



# Correlation of EEG Images and Speech Signals for Emotion Analysis

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## Authors' contributions

*This work was carried out in collaboration between both authors. Author PAA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author BWG managed the analyses of the study and examines the literature searches and results. Both authors read and approved the final manuscript.*

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## ABSTRACT

**Aims:** The paper anticipates the correlation of EEG images and speech signals for understanding the emotions.

**Study Design:** The study focuses on recognition of emotions using EEG images and speech signals using various image processing and statistical techniques. For correlating these two modalities, Person's correlation coefficient is used.

**Place and Duration of Study:** System Communication Machine Learning Research Lab (SCM-RL). Department of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India. 2009 - till date.

**Methodology:** The study was performed using the data from 10 volunteers 5 boys and 5 girls, vocally sharing the experiences for happy and sad emotional states. Image processing techniques were employed to extract features from EEG images. A Threshold and Sobel Edge detection technique is used to extract the active regions of the brain during the emotional states. MatlabR2012 is used to calculate the active size of EEG images. PRAAT software is used to extract the features of speech signals. Pitch, intensity and RMS energy parameters were used for

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the analysis of speech features. The correlation is calculated using size of active region from EEG images with pitch and intensity for said emotional state.

**Results:** The correlation of EEG images with speech signals is implemented using SPSS software using Person's correlation coefficient with significance of about 95% which can further be inspected in results.

**Conclusion:** The correlation of both EEG images and speech signals found to be between moderate to strong relationship and is signified through p value which is in the range of .001 to .081 in happy emotional state and .000 to .069 in sad emotional state. The results can be utilized in making the Robust Emotion Recognition System (ERS). This research study can also found to be significant in research domains like forensic science, psychology and many other applications of Brain Computer Interface.

*Keywords: BCI; emotion recognition; EEG; speech processing; EEG images; correlation.*

## 1. INTRODUCTION

Brain Computer Interface (BCI) is a part or a subset of Human Computer Interface that involves the communication between the user and the system via brain signals. BCI are projected for enabling people to operate electrical devices and applications by thinking process or through their psychological activity. Emotion recognition has become credible research topic in the field of BCI [1]. There also exists a broader range of techniques used for automatic emotion recognition of diverse emotional states. Emotion recognition is drawn on two foundational emotion conceptualization. The first type focuses on the basic emotions made up of finite array of emotional constructs such as anger, fear, sad, happy. The second approach focuses on the arousal and valence model which characterize the emotions. The study of neurophysiology aimed to identify the two primary aroused emotional states which are related to positive and negative emotions, the eye blinks were used for identification and experimental work by using algorithms using wavelet transform [2]. It also [3] concentrates on recognizing the inner emotions from EEG signals. In this, two types of emotion induction experiments were performed using music and sound stimulus from International Affective Digitized Sounds (IADS) database which was used for implementation. The Bayesian Network [4] was used for recognizing emotions using multi-emotion states from EEG. The subjects have been gone through stimuli like emotional videos along with collecting EEG signals and applying Receiver Operating Characteristics to select the input features. The continuously detected emotions were collected using valence from EEG signals while showing the videos, the correlation between both EEG and facial expressions were studied [5]. The MRI [6] is also

used for lateralization of brain regions; mostly the positive and negative emotions found in music are studied. The happy and sad are the most dissimilar emotions. It is also seen that the results of EEG and MRI are found to be different in different brain activities. The study of EEG and MEG is seen in [7] which introduce the advances in signal processing methodologies. The frequency patterns are analysed to recognize the emotion processes in subjects, where as the popular brain imaging method adopted is the MRI, it returns a sequence of static images of the brain.

Emotion recognition can also be detected using speech. Emotions allow people to precise themselves beyond verbal domain. Emotion recognition from speech has gained rising attention [8]. The speech recognition is also called as Automatic Speech Recognition; it is the process of converting the raw data to a proper sequence, with the help of different algorithms and techniques. The main objective of this research is to develop different techniques, applications, systems which can be used for the benefit of society [9]. The research [10] focus on the study of speech signal performance, on how speech is modulated when speaker's emotion changes from neutral to other emotional state. It was observed that speech link with anger and happy are described by longer utterance duration, higher pitch and energy value with deep length. The study [11] has also been carried out for extracting features from speech to recognize emotions using classification technique i.e. Hidden Markov Model (HMM) and Support Vector machine (SVM). The recognition of different emotions depend on how well the EEG features can be mapped onto chosen emotion representation. The emotion representation used in the two dimensional mapping with arousal valence axes.

One of the most used frameworks for emotion recognition is best characterized by two dimensions: arousal and valence as seen in Fig. 1. The positive emotions are seen at the right part of the brain and the negative emotions are seen at the left part of the brain respectively [12].

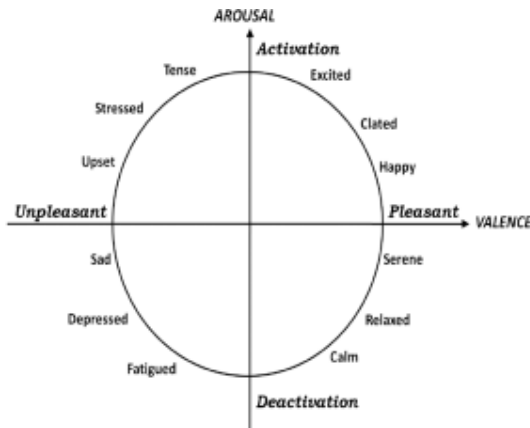


Fig. 1. Arousal- valence model

### 1.1 Human Brain

The brain is divided into three major areas: the cortex, the limbic system and the brain stem. The amygdale is important for processing emotions like happy, sad, anger, surprise, disgust and so on. The amygdale is the emotional centre of the brain. The prefrontal, frontal and temporal lobe regulates emotion and emotionally attuned communications, it is also involved with collecting information, thinking, processing, creating different options for responding.

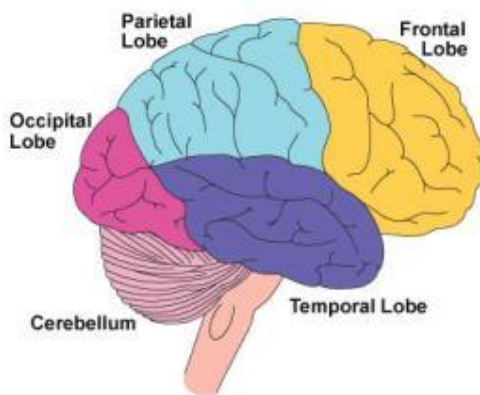


Fig. 2. Human brain with lobes

Each part of the brain can further be divided into different lobes as seen above in Fig. 2. Each

lobe is described for specific purpose which is described below:

- Frontal Lobe: In this lobe we can, think, conceptualize plan, emotions.
- Prefrontal Lobe: In this lobe emotions are recognized, visual processing is done.
- Parietal Lobe: This lobe can be seen in movement, orientation, calculation, recognition.
- Temporal Lobe: This lobe describes sound and speech processing, aspects of memory and emotions can also be seen.
- Occipital Lobe: This lobe concentrates on visual processing [13].

### 1.2 Electroencephalography (EEG)

Electroencephalography (EEG) is a technique which measures electrical activity produced from the scalp. EEG is used for diagnosing epilepsy, sleep disorders, coma patients and many more. For collecting the data, RMS EEG 32 channel 19 electrodes data monitoring equipment is used, the 19 electrodes are placed on the scalp of the subjects with the help of 10-20 international system.

As shown in Fig. 3, 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 [14]. EEG signals emanate due to electrical activity produced by the brain, the EEG signals are classified in four different frequency bands; Delta (<3.5), Theta (4-7 Hz), Alpha (8-13 Hz), Beta (14-30 Hz) shown in Fig. 4.

- Delta ( $\delta$ ) wave ranges from < 3.5 Hz. Delta brainwaves are slowest, but loudest brainwaves. They are generated in deepest meditation and dreamless sleep, also found in infants.
- Theta ( $\theta$ ) wave ranges from 4 to 7 Hz. Light sleep or extreme relaxation. Theta is seen in mental state that has proven useful for hypnotherapy.
- Alpha ( $\alpha$ ) 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 ( $\beta$ ) wave ranges from 14 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 [15].

### 1.3 EEG Images

Apart from EEG signals, EEG images are also integrated in the software, which are considered in this article for experimentation. The machine provides Brain mapping colour coding as per international standard. RMS EEG machine also provides software i.e. "Acquire" and "Analysis".

- Acquire software: The software is used to acquire the recordings of the subject.

Features like patient info, impedance 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 Fig. 5.

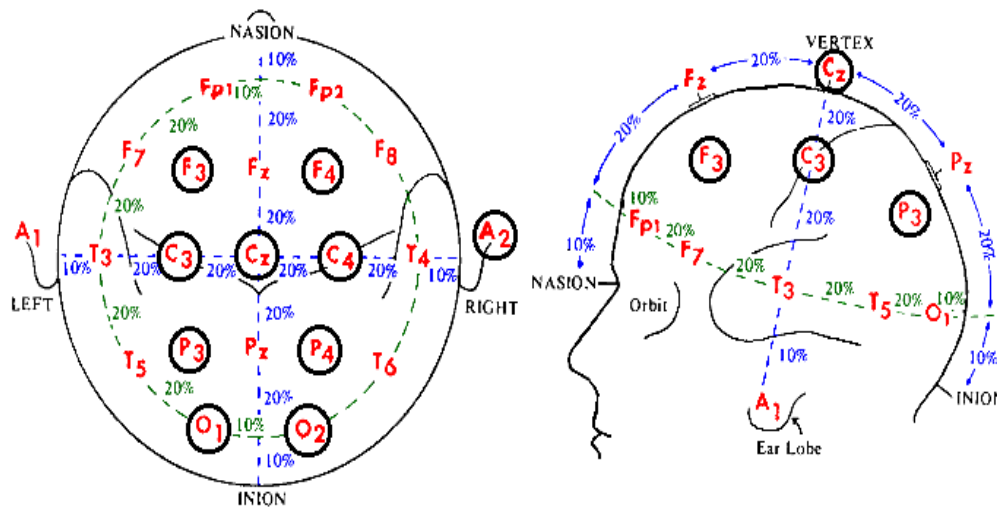


Fig. 3. The international 10-20 system

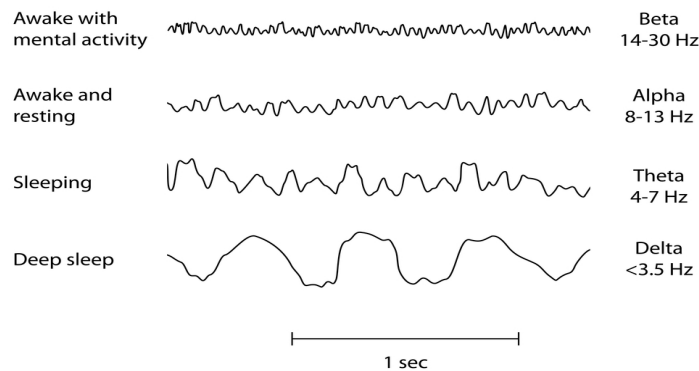


Fig. 4. EEG waves for different signals

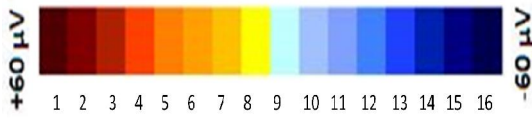


Fig. 5. Full colour spectra for EEG images



Fig. 6. Selected colour spectra for EEG images

The spectra ranges from +60  $\mu\text{V}$  to -60  $\mu\text{V}$ . According to literature the +60  $\mu\text{V}$  give the intense higher activity, and -60  $\mu\text{V}$  give the indistinct lesser activity. There are in all 16 colour shades in the spectra provided. We have concentrated on first 4 shades as shown in Fig. 6, to analyze the emotional activity in the brain [16].

### 1.4 Speech Processing

The speech processing is the process of converting the raw signal or data to proper sequence of words or sentences, with the help of various techniques. The Computerized Speech Lab (CSL) machine was used for recording and preprocessing of speech data, for extraction of features from speech signals PRAAT freeware

software is used. The parameters like pitch, energy and intensity make an important role in expressing the speech emotionally. We have focused on speech parameters which were used to determine the emotions.

- Pitch: which is the main acoustic correlate of tone and intonation; it gives highest peak of the wave by which we can recognize the state of emotions.
- Energy: the best parameter for emotion recognition.
- Intensity: the parameter is used to calculate the physical energy and degree of loudness in speech which is used for speech processing [17].

The data is acquired from both EEG and Speech simultaneously from volunteers. The acquired data is refined by which EEG images and speech signals were sorted. The active regions from EEG images were extracted using threshold. The sobel egde detection technique is also enforced on the EEG images to acquire the exact size of the active region. The speech signals are extracted using Praat software. Praat is a freeware software program used for analysis and reconstructing of speech signals. The statistical Correlation Coefficient i.e. the Person's correlation coefficient is used to calculate the correlation between the EEG images and speech signals for recognizing emotions; Fig. 7 shows the flow of experimentation.

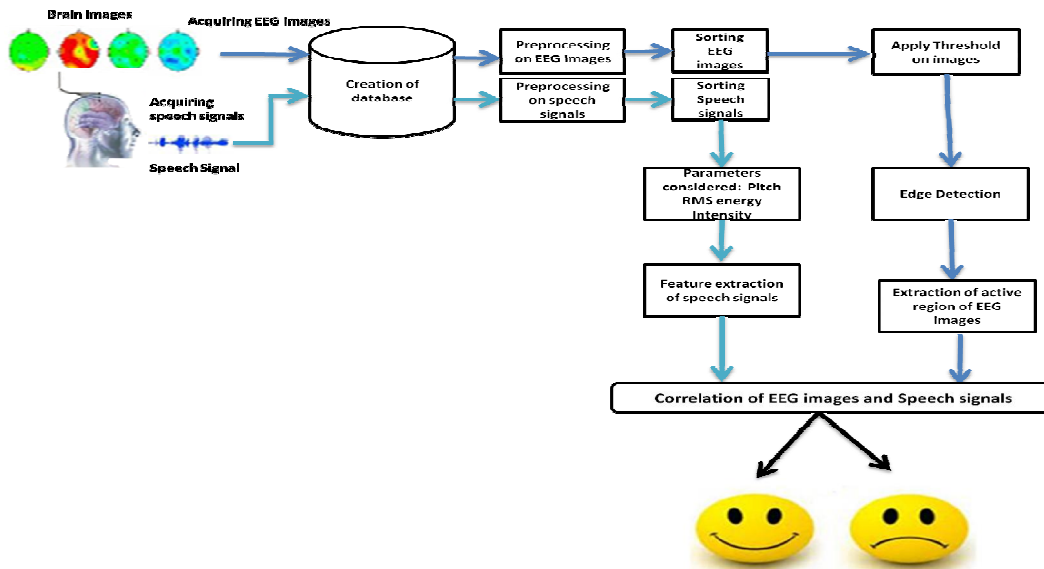


Fig. 7. Flowchart for emotion recognition

## 2. METHODOLOGY

### 2.1 Data Acquisition

#### 2.1.1 Emotion intelligence test (EII) and acquisition protocol

The subjects were selected from Department of CS and IT, Dr. B. A. M. University, Aurangabad. The subjects were counselled before the Emotional Intelligence Inventory (EII) Test. The EII test is 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. A threshold was targeted on the bases of which the subjects were selected. For experimental purpose 10 volunteers, were 5 boys and 5 girls with efficient emotion were considered. The consent is also taken from the subjects and the information is kept confidential.

The volunteers were selected from the age group of 22-26. The EEG recording was acquired, using RMS EEG 32 channel machine. 19 electrodes were placed on the scalp with the help of gel, and Computerised Speech Laboratory (CSL) machine was used to record the speech signals from the volunteers. The volunteers were asked to express about their happy and sad emotional incidence from their life, in the mean while the data was acquired for both EEG and speech signals for said emotional states.

#### 2.1.2 Tools used for data acquisition

- i) **RMS EEG Machine:** For data acquisition the RMS EEG 32 machine is used. The RMS EEG 32 channel 19 electrode EEG machine, provides a panel for connection of electrodes, all the electrodes are having individual wires which are metal plated which is to be placed on the scalp, a camera which is used for recording the movements of the subject.
- ii) **Computerized Speech Laboratory (CSL) machine:** For recording and analyzing speech CSL machine is used. The Computerized Speech Laboratory (CSL) is a speech and signal processing computer workstation (software and hardware) used for research and clinical speech therapy. CSL machine is used for collecting database, the setup includes the mic, speakers, desktop on which CSL software is installed, CSL key. The CSL suite of software covers speech analysis, teaching,

research, voice measurement, clinical feedback, acoustic phonetics, and forensic work. The data was collected at a sampling frequency of 11500 Hz.

- iii) **Acquire software:** The software is used to acquire the recordings of the subject, to start with the detail history of the concern subject is taken like name, gender, age, medical history if any, physically handicap and so on. Then impedance is checked, these shows the voltage of every electrode and whether it's placed on proper place. Then we start with proper EEG, the machine provides a record button which starts recording EEG, it also provides a stop button which can be used when the entire task are completed.
- iv) **Analysis Software:** The software only opens the file with .eeg extension and which are saved in acquire 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, for this research work this tool have been taken into consideration.
- v) **Matlab R2012:** The Matlab R2012a is used as frontend software, it is a high level language and interactive environment software used by students of different faculties, also includes tool like signal processing, image processing and many other packages.
- vi) **Praat:** For feature extraction from speech signal Praat is used. This is a freeware program for the analysis and reconstruction of acoustic speech signals. PRAAT is a very flexible tool to do speech analysis. It offers a wide range of standard and non-standard procedures, including spectrographic analysis, articulatory synthesis, and neural networks and many more features are included in the software.
- vii) **Statistical Package for the Social Sciences (SPSS):** The Statistical Package for the Social Sciences (SPSS) was the first comprehensive data analysis software. As the software is user-friendly and easy to acquire it is rapidly used for different

statistical operations, it also offers good data management.

## 2.2 Analysis of EEG Images and Speech Signals

### 2.2.1 Features extraction using Image processing techniques

Image processing involves handling image as two dimensional signals; techniques applied on EEG images are;

- i) **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, the red section which is seen active is extracted as seen in Fig. 8 [18].

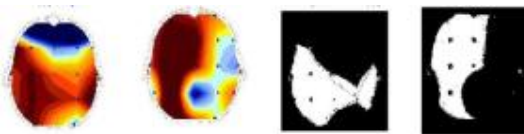


Fig. 8. Threshold applied on EEG image

- ii) **Sobel Edge Detection:** 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 gray scale image as seen in Fig. 9 [19].

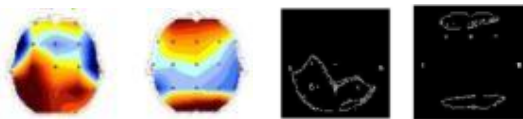


Fig. 9. Sobel edge detection applied on original image

- iii) **Statistical Technique:** There are different statistical techniques used like mean, standard deviation, variance, covariance, like wise we have concentrated on correlation. Its numerical value ranges from +1.0 to -1.0. It gives us an indication of the strength of relationship. In general,  $r > 0$  indicates positive relationship,  $r < 0$  indicates negative relationship while  $r = 0$  indicates no relationship; greater is the strength of the relationship between the

variables, the strength of correlation in seen in Table 1. The Pearson's Correlation coefficient is used to calculate two continues variables. It shows the linear relationship between two sets of data [20].

Table 1. Strength of relationship

+ .70 or higher	Higher very strong positive relationship
+ .40 to + .69	Strong positive relationship
+ .30 to + .39	Moderate positive relationship
+ .20 to + .29	weak positive relationship
+ .01 to + .19	No or negligible relationship
- .01 to - .19	No or negligible relationship
- .20 to - .29	weak negative relationship
- .30 to - .39	Moderate negative relationship
- .40 to - .69	Strong negative relationship
- .70 or higher	Very strong negative relationship

The Pearson's Correlation coefficient is usually used to calculate two continues variables. It shows the linear relationship between two sets of data.

The simplest way of defining Pearson's Correlation is;

$$r = \frac{\text{Cov}_{xy}}{S_x S_y}$$

Where,

$\text{Cov}_{xy}$  is covariance between X and Y  
 $S_x$  is standard deviation for X  
 $S_y$  is standard deviation for Y

$\text{Cov}_{xy}$ , is always smaller than or equal to  $S_x S_y$ . Thus the maximum value of correlation coefficient is bound to be 1. The sign of Pearson's  $r$  depends on the sign of  $\text{Cov}_{xy}$ . If the  $\text{Cov}_{xy}$  is negative then  $r$  will be negative and if  $\text{Cov}_{xy}$ , is positive then  $r$  will be positive value.

The statistical significance testing uses data to evaluate a hypothesis by comparing sample point estimates of parameters to values predicted by the hypothesis. Different values of correlation can be obtained between two variables for different samples of different sizes belonging to the same dataset. Null hypothesis ( $H_0$ ) states that parameters take specific values, usually have no effect. Alternative hypothesis ( $H_a$ ), states that parameter values falls in some alternative range of values, usually have an effect. The smaller the P-value, the stronger the evidence against  $H_0$  [21].

## 2.3 Speech Parameters

### 2.3.1 Pitch

Pitch is an important parameter for voiced speech. The pitch values contain the speaker specific information. The pitch variation carries the intonation signal associated with rhythms of speech, speaking manner, emotions and assent. The gender is one of the factors which convey a part in characterization of vocal tract. Randomly, the average pitch for female is about 200 Hz and for male it is about 110Hz. In pitch variation emotion signals in voice is one indicator, speech like excitement, stress can be easily justified. Pitch variation is often correlated with loudness in speech, happy, fear and many other emotions in voice are signaled by fluctuations of pitch.

### 2.3.2 Intensity

The correlate of physical energy and the degree of loudness of a speech sound is intensity. The measure of amplitude via a microphone signal of a person's voice fluctuation is the intensity of that signal. The intensity reflects watts divided by a unit area because it is describing how much energy has radiated.

### 2.3.3 RMS Energy

RMS energy is the best signal parameter to separate emotion classes; it is used to measure the energy while speaking. The energy also affects the performance of acoustic model in the speech recognition. The voiced frame was determined by calculating the energy contained within certain bandwidths [17].

## 3. RESULTS AND DISCUSSION

Expression of emotion is a multimodal activity. Therefore modalities like facial expression, speech, gestures, tone, speech, force-feedback and bio-signals may be more supportive for the development of Robust Emotion Recognition

System (ERS) [22,23]. This paper attempts to investigate the correlation of EEG brain images and speech signal which ultimately is useful for ERS. In this attempt database is acquired for EEG images and speech signals for 10 subjects. The duration of the recording was 15 min for each of two (happy and sad) emotional states. Before the activity the subjects were asked to be relaxed.

The total 20 EEG images were selected for the experiment. Each of 20 images represents data of 45 sec.

Table 2; characterize the database.

Table 3; expresses the EEG images with its threshold and edge detection for happy emotional state. It is seen that the activity is large in the right part of the brain. Prefrontal, frontal, right temporal, central regions are seen to be more prominent.

Table 4, illustrates the EEG images with threshold image and Edge detection for sad emotional state, the activity is seen in left part of the brain. The active regions seen more dominant are the prefrontal, frontal, left temporal, occipital, partial regions. The detail of image no. 3, 7 and 14 are represented in the paper.

Table 5; details the EEG image size for selective happy EEG images Table 6; details the EEG image size for selective sad EEG images.

The database of speech signal is acquired along with EEG recordings. Thus the recording of speech signals was also for 15 min. The signal is divided into 20 speech samples which correspond to the selected EEG images. The parameters considered to extract the emotions from speech are pitch, intensity and RMS energy. The similar results are observed and presented in [24]. Where it is observed that in happy, the pitch and intensity are higher as compared to sad.

**Table 2. Details 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 images
Speech signals	10	2 (happy, sad)	3	--	60 speech signals



Table 3. Representative EEG images for happy emotional state

	Image 3			Image 7			Image 14		
	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									

**Table 4. Representative EEG images for sad emotional state**

	Original image	Image 3 Threshold image	Edge detection	Original image	Image 7 Threshold image	Edge detection	Original image	Image 14 Threshold image	Edge detection
Subject 1									
Subject 2									
Subject 3									
Subject 4									
Subject 5									
Subject 6									
Subject 7									
Subject 8									
Subject 9									
Subject 10									

**Table 5. Representative image size for happy EEG images**

Image number	Subj 1	Subj 2	Subj 3	Subj 4	Subj 5	Subj 6	Subj 7	Subj 8	Subj 9	Subj 10
3	9199	6688	9431	16404	4652	5026	13509	11495	3014	8705
7	7639	6460	11659	15075	4193	5180	13163	10175	3205	14068
14	4882	10781	20117	15742	4935	4072	8419	5582	6079	5676

**Table 6. Representative image size for sad EEG images**

Image number	Subj 1	Subj 2	Subj 3	Subj 4	Subj 5	Subj 6	Subj 7	Subj 8	Subj 9	Subj 10
3	10130	4002	6144	4241	2941	3630	1982	6152	14196	9409
7	10754	7111	11790	4390	1755	2727	4330	5169	11166	6364
14	7139	3597	6769	4201	1969	4709	3740	9413	14172	5272

**Table 7. Representative pitch, intensity and RMS energy for happy selective images**

Speech subject	Pitch			Intensity			RMS Energy
	Relative pitch value image 3	Relative pitch value image 7	Relative pitch value image 14	Relative intensity value image 3	Relative intensity value image 7	Relative intensity value image 14	Happy RMS energy
1	254.95	253.85	247.67	58.14	58.86	58.98	0.026
2	241.24	224.42	250.55	61.29	61.16	61.90	0.024
3	345.72	458.75	753.25	66.98	63.58	46.17	0.058
4	178.01	176.48	185.28	64.22	63.52	63.63	0.053
5	145.27	176.47	172.60	69.38	54.77	66.45	0.059
6	156.08	154.20	154.80	48.91	44.61	68.61	0.046
7	331.53	381.60	366.32	68.75	69.78	67.04	0.040
8	234.11	230.97	232.81	62.48	62.81	63.72	0.046
9	253.44	247.07	243.38	37.81	40.69	44.86	0.015
10	306.29	310.07	280.80	39.41	38.18	37.18	0.025

**Table 8. Representative pitch, intensity and RMS energy for sad selective images**

Speech subject	Pitch			Intensity			RMS Energy
	Relative pitch value image 3	Relative pitch value image 7	Relative pitch value image 14	Relative intensity value image 3	Relative intensity value image 7	Relative intensity value image 14	Sad RMS energy
1	244.62	213.05	219.22	66.23	70.43	71.57	0.018
2	212.43	206.64	357.01	65.56	85.86	72.69	0.021
3	258.88	267.29	248.42	60.42	62.07	60.62	0.046
4	201.97	199.14	199.32	62.60	64.66	67.34	0.071
5	167.08	164.03	172.53	64.04	62.53	44.95	0.049
6	166.55	169.34	170.28	59.83	63.16	60.60	0.053
7	278.56	286.06	309.55	59.36	58.56	58.55	0.032
8	223.98	222.41	224.93	59.79	58.17	59.75	0.031
9	233.47	229.58	234.40	40.15	36.54	37.10	0.013
10	267.52	266.70	262.85	44.03	43.08	43.90	0.23

Above Table 7; express the happy speech values for representative pitch, intensity and RMS energy for selective happy images. It is observed that the pitch is higher as compared to intensity and RMS energy.

Above Table 8; interprets the speech value for representative pitch, intensity and RMS energy for selective sad emotional states.

The comparative correlation of EEG images size with happy pitch and happy intensity and EEG image size with sad pitch and sad intensity are seen in Tables 9 and 10 respectively. The (\*) Correlation is significant at the 0.05 level for 2-tailed, and (\*\*) Correlation is significant at the 0.01 level for 2-tailed correlation.

**Table 9. Correlation for happy and sad pitch**

Subject	Happy pitch		Sad pitch	
	Correlation	significance	Correlation	Significance
Subject1	.598 (**)	.005	.566 (**)	.009
Subject2	.400	.081	.495 (*)	.027
Subject3	.451 (*)	.046	.458 (*)	.042
Subject4	.436	.055	.456 (*)	.044
Subject5	.499 (*)	.025	.415	.069
Subject6	.431	.058	.536 (*)	.015
Subject7	.443	.050	.438	.053
Subject8	.518 (*)	.019	.421	.065
Subject9	.477 (*)	.034	.508 (*)	.022
Subject10	.574 (**)	.008	.452 (*)	.045

**Table 10. Correlation for happy and sad intensity**

Subject	Happy intensity		Sad intensity	
	Correlation	significance	Correlation	Significance
Subject 1	.555 (*)	.011	.417	.067
Subject 2	.495 (*)	.027	.445 (*)	.049
Subject 3	.410	.073	.573 (**)	.008
Subject 4	.457 (*)	.043	.449 (*)	.047
Subject 5	.492 (*)	.028	.450 (*)	.046
Subject 6	.420	.065	.468 (*)	.037
Subject 7	.553 (*)	.011	.490 (*)	.028
Subject 8	.676 (**)	.001	.620 (**)	.004
Subject 9	.694 (**)	.001	.846 (**)	.000
Subject 10	.423	.063	.498 (*)	.025

The correlation of EEG image with happy pitch and intensity and sad pitch and intensity falls under the category of strong positive correlation as mention in Table 1. This result efficiently presents that speech signals and EEG images can be considered as powerful candidate modalities for designing Robust Emotion Recognition System.

**4. CONCLUSION**

The study aimed to identify the Emotion recognition utilizing EEG images and speech signals which is a new approach in Brain Computer Interface, since correlation of EEG images and Speech signals for recognizing emotions are studied and observed as follows:

- 1) In happy mental state the activities are seen in right hemisphere, the prefrontal, frontal, temporal, occipital regions are seen active and in sad mental state the activities are seen in left hemisphere, the prefrontal, frontal, temporal, occipital regions are seen active.
- 2) The active size are seen more prominent in happy as compared to sad mental state.
- 3) The speech signals for happy pitch is seen eminent as compared to sad pitch, whereas happy intensity is leading sad

intensity, the happy RMS energy can also be seen salient then sad RMS energy.

- 4) The correlation of both EEG images and speech signals found to be between moderate to strong correlation and this correlation is signified through p value which is in the range of .001 to .081 in happy state and .000 to .069 in sad state.
- 5) The correlation coefficient significance accuracy is about 95% for said emotional state.
- 6) The results can be utilized in making the Emotion Recognition System (ERS). This research is also found to be significant in research domains like forensic science, psychology and many applications of Brain Computer Interface.
- 7) As we have studied the database of 10 subjects, but if the number of subjects are increase the accuracy of recognition can also be increased.

**CONSENT AND ETHICAL APPROVAL**

The subjects were selected from Department of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. The subjects were counselled before the Emotional Intelligence Inventory (EII) test. The consent was also taken

from the subjects and the information is kept confidential.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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