are below or above the specified threshold value. It is however far more efficient to use the image Threshold operation which also provides several methods for finding the "optimal" threshold value for a given images. [11]

Figure 6: Thresholding applied on EEG image

The thresholding is applied on original image, by which the red active region of the image is detected as seen in figure 6.

A) Sobel Edge Detection Technique

The Sobel Edge detection performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image as seen in figure 7.

Figure 7: Sobel Edge Detection applied on original image

B) Classification Techniques

In this work we have used two simple classifiers namely, Principle Component Analysis (PCA) and Linear Discriminant Analysis (LDA)

a) PCA

Principal Component Analysis is a statistical procedure concerned with clarifying the covariance structure of a set of variables. It allows us to identify the principal directions in which the data vary. [12].

a) LDA

This method is used to incline between two or more groups of data samples. It manages the data from within class frequencies which are equal and their performance has been studied on indiscriminant data[13].

III. RESULTS

The database for EEG images was acquired from 10 volunteers, emotionally, physically and mentally healthy. The database is described in Table I. Table II; represents the result of Image processing techniques on the representative images for relax mental state of 10 subjects. Table III, describes the EEG images with its threshold and edge detection for happy mental state. It is seen that the activity is large in the right part of the brain, while prefrontal, frontal, temporal regions are more prominent. Table IV, describes the EEG images with threshold image and Edge detection for sad mental

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state, the activity is seen in left part of the brain, the active regions seen more dominant are the prefrontal, left temporal, occipital regions.

Table V; gives a brief description of active regions, active size and active electrodes with respect to selected representative images for relax, happy and sad mental state. The full form of abbreviation used in table for active regions are: PR= Prefrontal, F= Frontal, C=Central, P=Parietal, T=Temporal, O=Occipital

Table 1 Detail of Database

EEG images	No. of Subjects	Emotional mental state	No. of Sets acquired for each subject	No. of EEG Images	Total EEG images
	10	3(relax, happy, sad)	3	20	1800

The PCA is implemented to observe the classification of mental states shown in figure 8, depicts the result of subject 1 for set1for the said three states. It is seen that all the three states are distinctly classified. The same is experienced for rest of the nine subjects

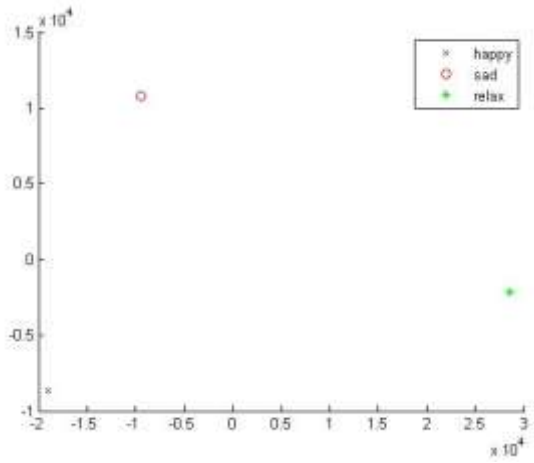

Figure 8: PCA result for subject 1(set1)

The LDA classification technique is applied on the data of 10 subjects of set1as shown in figure 9. The classification accuracy is obtained from the formula:

$$\text{accuracy} = \frac{x}{n} * 100$$

where: n= 10;

x= number of clusters in circle

Table VI, describes the classification accuracy rate for all said mental states; relax is 70%, happy is 90% and sad is 90% and the overall accuracy is 83% respectively.

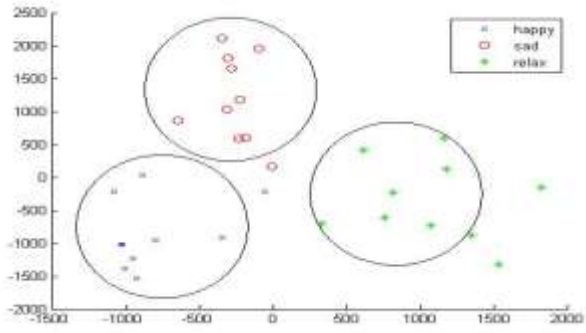

Figure 9: LDA results of all 10 subjects for happy, sad and relax mental state

Table 6: Accuracy for three states

Emotion mental state	n	X	accuracy	Overall accuracy
Relax	10	7	70%	83%
Happy	10	9	90%	
Sad	10	9	90%	

IV. CONCLUSION

Brain regions which are involved for recognizing emotion using EEG images have been extensively studied and associated according to literature with functional abilities. It is observed that,

1) In relax mental state, as the volunteers has been asked to be relax .The active regions were found to be less, whereas the activity can be seen in frontal and prefrontal regions.
2) In happy mental state, the emotions in EEG images were seen more prominent towards right hemisphere the prefrontal, frontal, temporal were seen active.
3) In sad mental state, the emotions in EEG images were seen dominating towards left hemisphere in which the prefrontal, frontal, temporal regions are seen active.
4) The active size of happy is large as compared to relax and sad.
5) The active regions are seen more in happy mental state as compared to relax and sad, whereas the active electrodes are also seen more in happy.
6) The PCA classification was applied on data of one subject of one set in which we can see the diversity in emotions.
7) The LDA classification techniques was used to differentiate the emotions and calculate the classification accuracy, the classification rate for relax is 70%, happy is 90% and sad is 90% and overall accuracy is 83% respectively.
8) The results can be utilized in making the Emotion Recognition System.

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Table 2 Representative EEG images for Relax Mental State

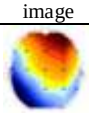
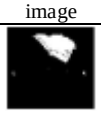
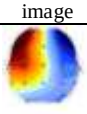
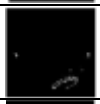
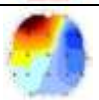
	Image3			Image7			Image14		
	Original image	Threshold image	Edge detection	Original image	Threshold image	Edge detection	Original image	Threshold image	Edge detection
Subject1									
Subject2									
Subject3									
Subject4									
Subject5									
Subject6									
Subject7									
Subject8									
Subject9									
Subject10									

Table 3 Representative EEG images for Happy Mental State

	Image3			Image7			Image14		
	Original image	Threshold image	Edge detection	Original image	Threshold image	Edge detection	Original image	Threshold image	Edge detection
Subject1									
Subject2									
Subject3									
Subject4									
Subject5									
Subject6									

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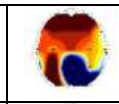
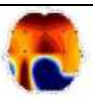
Subject7									
Subject8									
Subject9									
Subject10									

Table 4 Representative EEG images for Sad Mental State

	Image3			Image7			Image14		
	Original image	Threshold image	Edge detection	Original image	Threshold image	Edge detection	Original image	Threshold image	Edge detection
Subject 1									
Subject 2									
Subject 3									
Subject 4									
Subject 5									
Subject 6									
Subject 7									
Subject 8									
Subject 9									
Subject 10									

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Table 5: Representation of Active Size, Regions and Electrodes for Reprehensive Image of Three Mental States

	happy			sad			relax		
Subject 1	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	9199	7639	4882	10130	10754	7139	2759	4728	4745
Active electrodes	FP1,F3,Fz ,F4,F8	F4,F8, C4,P4	FP1,F7,F3, T3,C3	T3,C3,C z, P3,Pz	F3,T3,C 3, Cz,C4,P 3, Pz	C3,T5,P3, Pz,O1	O1,O2	FP1,FP2, Fz,F4	FP1,F7,F3, T3,C3
Active regions	PR,F	F,C,P	PR,F,T,C	C,T,P	F,C,T,P	C,T,P,O	O	PR,F	PR,F, C
Subject 2	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	6688	6460	10781	4002	7111	3597	1243	3012	1416
Active electrodes	FP2,F4,F8, C4,O2	FP1,FP2, F4, F8,C4	FP1,FP2,F 3,F7,	F7,T3,C 3,T5	F7,T3,C 3,T5,P3, O1	FP1,F7,F3, C3	O2	O1,O2	O2
Active regions	PR,C,F,O	PR,F,C	PR,F,C	F, T, C	F,T, C, P	PR,F, C	O	O	O
Subject 3	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	9431	11659	20117	6144	4390	4201	2211	2422	2367
Active electrodes	F4,F8,C4,T 4,P4, T6,O1,O2	T3,T5,P3, F4,F8, C4,T4,Pz, P4,T6, O2	F7,F8,T3,C 3,Cz, C4,T4,T5,P 3,Pz,P4,T6 ,O1	F7,F3,T 3,C3,P3, Pz	FP1,FP2 ,F7,F3, T3,C3,O 1,T6	FP1,FP2,Fz	O1,O2	O1,O2	O1,O2
Active regions	P,T,O	PR,F,C	F,P,O,T,C	F, C, P	PR,F, C,T, O	PR,F	O	O	O
Subject 4	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	16404	15075	15742	4241	4390	4201	2057	2774	2548
Active electrodes	FP1,FP2,F 7, F3,Fz,F4,F 8, T3,C3,Cz,C 4, T5	FP1,FP2, F7,F3, Fz,F4,F8, Cz,T4, O1	F3,T3,C3,C z,C4, T5,P3,Pz,P 4,T6, O2	C4,P4,O 2	O1,O2	FP1,FP2,F 4,Fz	F4,F8	FP1,F4	F3,F7,T3,C 3
Active regions	PR,F,C,T,O	PR,F,C,T, O	F,C,P,O,T	C, P, O	O	PR,F	F	PR,F	F, T, C
Subject 5	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	4652	4193	4935	2941	1755	1969	2575	593	2302
Active electrodes	C4,P4,T6, O2	FP1,FP2, Fz	FP1,FP2,F 7,F3	T5,P3	F7,F3	F7,F3	T5,P3	F7,F3	F7,F3
Active regions	C,T,P,O	PR,F	PR,F	T,P	F	F	O	F	PR

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Subject 6	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	5026	5180	4072	3630	2727	4709	1924	5428	1757
Active electrodes	FP1,FP2,Fz, F4	FP1,FP2, Fz, F4,F8	F8,T4,P4,T6, O2	C3,FP2, F4,F8	FP1,FP2 ,C3	FP1,FP2,Fz	F4,P4	F4,Pz,P4 ,T6, O2	C3
Active regions	PR,F	PR,F	F,T,P,O	PR,F, C	PR,F	PR,F	F, P	F, P, T, O	C
Subject 7	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	13509	13163	8419	1982	4330	3740	2759	1683	1193
Active electrodes	FP1,FP2, F3,FZ,F4, CZ,P3	FP1,FP2, F3, Fz,F4, Cz,P3,T5, O1	Cz,P4, F4,C4,T4, F8	P3,O2	F3,Fz, Cz,C3	Fz,Cz,C3	O1,O2	FP1,FP2	FP1,FP2
Active regions	PR,F,P,C	PR,F,P,C, O	C,F,P,T	PR, O	C, F	C, F	O	PR	PR
Subject 8	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	11495	10175	5582	6152	5169	9413	1564	5835	1120
Active electrodes	FP1,F3,Fz, F4,F8	F4,F8, C4,P4	FP1,F7,F3, T3,C3	FP1,F7,F3	FP1,FP2 ,Fz, O2	T4,T5,P3, Pz,P4,T6	FP2	FP1,FP2, Fz, F4	FP2
Active regions	PR,F	F,C,P	PR,F,T,C	PR,F	PR,F ,O	T,P	PR	PR,F	PR
Subject 9	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	3014	3205	6079	14196	11166	14172	4782	3805	4039
Active electrodes	O1,T4	T5,T6	O2	F3,Fz,F4, Cz	T3,T5,O1	F7,F3,T3, C3,Cz	FP1,F7	FP1,F7,F3	FP2,F4
Active regions	O,T	P	O,T	F,C	O, T	C, F, T	PR,F	PR,F	PR,F
Subject 10	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**	**Image3**	**Image7**	**Image14**
Active size	8705	14068	5676	9409	6364	5272	620	1297	1957
Active electrodes	F4,Pz,P4,T6, O1,O2	F4,C4,T4, T5, Pz,P4,T6, O1,O2	F4,F8,C4,T4, P4,T6,O2	T3,C3,Cz,C4, P3,Pz,P4	F7,T3,C3,T5, P3,O1,T6	T3,T5,P3, O1	O2	O2	O2
Active regions	F,P,T,O	F,C,P,O,T	F,C,P,T,O	P, T, O	F,C,T,P	T,P,O	O	O	O

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