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BCI Application: Emotion Recognition from EEG (Electroencephalography) Signals- A Survey

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Abstract:

Interfacing computer with human brain signals has been an active research area in the past few years. An efficient human emotion recognition system will help to make the interaction between human and computer more natural and friendly. Assessing human emotions can be interpreted into various Brain Computer Interface (BCI) and Human Computer Interaction (HCI) applications. A wide investigation on human emotion recognition by facial expressions, speech and gestures has been carried out in earlier period [12]. Reading human mind has always remained an ambiguity for science and so is the case with human emotions [10]. Emotion recognition is the process of identifying human emotion. People vary widely in their accuracy at recognizing the emotions of others. Use of technology to help people with emotion recognition is a quite promising research area. Generally, the technology works best if it uses multiple modalities in context. A lot of research has been conducted on automating the recognition of facial expressions from video, spoken expressions from audio, written expressions from text, and physiologyas measured by wearable. Here, a survey on the novel approach of emotion recognition has been presented. The techniques involved in the process have also been discussed in brief. The emotional status of a human subject can be evaluated using the EEG signals as humans could control their facial expressions or vocal intonation. Hence, techniques involving the emotion recognition from EEG signals have been discussed elaborately.

Keywords—**Emotions, EEG(Electroencephalography) signals, Features, database**, **frequency components**

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I. INTRODUCTION

Emotions play an important role in the learning process. Considering the learner's emotions is essential for electronic learning (e-learning) systems. Some researchers have proposed that system should induce and conduct the learner's emotions to the suitable state. But, at first, the learner's emotions have to be recognized by the system.

There are different methods in the context of human emotions recognition. The emotions can be recognized by asking from the user, tracking implicit parameters, voice recognition, Facial Expression Recognition(FER), vital signals and gesture recognition. Moreover, hybrid methods have been also proposed which use two or more of these methods through fusing multi-modal emotional cues. Human Face expression Recognition is one of the most powerful and

challenging tasks in social communication. Generally, face expressions are natural and direct means for human beings to communicate their emotions and intentions. Face expressions are the key characteristics of non-verbal communication.

II. FACIAL EXPRESSION RECOGNITION(FER) SYSTEM

A. Overview of the FER system

The overview of the FER system is illustrated in Fig.1. The FER system includes the major stages such as face image pre-processing, feature extraction and classification[5].

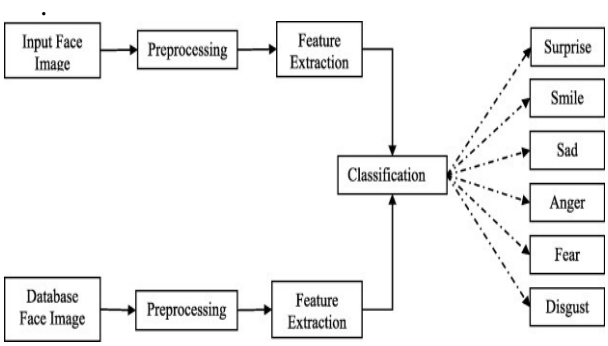

Figure 1. FER system

The various types of basic emotions are shown in Figure 2.

Figure 2. Types of basic emotions

B. Facial Gesture Identification Using Lip Contours

A robust technique to determine happy/sad/neutral facial gestures of humans by processing an image containing human face has been proposed[8]. Difficulty of training the computer with images has been reduced thereby reducing the processing time. In this technique, human face is identified using skin color identification on various spaces like HSV and YCbCr. Using unique face feature determination, segmented features of face like the lips are determined. Contour of lips formed for different human moods are analyzed to identify, facial gesture. Edge detection of lips, followed by morphological operation, gives lip structure. Pattern analysis of lips using the unique histogram algorithm and subsequent comparison with different facial gesture icons gives facial gesture of human being in an image. This technique when tested on a huge database of human images under varying illumination conditions gave acceptable accuracy rates and was found fast enough to be used in real time video-stream. The overall success rate for the model was 87% when tested on a database of 3000 images. The overall process involved is shown in Figure 3.

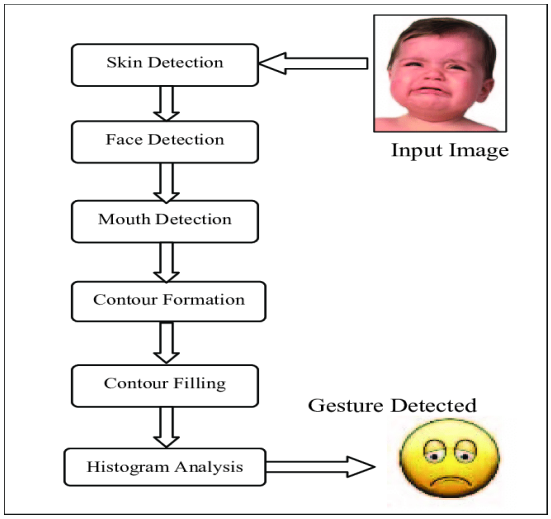

Figure 3. Facial Gesture Identification Using Lip Contours

C. Emotion Recognition using 3-D model

A real-time 3D model-based method that continuously recognizes dimensional emotions from facial expressions in natural communications has been proposed[4]. The proposed system utilizes automatic feature extraction and motion estimation techniques, along with 3D face models to compare motion data to pre-defined prototypes. These results to muscle activation information whichis mapped to groups of emotions, through the Mimic Language as shown in Figure 4.

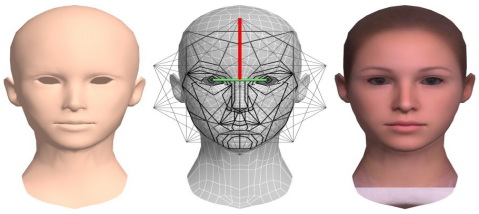

Figure 4. 3D Face model

D. Drawbacks

The drawbacks of various face recognition techniques utilized for emotion recognition is listed below:

(i) Model based:

- Needs high expensive camera(stereo version).
- Construction of 3D model is difficult and takes more time.

(ii) Appearance based:

- Performance depends on the quality of extracted features

(iii) Feature based:

- extracting features in different poses and lighting conditions is a very complex task
- for applications with larger database, large set of features with different sizes and positions, identification will be difficult

III. EMOTION REOGNITION FROM EEG SIGNALS

Electroencephalogram (EEG) is mainly used in various medical applications, in sleep analysis and also used in brain-machine interfacing systems. The electrical signals emanated from the scalp can be recorded by means of Electroencephalography. Since emotions play an important role in the daily life of human beings, the need and importance of automatic emotion recognition has grown with increasing role of human computer interface applications. The various emotions of the subjects, happy, pleasant, sad, fear and frustration can be used to make the analysis. EEG signals emanated while a human subject is in a state of emotion can be used to classify the type of emotion.Comparatively Emotion recognition using EEG signals gives more accuracy than other methods.

Emotion recognition using EEG become quite new, which attracts the BCIresearchers to develop new prototype models for helping the physically challengedindividuals. Most of the researchers have focused on classifying the emotions in two dimensional aspects(valence-arousal)[3]. The-dimensional model consists of two main dimensions which are valence and arousal. The arousal emotion ranges from relaxed to excited and the valence emotion ranges from negative to positive. This model is called the standard circumplex, and is shown in Figure 5.

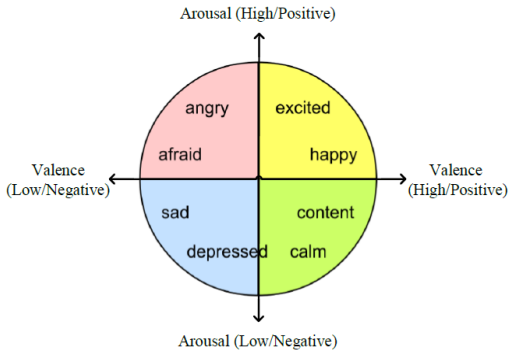

Figure 5. Arousal-valence model

It is the most commonly used model, allowing for graphical representation of emotions and mapping them on a coordinate structure

A. Emotion Recognition audiovisual simulation

Investigations were that the Visual and audiovisual stimulation based protocols can be designed that use 63 biosensors to obtain the EEG signals on five healthy subjects. EEG signal analysis using discrete wavelet transformation and neural network classification has been carried over[7]. Using 'db4' wavelet tool, EEG signals were decomposed into five frequency sub-bands, and two statistical features were extracted from the alpha waves. Such statistical features were used to identify five emotions (disgust, joy, surprise, sadness and anger) as classified by the neural network. The experimental result proved that identification of emotions based on audiovisual stimuli provides greater classification precision over visual

stimulus. Data acquisition protocol followed during the recording of the EEG signals is shown in Figure 6 and theEEG frequency band decomposition using Wavelet Transform is shown in Table 1.

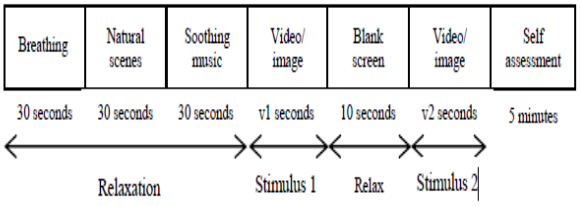

Figure 6. Data acquisition protocol for EEG recording

TABLE 1.

EEG FREQUENCY BAND DECOMPOSITION USING WT

Frequency range (Hz)	*Decomposition labels*	*Frequency bands*
0–4	A5	Theta
4–8	D5	Delta
8–16	D4	Alpha
16–32	D3	Beta
32–64	D2	Gamma
64–128	D1	Noises

B. Emotion Recognition using physiological signals and fuzzy logic

An emotional recognition system based on physiological signals has been proposed. Using the Emotiv EPOC headset and the fuzzy logic techniques, classification of the EEG signals has been performed[6]. A cognitive emotion analysis system that identifies the user and his emotional state in real time to satisfy his needs has been proposed. The system identifies the person via a video camera and follows continuously his emotional state through his face and his physiological state detected from an EEG headset. According to the user's state, the system reacts based on the user preferences stored in its database as shown in Figure 7.

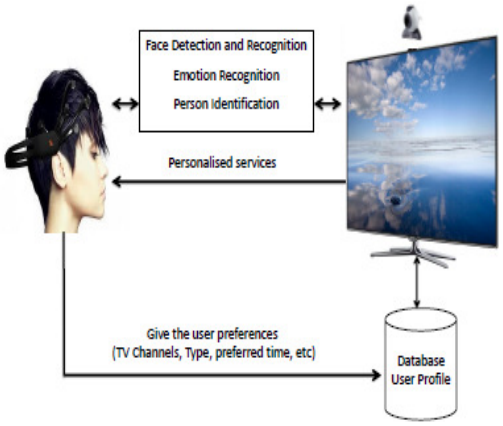

Figure 7. System overview

The Fuzzy logic system developed is shown in Figure 8.

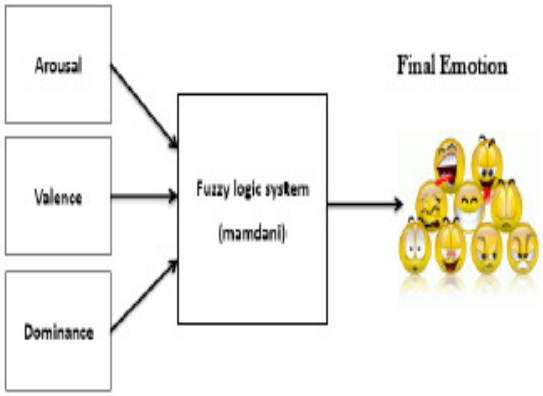

Figure 8. Fuzzy logic system

C. EEG signal analysis using Neural Networks

An integrated system for detecting brain changes during relax and mental stress condition has been presented[9]. In most studies, which use quantitative EEG analysis, the properties of measured EEG are computed by Applying Power Spectral Density (PSD) estimation for selected representative EEG samples. The sample for which the PSD is calculated is assumed to be stationary. A comparative study of the PSD obtained from resting and mental stress condition of EEG signals has been done. The power density spectra were calculated using Fast Fourier transform (FFT) by Welch's method, Yule–Walker and Burg's method. Finally a neural network classifier has been used to classify these two conditions. It is found that maximum classification accuracy was obtained for the Burg Method compared to Yule Walker

and Welch Method technique. This analysis can be further enhanced to classify the emotions depending on the frequency components.

A 19 Electro cap channel was used to record brain signal. EEG signals were measured with the electrodes fixed on the scalp at 19 sites namely Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6,O1 and O2 according to the international 10-20 system as shown in Figure 9.

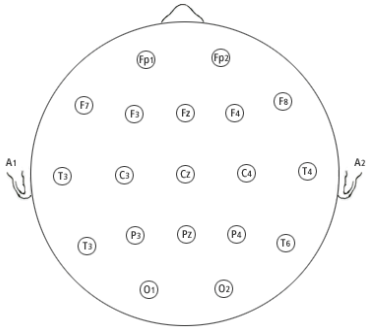

Figure 9. The position of electrodes according to 10-20 International System

The signal processing involves main processes as namely pre-processing and feature extraction as shown in Figure 10.

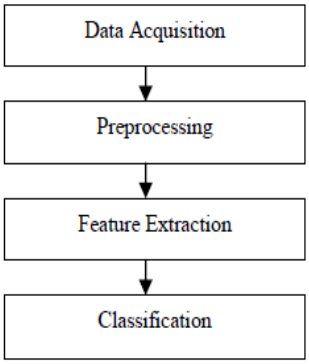

Figure 10. EEG signal processing

An Elliptic band pass filter is applied to extract the sub-band frequency components such as gamma, alpha, beta, theta and delta and they are shown in Figure 11.

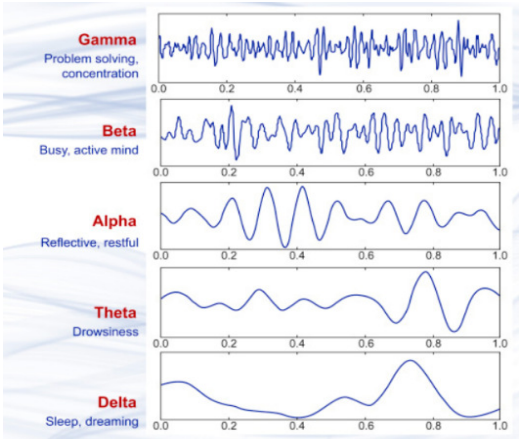

Figure 11. Frequency bands

A simple neural network model is developed for the classification of mental state either relax or during mental stress and the same can be extended to classify the emotions as well. The method involves the study of the PSD obtained from resting and mental stress condition of EEG signals. The power density spectra were calculated using fast Fourier transform (FFT) by Welch's method, auto regressive (AR) method by Yule–Walker and Burg's method. Finally a neural network classifier used to classify these two conditions. It is found that maximum classification accuracy was obtained for the Burg Method compared to Yule Walker and Welch Method technique.

IV. CONCLUSION

Emotion recognition by computers is becoming very popular. Various methods involved in the recognition process have been presented. Also the difficulties with the emotion recognition using facial expression have also been discussed. Finally, the importance of the EEG signals in the emotion recognition system has been discussed elaborately.

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