# PREPROCESSING OF EEG SIGNALS FOR ESTIMATING STATE OF MIND

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**Abstract—In biomedical Engineering it is been seen that the human brain waves are studied for finding out the current situation of brain. The brain activity is used to estimate whether the subject is in pleasure or stress. The aim of this study is to analyze brain activity. Brainwaves is divided into 5 sub frequency bands namely alpha, beta, gamma, theta and delta. To estimate the status of brain the dataset used here is Neuro Marketing where 25 subjects are used. This dataset is used to even find the EEG rhythms in association with normal active or patient is Anesthetized. The similar attempt has been done here to estimate the brain activity on the basis of power spectrum analysis. For this, the modified approach involving both Independent Component Analysis (ICA) and Principal Component Analysis (PCA) methodologies has been used in this report to investigate the behavior of brains electrical activity for a simple case of visual attention. The proposed method of EEG classification can be very useful in predicting the action or the intention of brain performed on the basis of EEG which leads to more development in brain computer interface.**

**Keywords— EEG, ICA, PCA, Power spectrum**

## I. INTRODUCTION

Electrical recordings collected from the scalp of the brain or even from the outer surface of the head shows that there is continuous electrical activity in the brain. Both the intensity and the patterns of this electrical activity are determined by the level of excitation of different parts of the brain resulting from sleep, wakefulness, or brain diseases such as epilepsy or even psychoses. The undulations in the recorded electrical potentials are called brain waves, and the entire record is called an EEG [1]. The intensities of brain waves recorded from the surface of the scalp range from 0 to 200 microvolts, and their frequencies range from once every few seconds to 50 or more per second. The character of the waves is dependent on the degree of activity in respective parts of the cerebral cortex, and the waves change markedly between the states of wakefulness and sleep and coma. Much of the time, the brain waves are irregular, and no specific pattern can be discerned in the EEG [1].

There are mainly five types of Brain waves as shown in Fig 1: Delta waves(0.4-4 Hz) which occurs in sleeping adults, premature babies or if there is any sub cortical lesions and is found in the frontal region of brain in adults and posterior region in children , Theta waves (4-8 Hz) which occurs in children, in adults when they are in emotional stress or they have deep midline disorders and is found in parietal and occipital region, Alpha waves (8-13 Hz) which occurs in quiet resting state but not sleep and is found in the occipital region, Beta waves(13-30 Hz) which occurs in active ,busy, active concentration or anxious thinking state and is found in the frontal and parietal region and Gamma waves (26-100 Hz) and occurs in certain cognitive or motor functions [2-3].

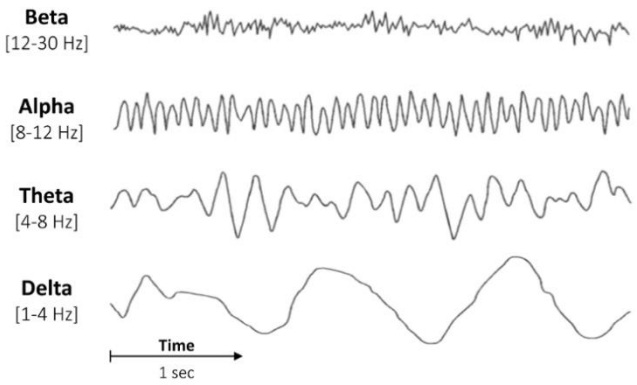


Fig.1. Brain waves

To perform these various actions, artificial neural network techniques are used. Power spectrum analysis [4] of EEG signals finds out the minor change in alertness or movement of body. Even Test of Variables of Attention (TOVA) is performed with power estimation like Principal Component Analysis (PCA)[5]. The minute stress of a human being is also studied using Power spectrum analysis. In this paper with help of NeuroMarketing Data which is available on web [6], this EEG signal has been given to filter to remove unwanted signals and the second stage was removal of artifacts manually. Hence after preprocessing of the signal Independent Component Analysis (ICA) is also being performed to separate out the components. Once the components are separated out, they are converted in single component by Principal Component Analysis (PCA). These separated the EEG signal into various frequencies like Delta,



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Alpha, Beta and Theta frequency bands which has a unique identity of respective brain wave.

## II. Experimentation

The complete experimentation has the following steps which are shown in Figure 2. This starts with EEG signal filtering where artifacts are removed [7]. Initial power spectrum is created of each channel and then Independent Component Analysis and Principal Component Analysis were applied on to the signal wherein the final power spectrum with different frequency bands were generated [8]

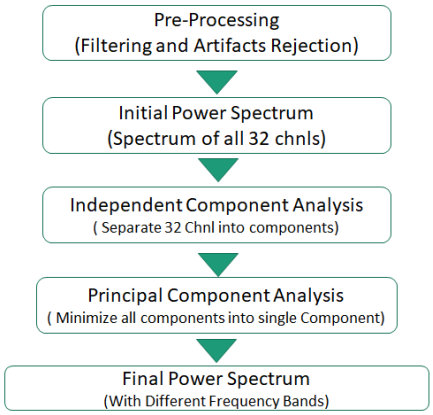



Fig 2: Various steps involved in Experimentation

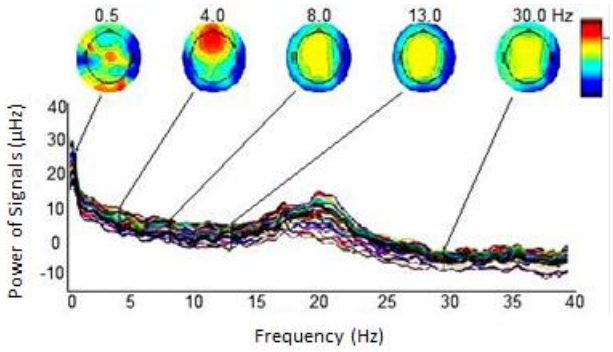
### *A. Preprocessing of EEG signals*

The recorded EEG signals are applied to the FIR Filter of second order. Simultaneously notch filter is also used to remove unwanted interferences in the spectrum. The disturbances created in the dataset are nothing but the artifacts created due to blinking of eyes or muscle movement or poor conductivity of electrodes. These artifacts are clearly seen in time domain of the signal and hence portion of the data is removed manually due to existence of these artifacts in all the components.

### *B. Initial Power Spectrum Study*

The next stage is of observing the initial power spectrum of all the generated waves as shown in Figure .3, where the various frequencies are distributed with signal power. It is clearly observed that power spectrum of these signals are overlapped and hence little difficult to find detailed delta, alpha, beta etc. signals. Hence these signals are to be undergone through Independent Component Analysis (ICA) to get individual components of each signal.

There are various channels while examining EEG signals. The brain status and the establishment locations are observe red and gathered during the complete process.




- *Independent Component Analysis (ICA)*

Mostly for EEG processing Fourier analysis and wavelet transform are widely used methods. They have the feature of its strong randomness and non-stationary nature, hence used for pre-processing but for prediction of inter-dependence of data of various channels these two methods are not strongly recommended.

Hence ICA is proposed for statistical signal processing and even can appropriately separate the statistically independent signals from the acquired channel. Also, it is used to improve variations in EEG signals[9-10]. ICA works in following method:

1. Assume there are N number of observed signals *Xi*, where *i=1,….,N*, from *N* number of electrodes.
2. Every signal is a combination of Linear mixture with N independent Signals sources *Si.*
3. Then *X*= , where *X=[x1, ..., xN]T* is observed signal vector.

   Where S=*[s1, ..., SN]T* is source signal vector and *A* is an unknown *NxN* mixing matrix.
4. Hence it is expected that source signal S is been separated from signal vector X.
5. But as Independent source S and Mixing Matrix A both are unknown, we need to have a proper algorithm for solving problem of blind source separation (BSS).

It is seen that there are many theories and various algorithms used for ICA to estimate the separation matrix W ,so as to separate the multichannel signals successfully ,as *S= WX*

Hence Independent Component Analysis (ICA) decomposes the input data using either logistic infomax ICA algorithm with the natural gradient feature or optionally the extended-ICA algorithm [11] with sign estimation *N* training blocks. If *N*=0, automatically estimate the number of sub-Gaussian sources, use single training block (*N=1*). The extended ICA has been followed here for input data decomposition.

- *Principal Component Analysis (PCA)*

The Principal Component Analysis (PCA) is a data analysis method in which the linear features are extracted very accurately. Even data compression and dimension reduction are done very accurately where in it may be also used for



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background noise reduction. This method follows the second order statistical computation where it finds the linear transformation $V = Wu$ such that the retained variance is maximized [12]. It can even reduce the reconstruction error by using as linear transformation. The row vectors of $W$ correspond to the normalized orthogonal eigenvectors of the data covariance matrix. PCA can be used as singular value decomposition (SVD) also.

PCA works in following method[13-14]:

1.The data covariance matrix is represented as $Ru= E\{uu'\}$.

*2.* Then the SVD of *Ru* gives Ru= UuDuU′u

Where *Uu* is the eigenvector matrix (i.e., modal matrix) and *Du* is the diagonal matrix whose diagonal elements correspond to the eigen values of *Ru*.

3.Then the linear transformation W for PCA is dominant given by $W = U'u$ .

For dimensionality reduction, one can choose p column vectors in *Uu* that are eigenvectors that have the largest eigen dimensions.

Here in PCA 32 components are now reduced to single value to construct a linear transform *W*. Conversion of all components into single component is done with PCA to reduce component. This single component gives more accurate reading of Activity Power Spectrum corresponding to different frequencies.

***C.Analysing frequency bands with power spectrum analysis:***

The various frequency classes like Alpha ranges from 8-13 Hz, Beta ranges from 14-30 Hz, Theta ranges from 4-7 Hz and finally Delta of 0.5-3 Hz ,to segregate them we use FIR digital bandpass filters. Once filtered out the power spectrum of each signal is analysed on various frequency bands. The low frequency and high amplitude EEG signals are generated at the time of sleep or in relaxed state of healthy person, while the high frequency and lower amplitude EEG signals are generated in awake and working state of person. This could be resulted in finding out how alert is the subject is during the complete recording.

## III. Results and Discussion

In this study, the EEG dataset known as NeuroMarketing is used in which 25 subjects, 14 electrodes are used and their Like/Dislike on commercial e-commerce products over 14 categories with 3 images each is examined. This is particularly knowing consumer preference for decision making and behavior prediction for effective utilization of a product using unconscious processes is called “Neuromarketing”.

Above specified data after processing gives following results shows in Figure 4 with various subjects.

- Average Power Spectrum Density of each wave is noted in Hz
- Sample of few subjects are jotted down in the table.
- Deep Sleep, Light Sleep, Awake in Focused state and Awake in relaxed state are categorized.

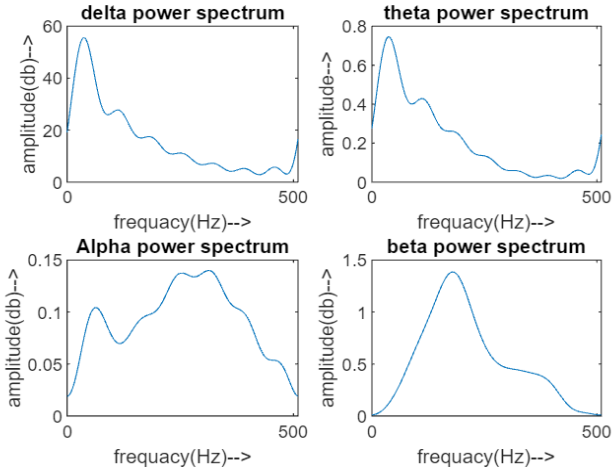


Fig 4. Result of Power spectrum of various frequencies of one subject.

From the results above it is seen that maximum signal power is up to 50 db and minimum power in db is 0 to 5 db. Various signals of delta, alpha ,beta and theta ,each consists of various maximum and minimum power designated in amplitude where in each feature explains its characterization

## IV. Conclusion

From the complete study in this paper, we conclude that any EEG signal can be studied by knowing its frequency range known as delta, alpha, beta and theta. This can categorize whether the subject or human being is in which state of mind. For this purpose, we have used dataset of Neuromarketing where the EEG signals of volunteers with varying age and gender were recorded while they browsed through various consumer products, 25 subjects, 42 trails each, 14 electrodes, Like/Dislike on commercial e-commerce products over 14 categories with 3 images each. Using Neuromarketing Dataset we could find out the Power spectrum Density of EEG signal and could differentiate Alpha, Beta, Theta and Delta signals. From this study of power spectrum, we concluded that the power in in each of subject available in the dataset. Deep Sleep, Light Sleep, Awake in Focused state and Awake in relaxed state are categorized for knowing the state of mind of a human being.

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