Application of Signal Processing in Brain Computer Interface

Abhishek Aravind Deshpande
Dept. of Electronics and Communication
B.V.B college of Engineering and
TechnologyVidyanagar, Hubli-India

ABSTRACT
Brain Computer Interface is a technology which helps us to interface human brain with the computer. The signal processing concepts play an important role in dealing with the raw brain signals. Recent trends in signal processing such as proximal splitting and Hilbert spacing method can be used to address some of the problems in the field of BCI. The field of Brain Computer Interface research and development has since focused primarily on neuroprosthetics applications that aim at restoring damaged sight, hearing and movement. The brain normally produces tiny electrical signals that come from the brain cells and nerves which communicate with each other. With the help of electroencephalograph (EEG) machine, these electrical signals can be detected and recorded. Electroencephalograph (EEG) is the recording of brain activity. It measures the voltage fluctuations due to ionic current flows within the neurons of the brain. In clinical terms, EEG refers to the recording of the brain's electrical activity over a short period of time, usually 30–40 minutes as recorded from multiple electrodes placed on scalp. Diagnostic applications mostly focus on the spectral content of EEG, the type of neural oscillations that can be observed in EEG signals.

Keywords
Electro-Encephalograph (EEG), Brain Computer Interface (BCI), MND (Motor Neuron Disease).

1. INTRODUCTION
The BCI is an interfacing technique which helps in communicating human brain with the computer. The applications of BCI will be helpful to the people who are completely bedridden and have no muscular movements. But these classes of people have functional brain. This important analysis helps in choosing Brain Computer Interface as the suitable solution. The Brain Computer Interface offers an alternative, a natural way of communication and control. The central idea behind working in the field of the BCI arises from the basic functionality of the brain. Whenever a person thinks, some neurons get excited and thus take care of transferring the electric impulses. The strength of the signals generated is very low, usually in terms of micro-volts. So in order to measure these signals the NeuroSky Company has developed sensor for getting the EEG data. The research shows that, different set of neurons get excited for different thinking process [9]. Whenever the changes are observed in the pattern of the signal, the machine will learn about the change and keeps it for further reference Thus Machine learning along with the Signal processing methods suits to these fields [10]. The human brain is complex the analysis of the Brain signals becomes very tedious job. All the signals which are captured from the brain are called raw data. The BCI revolves around the revealing the information about the thinking process of the person. There are many ways in which the brain signals can be sensed. Depending on the position of the sensor placed they are categorized into Invasive BCI, Non Invasive BCI and Partially Invasive BCI [5].

Non invasive –In this method, the signals are obtained by making use of electrodes which are placed externally by making use of jacket like structure

- EEG-Electro Encephalography
- MEG-Magnetic Encephalography
- fMRI -Function Magnetic resonance Imaging

Invasive-In this method, the signals are tapped by placing the electrode inside the gray matter of the brain

- Neurosurgery is done to place the electrode

Partially Invasive-In this method the electrodes are placed in between the skull and the grey matter

- EcoG – Electrocorticography.

The translation of thinking process in to the decisions is made by using Machine learning concepts, digital signal processing and pattern recognition [4], which is done by a computer. The machine learning algorithms helps in learning of the data set, extracting the features and finally taking the decisions [10]. The BCI will be gift for the people who are unable to express their feelings and patients who are suffering from the MND. The signal processing is very much required in understanding the behavior of the signals. The signals which encounters in BCI are mainly random signals. Thus it becomes very important to make use of probabilistic approach while solving. As the brain activity originates from the brain and not from the peripheral systems or muscles, the system is called as Brain–Computer Interface [1].

The EEG device is single-channel Mind Wave sensor by Neurosky Inc., San Jose, CA. It cost only around $80. The device has of eight parts namely, ear clip, flexible ear arm, battery area, power switch, adjustable head band, sensor tip, sensor arm and think gear chipset [7]. The operation of this sensor is as follows. Two dry sensors are used to detect and filter the EEG signals. The sensor tip detects EEG signals from the forehead of the brain. On the other hand, the sensor also measures noise generated by human eye, human muscle, computers, bulbs, and other electrical devices. The second important part of the device, sensor, ear clip, provides grounds and reference, which allows think gear chip to filter out the electrical noise .In addition to this the device also measures the raw signal, power spectrum(alpha, beta, delta, gamma, theta), attention level, mediation level and blink detection. The raw EEG data receive data rate of 512 Hz (data rate may vary).Other measured values are made every second. Therefore, raw EEG data is a main source of data on EEG signals. The think gear technology provides control over

Connection of wireless dongle with sensor [6].

2. BRAIN COMPUTER INTERFACE SYSTEM

The Brain computer interface system involves four main units [8].

- EEG Data Acquisition unit.
- EEG Signal Pre-processing unit.
- EEG Feature extraction unit
- EEG Classifier unit

2.1 EEG Data Acquisition unit

EEG Data Acquisition includes the following tasks

- Recording data from the brain.
- Doing some low level filtering.
- Passing the data on to be interpreted.

The sample data signal taken from the human brain looks like as shown in the figure below. As the time domain analysis is difficult, the use of frequency domain approaches are used to get the necessary information about the thinking process. The sensor which gives the brain signals along with the data acquisition system decides the sampling rate of the brain data. The sample signal shown below has the sampling rate of 128 samples per sec. During recording of brain signals the patient will be asked to think of let's say left. In this stage the training process begins.

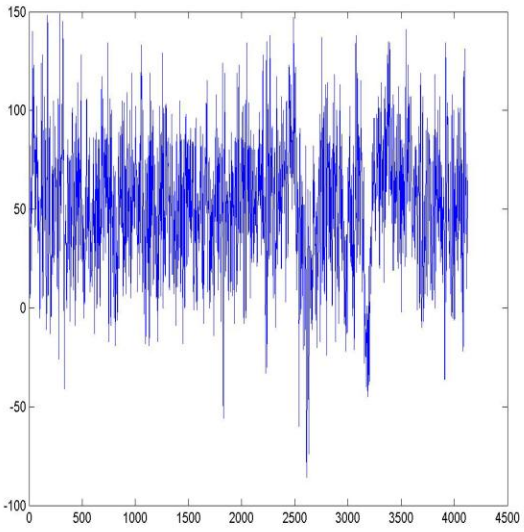

Fig 1: EEG signal

2.2 EEG Signal Pre-processing unit.

Signal Pre-processing helps in simplifying subsequent processing operations without losing important information; it uses filters and methods including proximal splitting. The use of Wavelet transform and Hilbert Huang Transform (HHT) [3] contribute mainly in the feature extraction. Wavelet Transform is a widely-used technology in time and frequency domain analysis [4]. It is a multi frequency analyzing method because it can use different resolution rate for high frequency signals and low frequency signals. During the process of recording stage the user may shake his hands legs blinks his eyes, all these effects collectively called as Artefacts. These Artefacts can be removed with the help of the filtering Usually the frequency bands which are required for analysing person thought lies in the range of 12-60 Hz. So the job here is to extract these frequencies and decode them using various signal processing methods.

Signal processing techniques suitably find applications in the Extraction of the wanted signals from unwanted signals. Here the table below demonstrates the use frequencies range for different brain activity. The Matlab environment provides all the necessary algorithms to implement.

Fourier analysis is mainly used while extracting the features from the signal and can be given by the equation.

Fourier's Theorem states that any periodic function of time, f (t), (i.e. a periodic signal) can be expressed as a Fourier series consisting of:

- A DC component – the average value of f (t).
- A component at a fundamental frequency and harmonically related components, collectively the AC components.

i.e. f (t) = DC + AC components.

$$f(t) = a_0 + \sum_{n=1}^{\infty} \{a_n \cos n\omega t + b_n \sin n\omega t\} \quad (1)$$

a0, an and bn are coefficients given by:

$$a_0 = \frac{1}{T} \int_{-\frac{T}{2}}^{+\frac{T}{2}} f(t)dt \quad (2)$$ Which gives the average value or DC component?

$$a_n = \frac{2}{T} \int_{-\frac{T}{2}}^{+\frac{T}{2}} f(t) \cos n\omega t dt \,, \quad (3)$$

$$b_n = \frac{2}{T} \int_{-\frac{T}{2}}^{+\frac{T}{2}} f(t) \sin n\omega t dt \quad (4).$$

Table 1. Table below demonstrating the frequency ranges

Brain Wave Type	Frequency range	Mental states and conditions
Delta	0.1 to 3Hz	Deep dreamless sleep, non REM sleep, unconscious
Theta	4 to 7Hz	Intuitive , Recall , Fantasy, Imaginary ,dream

Alpha	8 to 12Hz	Relaxed ,Tranquil, sleep, consciousness
Low Beta	12 to 15Hz	Formerly SMR, Relaxed yet focused, integrated
Medium Beta	16 to 20Hz	Thinking, aware of self and surroundings
High Beta	21 to 30Hz	Alertness, agitation

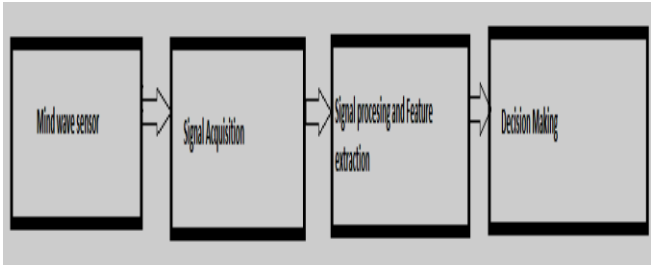

Fig 2: Typical BCI system

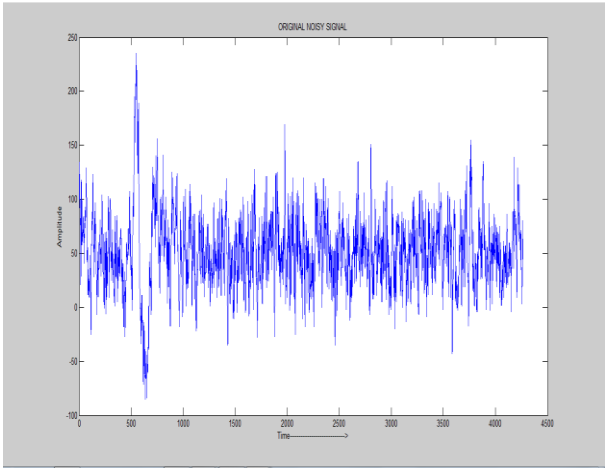

Fig 3: Original signal

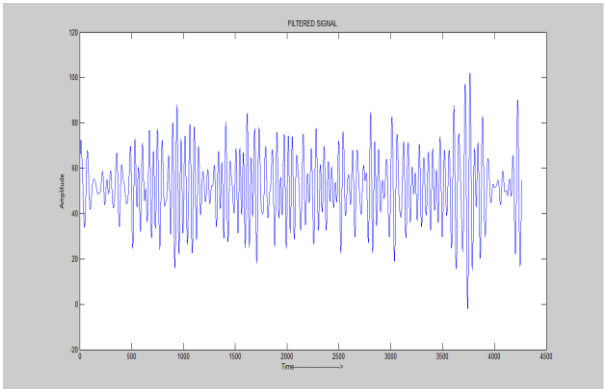

Fig 4: Filtered signal

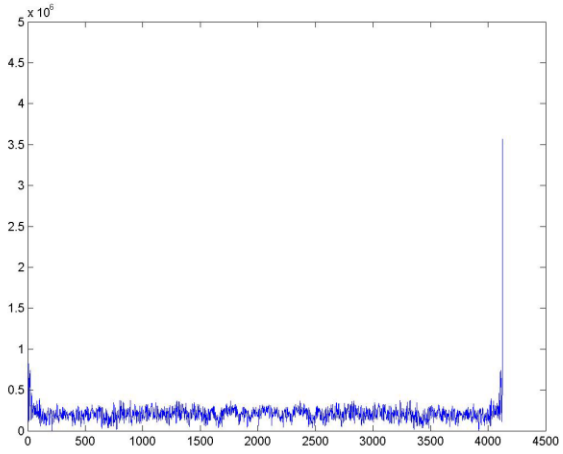

Fig 5: Fourier Transform of the sample signal.

2.3 EEG Feature extraction unit

The feature extraction algorithms in BCI extract the features. Feature extraction is another step in preparing the signals to facilitate the further processing [8]. This unit makes use of Fourier Transform algorithms [2] .The feature extraction is an important aspect of BCI .Basically features of the signal mean the statistical data, probabilistic data, geometric data. The selection of features is done based on the domain knowledge. More the no of the features give more accurate results. Some of the spectral properties can also be used as the features.

2.4 EEG Classifier unit

Certain selected features of the signal are then classified using Support vector machine (SVM), Neural Networks, multilayer preceptor (MLP) [2] method, etc.Classification can also be done by making use of the K means clustering method.

3. RESULTS

During data acquisition, the person is made to think. After training, feature extraction, clustering done in Matlab environment with digital signal processing algorithms, the plot for two different thoughts are as follows in the figure shown below. From the graph it can be observed that, if the patient is thinking left the main lobe shifts left. If the patient is thinking right, then the main lobe shifts right. In the similar manner the results can be achieved for front, back and stop thinking.

Out of 10 samples taken for left the method proposed above yields 9 samples correctly classifying as left .The same results are also obtained for the right. But for front and back samples the accuracy is about 70-80 percent.

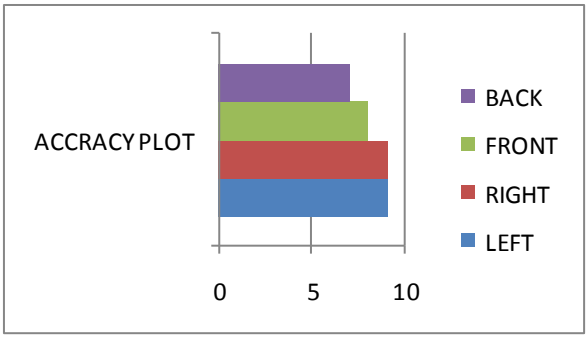

Fig 6:Experimental results plot.

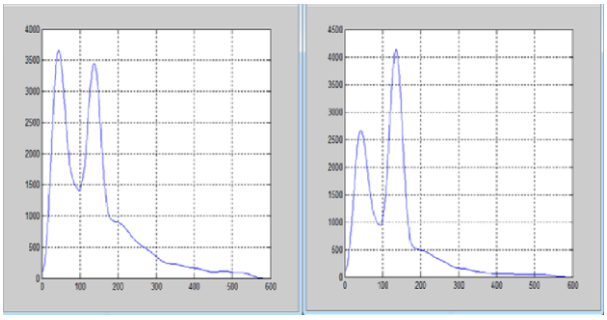

Fig 7: Graphs for Left and Right thinking.

4. CONCLUSION

Signal processing methods can be classed into four kinds: methods in time domain, methods in frequency domain, and methods in time-frequency domain and methods of nonlinear. EEG signal is time-variation and non-stationary, so the methods in time or frequency domain could not represent the features of EEG signal accurately. Wavelet Transform and HHT are both analysis methods in time-frequency domain. It is true that technology that has had a very prominent role to play in the field of medicine, but with the advent of BCI technology is has become a very useful invention to the people with severe neuromotory disorders, it helps them to express their emotions and helps them control certain things without requiring assistance

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] IEEE paper titled ' A New Scheme in EEG Signals Processing in Brain-Computer Interface Systems' by Andrzej majkowski, marcin kolodreij, Warsaw University of technology, Warsaw, Poland.

[2] 2010, 10th IEEE International Conference on Advanced Learning Technologies.By Katie Crowley, Aidan Sliney, Ian Pitt, Dave Murphy Department of Computer Science University College Cork Cork, Ireland

[3] Brain waves feature extraction using wavelet transform by DR. Abhishek Vaish ,Associate Professor Information Security Lab Indian Institute of Information Technology-Allahabad

[4] Application and Contrast in Brain-Computer Interface between Hilbert-Huang Transform and Wavelet Transform by Manling Huang, Pingdong Wu, Ying Liu, Luzheng Bi, and Hongwei.

[5] BRAIN COMPUTER INTERFACE AND ITS TYPES - A STUDYAnupama.H.S1 , N.K.Cauvery2 , Lingaraju.G.M3 1,2Department of Computer Sc. and Engineering, R. V. College of Engg., Bangalore, India 3 Department of Information Sc., M. S. Ramaiah Institute of Tech., Bangalore, India

[6] Brain Computer Interface System for Mind Controlled Robot using Bluetooth by Siliveru Ramesh, M.Gopi Krishna and Madhu Nakirekanti

[7] Processing and spectral analysis of the raw EEG signal from the Mind Wave by Wojciech SAŁABUN West Pomeranian University of Technology, Szczecin

[8] Kale Swapnil T, Mahajan Sadanand P, Rakshe Balu G, Prof. N.K.Bhandari "Robot Navigation control through EEG Based Signals" International Journal Of Engineering And Computer Science ISSN:2319-7242 Volume 3 Issue 3 March-2014 Page No. 5105-5108.

[9] Luzheng Bi, Xin-An Fan, Yili Liu "EEG-Based Braincontrolled Mobile Robots: A survey", Human-Machine Systems, IEEE Transactions on (Volume: 43, Issue: 2).

[10] Evolving Signal Processing for Brain–Computer Interfaces By Scott Makeig, Christian Kothe, Tim Mullen, Nima Bigdely-Shamlo, Zhilin Zhang, and Kenneth Kreutz-Delgado, Senior Member IEEE.