A Survey on Signal Acquistion and Feature Extraction Techniques

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ABSTRACT
Brain computer Interfacing is a means of communicating to the outside world through brain thoughts. In the design of a Brain computer Interface, signal processing and classification techniques are the most important techniques. This paper aims at comparing the various algorithms and techniques required for detection of essential features for the classification of human emotions recorded using Electroencephalogram. This paper shows the advantages, disadvantages and accuracy of the different methodologies.

Keywords
Brain Computer Interface, EEG, Feature Extraction, Emotion Quantification

1. INTRODUCTION
The interpretation of human thoughts from brain signals without any speech or action is one of the most important and challenging areas of modern neuroscience. In patients, who are fully conscious and awake, but due to brain damage, are unable to show any behavioural response [Completely Locked in Syndrome (CLIS)], a Brain Computer Interface to detect their emotions will make a considerable change in their lives.

Since emotions play an important role in the daily life of human beings, the need and importance of automatic emotion detection has grown with increasing role of human computer interface applications. Emotion detection could be done from speech, facial expression or gesture.

Here the focus is on detection of "real" emotions from electroencephalogram (EEG) signals.

BCI can be of two types, Invasive and Non-Invasive BCI. Non-Invasive BCI is always preferred as it is easy and affordable.

A BCI system is composed of four phases- signal acquisition, signal pre-processing, feature extraction and classification. Various signal acquisition techniques like fMRI, MEG,NIRS and EEG are available. More often EEG is used for acquiring brain signals due to its ease of usability. Signal preprocessing techniques are required to remove any artifacts present in the source signal. Feature extraction is needed to extract the required feature from the signal for analysis and further classification

2. METHODOLOGY

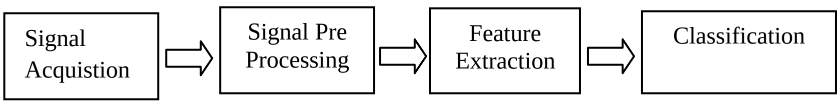

Fig1: Block Diagram- Human Emotion Detection System

A. Signal Acquisition:

There are various non invasive methods for acquiring brain signals. The available methods are functional magnetic resonance imaging(fMRI), Near infrared spectroscopy(NIRS), Magneto encephalography (MEG) and Electroencephalography(EEG)

1. fMRI:

fMRI is a functional neuro imaging technique thatmeasures the brain activity by detecting the haemoglobin flow to a particular region of the brain. Spatial and temporal resolution in fMRI is very high. The data acquisition time using fMRI is high and patients also feel claustrophobic. The high static currents could also pose problems to a few patients.

Fig 2 :Signal Acquisition Technique::fMRI

2. NIRS:

NIRS technique quantifies the amount ofchromophore concentration determined from the measurement of near infrared (NIR) light attenuation. fNIR has several advantages in cost and portability over fMRI, but cannot be used to measure cortical activity more than 4 cm deep due to limitations in light emitter power and has more limited spatial resolution.

Fig 3:Signal Acquisition Technique::NIRS

3. MEG:

MEG is a functional neuro imaging technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain, using very sensitive magnetometers.MEG provides high temporal and spatial resolution. MEG is more sensitive to areas inside the cortical regions than at the top. It is highly expensive

Fig 4: Signal Acquisition Technique::MEG

4. EEG

EEG, discovered by R. Caton is considered to be the most utilized signal to clinically assess brain activities. As EEG signals carry lots of information which may represent brain activities, many research have been done in this field and advanced signal processing methods and new techniques have been applied to analyse the EEG signals. EEG signal are the effect of the superimposition of diverse processes that takes place at a point of time in the brain. It uses the electrical activity of the neurons inside the brain.EEG signals are composed of alpha, beta, theta and gamma waves.

Fig 5:Signal Acquisition Technique::EEG

Table 1 Comparison Of Signal Acquisition Methodsused In Non-Invasive Bci Systems

Sl. No	Method	Signals Acquired	Advantage	Disadvantage
1	fMRI	Detection of blood flow to a particular region of brain-Metabolic Signal	*High spatial and temporal resolution	*Time delay in data acquisition *Higher Cost *Patient dis comfort
2	NIRS	Detection of blood flow to a particular region of brain-Metabolic Signal	*High spatial resolution *Lower Cost	*Low temporal resolution

3	MEG	Magnetic signals due to electrical currents	*Very high spatial and temporal resolution	*Expensive
4	EEG	Electrical signals measured using scalp electrode	*Easy and Affordable *High temporal resolution	*Low spatial resolution *Non stationary signal *Affected by artefacts

B. Emotion Quantification

Many researchers prefer the two dimensional plane for the classification of human emotions

1. Valence: Indicates the emotional direction of the emotion
2. Arousal: Indicates the level/amount of physical response and varies from being very excited to calm

Based on Valence and Arousal, emotions can be mapped varying from positive to negative emotions and High to Low Arousal.

Figure 6 Indicates the classification of various emotions on the Valence and Arousal two dimensional plane.

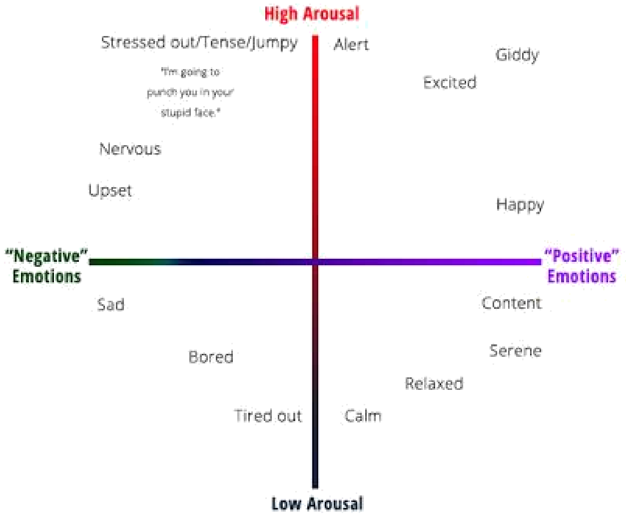

Fig 6: Valence Arousal Emotion depiction

The International Federation of Societies for Electroencephalography and Clinical Neurophysiology has recommended the 10-20 system of electrode placement depicted in the figure below. The name 10-20 indicates that the electrodes along the midline are placed 10, 20,20,20,20 and 10% of the total nasion and inion distance. The other electrodes are also placed at similar fractional distances of the corresponding reference distance. Every electrode detects the electric potential in the area of the brain produced due to neuronal activity. EEG signals are noisy and pose difficulties in signal processing and classification.

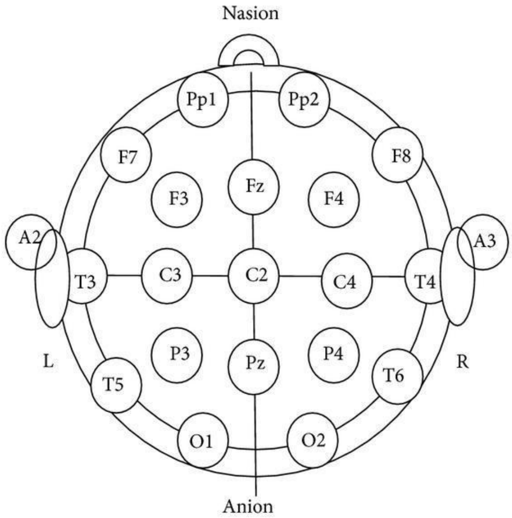

Fig 7: Standard Electrode Placement System

Earlier researchers concentrated on single electrode analysis. More recently, some researchers considered functional brain connectivity in emotion research and have started examining emotional specificity using EEG-based functional brain connectivity.

Researchers have shown that valence and arousal dominance can be seen in theta and gamma power using the standard 10-20 electrode placement system

Table 2 Valence-Arousal Dominance Level

Valence (+/−)	Theta power (ERD/ERS)	Anterior temporal region (left-hemisphere) Negative : left < right Positive: left > right Parietotemporal region Negative : left < right Positive: left < right
Arousal	Gamma power	Gamma power (46–65 Hz, 500 ms): arousing ↑

C. Signal Pre processing

Signal pre processing is very important as it removes any external disturbances and artifacts that may interfere with the EEG signals required for processing and feature extraction. Eye movement or eye blinking, any muscular activity, ECG and EMG are some of the common artifacts present in the recorded EEG signals. Basically, EEG signals are low amplitude signals with a very poor signal to noise ratio. There are various methods designed by biomedical researchers.

Various filtering techniques have been employed for the removal of artifacts. The frequency rangeof the artifiacts are usually undefined. Therefore the use of basic filters for artifact removal is insufficient. Researchers use Adaptive filtering techniques that adapts to the change in frequency by a change in the coefficients of the linear filter to generate a signal close to noise signal for cancellation.

D. Feature Extraction:

A feature is a distinctivemeasurement or component extracted from the signal. Feature extraction process, extract the essential features needed for the classification of emotions. Various feature extraction techniques like wavelet transformantion(WT), Primary component Analysis(PCA), Independent Component Analysis(ICA), Fast Fourier Transforms(FFT), Adaptive Auto Regressive parameters (AAR), Bilinear AAR, multivariate AAR, Kernel Density Estimation (KDE) are available.

1. ICA:

ICA is one of the most commonly feature extractiontechniques.ICA is a blind source separation technique (of knowing the source and channel characteristics), for the extraction of individual signals from mixture. It assumes that the different physical processes generate signals that are independent from each other. The observation signal is obtained by multiplying source signal with unknown mixing matrix. The aim of ICA will be to obtain un-mixing matrix so that original source signals can be reconstructed. It is not possible to determine energies(variance of the independent components using ICA and also the order of the independent components is undetermined

2. PCA:

PCA is a type of dimensional reduction orordination analysis technique for feature extraction. Ordination analysis attempts to embed objects distributed
In high dimensional space into lower dimensional space. In PCA, dimensional reduction is achieved by projection to lower dimensional space using linear transformation. Although PCA is a simple and classical method, it can often effectively reduce redundant information. PCA assumes that the data is linear and continous.

3. WT:

Since the EEG is non-stationary it is befitting touse the time–frequency domain methods. Wavelet transforms is one of those methods. It does not impose the pseudo-stationary assumption on the data like the time- and frequency-domain methods. WT can be used to analyse the signal in both time and frequency domain. Hence it is possible to Wavelet transform represents the time function in terms of wavelets. The transforms are a family of functions derived from a generating function called mother wavelet using translation and dilation operations. Wavelet transform has an advantage of varying window size, being broad at low frequency and narrow at high frequency. In WT, long time windows are accustomed get a finer low frequency resolution and short time windows are accustomed get high frequency data. Thus, WT gives precise data at high frequencies. This makes the WT suitable to get frequency data at low frequencies and precise time for the analysis of irregular knowledge patterns, such as impulses occurring at various time instances. WT uses multi scale structure[5].

A. CWT:

A continuous wavelet transform (CWT) isemployed to divide a continuous time function into wavelets. Unlike Fourier transform, the continuous wavelet transform acquires the power to construct a time frequency representation of a signal that gives excellent time frequency localization.

However, its major weakness is that scaling parameter and translation parameter of CWT change continuously. Thus, the coefficients of the wavelet for all available scales after calculation will consume a lot of effort and yield a lot of unused information

B. DWT:

The disadvantages of CWT is overcome using discrete wavelet transform (DWT) DWT works on the principle of multi scale feature representation.. The multi resolution decomposition of the raw EEG data x(n) is shown in Figure 3. Each step contains two digital filters g(n) and h(n) and two down samplers. The discrete mother wavelet g(n) is high pass in nature, while its mirror image ,h(n)is is low-pass.

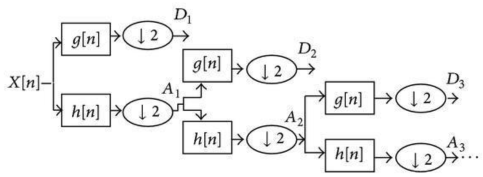

Fig 8 :Discrete wavelet transform

4. AR:

Autoregressive (AR) methods estimate the powerspectrum density (PSD) of the EEG using a parametric approach. Therefore, AR methods do not have problem of spectral leakage and thus yield better frequency resolution unlike nonparametric approach. Estimation of PSD is achieved by calculating the coefficients, that is, the parameters of the linear system under consideration. AR is not applicable to non- stationary data

5. KDE

Kernel density estimation is a feature extractiontechnique to extract signals by computing density estimate using kernel smoothing function

3. CONCLUSION

The paper gives a clear review of the different signal acquisition and feature extraction techniques employed in the detecton of human emotions. A brief review of the valence and arousal dominace level for different emotions is also specified. Researches are going on to improve the efficiency and accuracy in determinig the different emotional states of humans using functional brain connectivity

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