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Brain wave processing methods- A study

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Abstract--- *A method where human brain and a computer interact is called Brain computer interfacing. It allows communication between human brain and computer. They collect signals from the brain and observe them and interpret into instructions which are transferred to output machines to carry out a targeted action. Success of processing brain waves depends completely on the proper choice of processing methodology. This paper briefs the easiest and most efficient methods of signal processing which helps to analyze the various components of a brain computer system.*

Keywords- *Brain computer interfacing, signals, processing, analyze, system.*

I.INTRODUCTION

Brain computer interfacing system determines and measures the characteristics of human brain waves in order to meet the end users objective. It helps in delivering the brain's messages to the outside world. Depending upon the penetration capacity, there are two types of brain computer interface systems: Invasive BCI systems and non invasive BCI systems. Indians prefer non invasive BCI system since it causes no pain and it is cost effective. To analyze a BCI system, four steps are needed to be carried out which are as follows: signal collection, taking out useful features, change of features and the device output. BCI system is shown in Figure 1. Electrodes which are placed on the human scalp help in recording the brain waves.

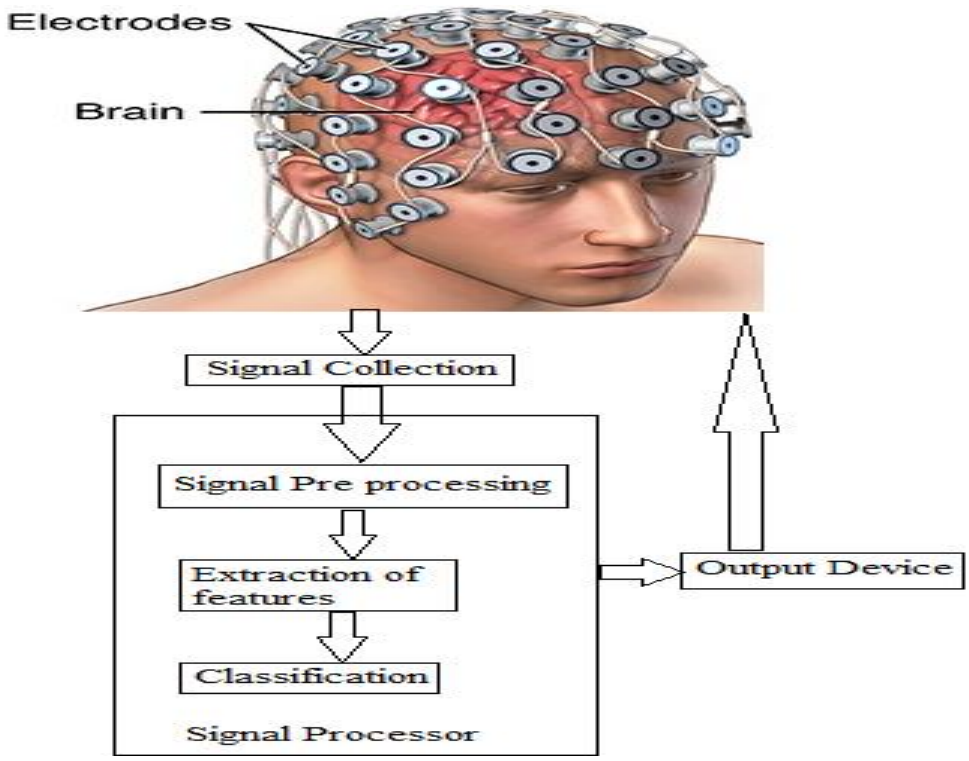

Figure 1. BCI System

II. SIGNAL ACQUISITION

Signal acquisition means measuring of waves from the brain with the help of electrodes placed on human scalp. Brain signals can be collected or measured by various methods such as Electroencephalography, magnetic resonance imaging, magneto-encephalography and computed tomography, positron emission tomography NIS etc. After the collection of brain signals they are modulated to levels which are useful for fruitful signal processing. Certain filters can be used to remove the unwanted signal features, followed by digitalizing the signal and transmitting to an output device preferably a computer. Signal acquisition is a non invasive process. Signal acquisition is the first stage of a BCI system where the excitation selected is by the use of electrodes, following by amplification stage and digitalization step.

Electroencephalography is a non penetrative technique. It won't have a sensation of hurt. The electrodes are placed on human scalp. This method promises high security and safety to the patients. It is an imaging approach. EEG records the electrical activity in the human brain. EEG can observe minute details of the neurons at very small time periods with very large resolutions. This is a non penetrative method. This recording is only for a small time period which maximum exceeds up to 40 minutes. Changes can be detected in a millisecond level. This method promises high temporal resolution. But this method is sensitive to eye movements, heartbeats etc.

Functional Magnetic Resonance Imaging also called as blood oxygen level dependent imaging is a technique which identifies or observes the level changes of oxygen in blood and flow of blood due to the motion of neurons. The signal collection from the human brain takes around 40 milliseconds and resolution is about 1*1mm, means high spatial and temporal resolution is guaranteed by this method. It is sensitive to the movement of head. It is price inefficient. It indicates the oxygen use in various parts of human brain. This method of scan doesn't require any injection before scanning process.

Magneto-encephalography helps in measuring the magnetic signals produced by the neurons electrical actions inside the brain. It makes use of devices such as squids. It provides high temporal decision. It is cost ineffective machines. It is not dependent on head geometry. It makes use of no radiation compared to other techniques. It is sensitive to actions happening inside brain. It is affected by actions in the cortical region of the brain.Near infrared spectroscopy is a technique which makes use of light to calculate the oxygen level in blood. It uses 700nm-2500nm in the electromagnetic spectrum. It is a circuitous method. It is cost efficient but have low resolution and performance.

Computed Tomography is based on differential absorption which makes use of X rays and has low resolution. It discloses massive characteristics. It removes the overlapping of images. It provides high contrast resolution of pictures. It uses medium to high radiation. In positron emission tomography, blood pour to various parts of human brain is being measured. 3D images are produced. In Electro-corticography, electrode is kept in outer part of brain. To calculate the potentials within the gray matter of human brain, Intra-cortical Neuron Recording is used. Table. 1 shows the various signal acquisition methods.

Table 1: Signal Acquisition Methods

Method of signal Acquisition	Advantages	Drawbacks	Nature of Activity measured/type
Magneto-encephalography	High resolution. Large range of frequency. Not dependent on head geometry.	Easily affected by actions in cortical region. Makes use of no radiation. Cost ineffective.	Magnetic/Direct
Functional Magnetic Resonance Imaging	High resolution.	Sensitive to head movement. Cost ineffective. Requires no injection before scan.	Metabolic/Indirect
Electroencephalography	High temporal resolution. Safe technique.	Requires a lot of time to collect signals. Affected by eye movements, heartbeats. Low spatial resolution.	Electrical/Direct
Near infrared spectroscopy	Cost effective and movable. Guaranteed spatial resolution.	Poor temporal resolution and show.	Metabolic/Indirect
Positron emission tomography	Non penetrative technique	Real time control is very poor, cost is high	Metabolic/Indirect
Electrocorticography	Real time controllable, stable	Expensive	Electrical/Direct
Intracortical Neuron Recording	Stable, compact	Expensive	Electrical/Direct

III. SIGNAL ENHANCEMENT

After signal collection, processing of signals should be carried out. This is called as signal enhancement. During the signal collection from brain, they are affected by various disturbances which weaken the signal characteristics. The disturbances caused by our eyes will lead to signal distortion. Moreover the heart beat and the muscle movements also have a significant contribution to the signal artefacts. Some ways to eliminate these distortions are described below. This feature extraction is done after the digitalization of signals which is done for analysis of spectral lines, filtering, neuron division etc. This is done in order to code the end user orders.

ICA sorts the artefacts independently. It does not depend upon any location base channels. Information carried by each channel is conserved during the exclusion of noise. This method is highly competent also when the information is too massive. It splits the brain waves into self sufficient temporal components rigid spatial components. The steps required to crumble signals is high in ICA technique.

CAR reduces electrode mean from all the electrodes which give noise free signals. CAR offers low signal to noise ratio. For progress of SNR, various referencing methods can be used. Signal categorization can be best achieved with CAR. Due to the improper electrode positioning in the scalp leads to inappropriate electrode distribution which leads to missing some areas in head. Surface Laplacian is measured by calculating the density of incoming and outgoing current density

through the scalp. It takes in to account outer shape of conductor volume only. Removal of artefacts considers the shape of artefacts. It offers very high spacial resolution.

Principal component analysis converts associated vectors into non linked vectors, also known by principal components. Independent component analysis can yield better results than this method. It thus ensures a drop in the size of feature characteristics. Information sorting is best supported by this method which is calculated on the basis of unevenness of signal characteristics.

CSP converts the signal from brain into variance matrix. This method won't depend upon the patient precise frequency. The place where the electrodes are kept and various artefacts affect this method. It detects unusual variations in the EEG. Positional change of electrodes leads to artefacts.

Adaptive filtering can alter the signal characteristics according to the need of observation. This method uses least mean square algorithm to remove the noise without removing the important and useful signal characteristics. Recursive least squares algorithm also helps in removal of artefacts. Table II shows the cons and drawbacks of signal enhancement using various methods.

Table II : Signal Enhancement Methods

Method of signal enhancement	Advantage	Drawback
Principal component analysis	Good in decreasing Feature size, good at information sorting	NOT good as ICA
Independent component analysis	Efficient calculation, very good end results	Not appropriate for levels below unwavering conditions. No of steps for calculation is more, hence time consuming.
Common average referencing	Best method, High signal to noise ratio	Inappropriate electrode distribution leads to false values
Surface Laplacian	No electrode position issues	Affected by artefacts
Common special patterns	Does not depend on patient precise frequency	Position change of electrodes lead to artefacts. No of electrodes used is high.
Adaptive filtering	Can alter signal characteristics according to the need of observation. Efficient for signals with overlapping	

IV. FEATURE EXTRACTION

Drawing out the useful signal information after removing noise in the signal enhancement method is called as feature extraction. This should match with the patient's objective.

ICA and PCA are also feature extraction methods. PCA decreases the information size without the loss of useful signal information. Formation of principal components and removal of disturbances helps in size decrement of signals. Blind source separation recognizes free signals components from uncorrelated data.

Wavelet transforms uses B-spline parameter. Here the low and high pass filters are being used. Multi-resolution helps in determining coefficients of filters.

Conversion of signals from time to frequency domain is done in Fourier transform method which helps in signal characteristics extraction. It cannot determine time as well as frequency. Here signals are split into 1 sec windows merging a half sec window. The latter merge gives huge information for classifier preparation. This is known as discrete frequency transform, power spectral density. Time domain analysis can be done by AR method. Spectral deficient problem does not occur in this method. For good frequency resolution, small period of information is used. For signals with motion, this method best suits.

Signal removal in frequency and time domain can be done by WPD also. Fisher's criteria are used for calculating the distinguishable features. Concluding vector is produced from coefficients with large independency. The initial signal will be separated into two based on frequency. It gives better performance in comparison with AR model especially with signals with motion. Table III shows the various feature extraction methods in a BCI system.

Table III: Feature Extraction Methods in a BCI System.

Method of Feature Extraction	Advantages	Drawbacks
Principal component analysis & Independent component analysis	PCA decreases size of information without the loss of useful data's. ICA gives good results for bulk data's.	PCA is not suitable for difficult data's. ICA requires more steps.
Wavelet transform	Can examine in frequency & time domain, irregular signals	Restricted performance.
Wavelet packet decomposition	Can observe signals with motion.	Computational steps taken are high.
Auto regressive	Need small length of information for analyzing.	Can't observe motionless signals.
Fast Fourier transform	Dominant method.	Can observe motionless signals only, affected by noise.

V. SIGNAL CLASSIFICATION

Here signals are classified using classifiers. Linear and non linear classifiers are used for classification purpose. Linear functions are employed in linear classifiers.

Support vector machine uses structural risk minimization method. It uses hyper-plane to sort information. Large space is left in between information for clarity which later helps in classification. Large space is maintained between hyper-plane and hold vectors. This method is computationally complex and offers a good performance. Linear discriminant analysis can be

easily used and requires small number of steps for calculation. Better performance is guaranteed by this method. In this method the inequitable function should always be expressed in its mean, otherwise it gives inappropriate results.

Artificial neural networks are a type of non linear classification which is composed of tiny basic elements known as neurons. It is capable of handling easy tasks. Multi layer perceptron networks has three basic layers which are named by input, output and the middle layer is called as the hidden layer. It is simple to execute and executes very fast. The response is the classes and excitation is the number of chosen features. However the number of neurons in the middle layer decides the computational complexity of this method. Higher the number, more will be the complexity and lesser the number, more will be the mistakes in classification. Trial and error basis is used for calculation of neurons in this layer.

NBC eliminates unsure and vague data's. Vector class having peak probability are allotted with a feature vector. For classification of time, Bayesian classifier is used. It is known to be an active classifier. Based on nearby vectors, NNC allots a feature vector. Training set feature vectors are known as k-NN classifier. It is not a parametric technique. Table IV shows the most commonly used signal classification methods.

Table IV : Signal Classification Methods.

Method of signal classification	Advantage	Drawback
Linear discriminant analysis	Less no. of steps required, easily used, guarantees good output.	Function should be expressed in its mean.
Support vector machine	Good output	More complex
Artificial neural network	Easily used, easy steps.	Neuron no plays an important role
Non linear Bayesian classifier	Small data is needed, need to calculate variance only.	Vague calculation
Nearest neighbor classifier	Easily known, build.	Susceptible to various features.

VI. CONCLUSION

This paper shows the various methods of signal processing techniques used in a BCI system. This paper allows the researchers to pick the most appropriate technique for signal processing. Various stages of a BCI system have been described elaborately so that it easily helps to choose the efficient method for processing signals. Execution of these stages in a fusion way is an ongoing process.

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