DETECTION OF ALTERATIONS IN CORTEX REGION DUE TO MOTOR IMAGERY

RANJITA DUTTA, PILLUTLA SOMA SUNDER, RAKESH KUMAR SINHA

Abstract: In this study, the Electroencephalogram (EEG) was examined to address the effect of motor imagination on the motor cortex region. It has already been established that the neuronal activity produced during motor imagination is same as the neuronal activity produced during real executed movement. ERD (Event Related Desynchronization) and ERS (Event Related Synchronization) give an indication about the activated and ideal condition of the cortical areas respectively. The EEG signals were acquired during left and right handmotor imagination from the subjects. Band Power and Entropy were selected as the major features from the EEG signals. The EEG signals were divided into sub frequency band of interest, which is alpha (α) band. Naive Bayes classifier has been used for classification of selected features for motor imagination task in the present study. Maximum classification accuracy (≥75%) was achieved with the EEG spectral features of maximum spectral coefficient, in the C3 and C4 channel in the alpha band. Considering the classification accuracy obtained by Naive Bayes classifier with Band Power and Entropy features in most of the EEG channels of motor cortex, it can be suggested that the non-invasive EEG signals can be used as a control signal and can be considered as a tool for incorporating these signals into the BCI system so that it can be used by the patients suffering from neuromuscular disability and can control an external device by their imagination thus revolutionizing the BCI system.

Keywords: Brain Computer Interface, Electroencephalography, Event Related Synchronization, Event Related Desynchronization.

Introduction:

Motor Imagination and BCI: Over the last couple of decades the evolution of a technology called Brain Computer Interface (BCI), has furnished a novel and promising alternative for communication with the surroundings. In BCI systems, messages or commands that a person wants to send to the external world don't pass through the brain's normal output channel of nerves and muscles. The BCI directly reads the patient's thought and translates it into signals that control the output devices [5].

Motor Imagination is a mental process by which a person mentally initiates a particular action. Motor imagination when incorporated with BCI is extremely beneficial for people having neuromuscular disabilities.BCI is responsible for producing a technology which can support the communication between the patients who are suffering from neuromuscular disabilities (such as last stage of amyotropic lateral sclerosis (ALS), cerebral palsy, stroke, or spinal cord injury and locked in syndrome) with a non-muscular device which can be used for gaining control. A Brain-Computer Interface (BCI) design helps its user to control external devices by patient's intent. In BCI system, EEG signals are recorded while performing a particular type of mental task. This is used as an input and provides selection of control using its output [8]. The gap between the communication channel present between the computer and brain is achievable by using changes in power spectra of EEG while movements are imagined. These variations in EEG can be recorded from Centro-parietal scalp areas [2].

In the present work, changes were observed in the Power Spectral Density (PSD) and Entropy obtained from the EEG which was extracted from the cerebral motor cortex. The brain signals were acquired using two bipolar electrodes. The electrode positions are C_3 and C_4. This electrode position is chosen because significant ERD due to motor imagination is found in these two electrode positions. These two electrode positions are mainly responsible for motor activities. Any physical activity, results in attenuation of amplitude known as Event Related Desynchronization (ERD). During rest condition, when no activity occurs, it results in enhancement of amplitude which is known as Event Related Synchronization (ERS). ERD can be observed when motor imagination starts and using this, left and right hand movement imagination can be discriminated. For EEG signals, features such as bandpower and entropy have been extracted using periodogram and other mathematical tools and classification has been done using Naive Bayes classifier for detecting changes in EEG due to motor imagination.

Research Methodology:

EEG Recording Procedure and Methodology: The study was carried out on a group of 5 male members whose age is below 35 years. Two channel EEG recordings were recorded using Biopac 100c system and Ag/AgCl scalp electrodes. All subjects were right handed. Two bipolar EEG channels (C_3 and C_4) were considered for evaluation of motor imagination. The subject sat in a relaxing chair with armrests. Then a cue appeared and the subject was asked to start imagining according to the cue which was displayed on the computer screen. The task was to control a

feedback bar by means of imagery left or right hand movements. The order of left or right cues was random. The EEG data was digitized at sampling rate of 200 Hz. 60 trials, 30 each for left and right imagination were recorded from each subject.

The EEG data was filtered using second order Butterworthband pass filter. It was seen that the noises could also be present due to interference of EMG signals i.e. the electrical activity caused by the muscles. Generally, the point of interest in the EEG data lies between 8-13 Hz. The data was thus filtered to extract the data of required bandwidth. C3 and C4 channels are mostly responsible for motor movements which explain the selection of the two channels for the present study. In this study we have used bandpower and entropy as features which have been extracted from the EEG signals. Classification is performed to detect the right and left side motor imagination. Naive Bayes has been used as a classifier in this study.

Paradigm:

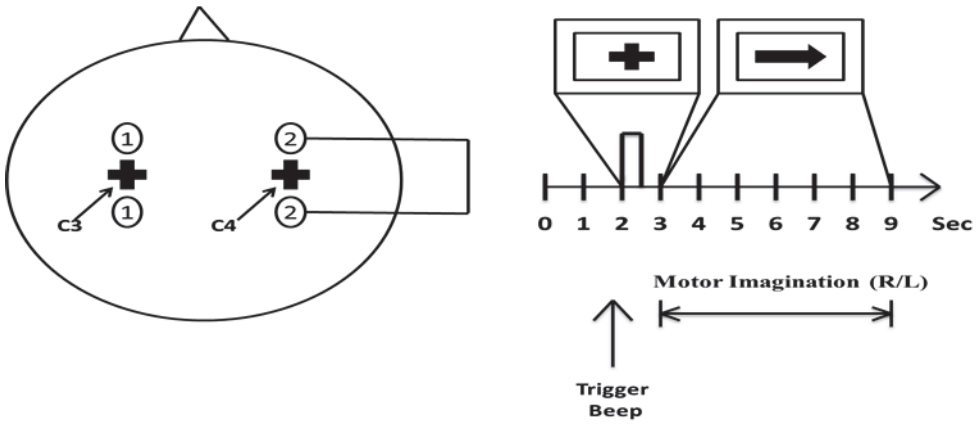

Fig 1: Paradigm used for the data recording

The paradigm has been designed for recording the data using two bipolar channels or electrodes i.e. C3 and C4. This paradigm is of 9 sec duration. The first two seconds are silent are silent and in the third second a cue appears which marks the starting of the motor imagination session then in the fourth second a arrow mark either towards left or right is showed in the computer screen according to which the patient has to imagine the movements according to the arrow displayed on the screen.

Power Spectral Density: In medicine, spectral density is used for extracting useful information from various signals which have been recorded from patient's body like EMG/EEG etc. for diagnostic purposes. Periodogram is dependent upon the PSD [1].

$$\boldsymbol{\phi_p(\omega)} = \frac{\mathbf{1}}{\boldsymbol{N}}\left|\sum_{t=1}^{N} \boldsymbol{y(t)e^{-i\omega t}}\right|^2 \qquad \textbf{(1)}$$

Periodogram is used to determine the hidden periodicities which are possible in the time series. For narrow bands, power is calculated as:

$$\mathbf{E_B(X)} = \sum_{\mathbf{f\in B}} \mathbf{|X(f)|^2} \qquad \textbf{(2)}$$

Entropy: Disturbance or randomness of a signal is denoted by entropy. Entropy is the uncertainty or the unpredictability of the information content. Difference in entropy is used to differentiate or separate two classes of EEG patterns [3]. One of the major problems in feature extraction of EEG is that the EEG signal is non-stationary, complex, non-linear and random in nature. In BCI, by calculating entropy the level of chaos can be measure. The distribution of energy for a specific data set values intervals were explained in reference to signal space probabilities$\{p_i\}$ where $p_i$represents the probability that $X=a_i$, entropy for discrete random variable is represented by X and it can be defined as

$$\boldsymbol{H(X)} = -\sum_{\boldsymbol{i}} \boldsymbol{p_i \log(p_i)} \qquad \textbf{(3)}$$

Naive Bayesian Classifier: Naive Bayes Classifier is a simple probabilistic classifier which uses Bayes theorem and has a strong assumption that the features are independent of each other in a given class variable.

Bayes' theorem is represented as

$$\mathbf{P(C_i|X)} = \frac{\mathbf{P(X|C_i)P(C_i)}}{\mathbf{P(X)}} \qquad \textbf{(4)}$$

Data sets with many attributes are extremely difficult to compute P(X|Ci). To reduce computation P(X|Ci), the naïve assumption of class-conditional independence is made. This assumes that the attributes' values are conditionally independent of one another. Thus,

$$\begin{aligned} \boldsymbol{P(X|C_i)} &= \prod_{\boldsymbol{k=1}}^{\boldsymbol{n}} \boldsymbol{P(x_k|C_i)} \\ &= \boldsymbol{P(x_1|C_i)} \times \boldsymbol{P(x_2|C_i)} \\ &\quad \times \dots\dots \\ &\quad \times \boldsymbol{P(x_n|C_i)} \end{aligned} \qquad \textbf{(5)}$$

Results: The present study shows that during a particular task, associated cortical areas are activated. Generally in hand motor imagination, C3 and C4 are solely responsible for it and this activation is depicted by amplitude attenuation (ERD) and in ideal condition amplitude enhancement (ERS) is found. In this study, the bandpower and entropy were calculated and then ERD and ERS were observed. It has been found that contralateral dominance has been found. During right hand imagination, C3 electrode is active and similarly C4 channel is active during left hand imagination. It means that during left hand imagination, C3 electrode position will give less deflection or ERS whereas in C4 electrode position we will be getting high deflection or ERD marking the initialization of the left hand movement imagination. Similarly, in case of right hand imagination, C4 electrode position will give less deflection or ERS whereas C3 electrode position will give high deflection or ERD hence marking the initialization of the right hand movement. Therefore, a contralateral dominance has been found.

Classification:

Table I: Classification accuracy in % for C3 and C4.

Naïve Bayes Classifier	C3	C4
BAND POWER	75.0	77.380
ENTROPY	71.42857	76.1904761905

Discussion: When a cortical area becomes activated in the course of information processing, oscillations in the alpha bands display an amplitude attenuation or **Event Related Desynchronization (ERD)**.

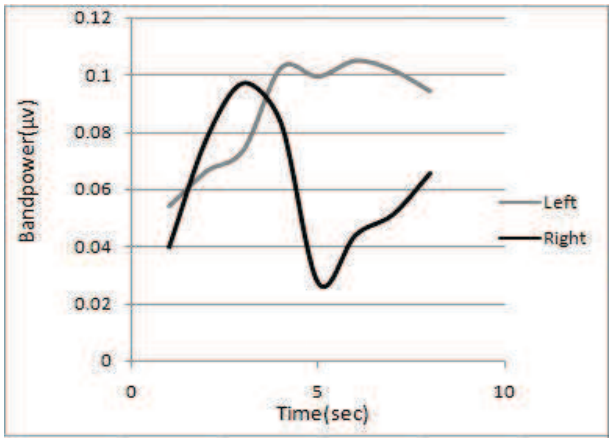

Fig 2(a): Bandpower of C3 for left and right imagination where maximum ERD can be found in 5th second means in the 5th second right imagination for C3 electrode has been initiated.

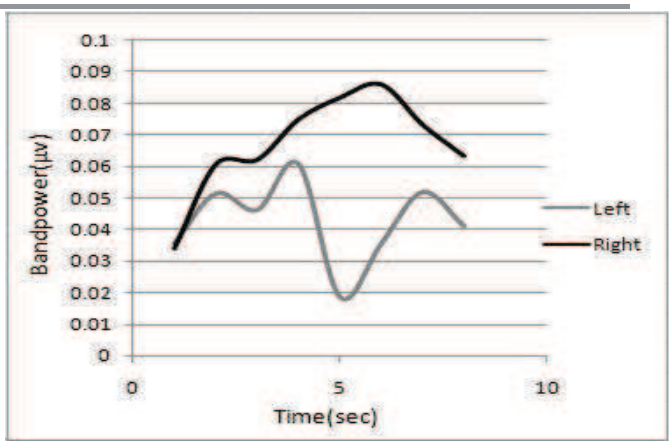

Fig 2(b): Bandpower of C4 for left and right imagination where maximum ERD can be found in 5th second means in the 5th second left imagination for C4 electrode has been initiated.

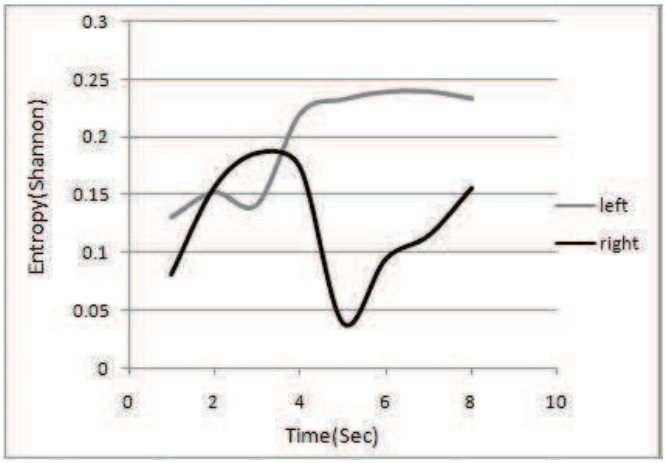

Fig 3(a): Entropy of C3 for left and right imagination where maximum ERD can be found in 5th second means in the 5th second right imagination for C3 electrode has been initiated.

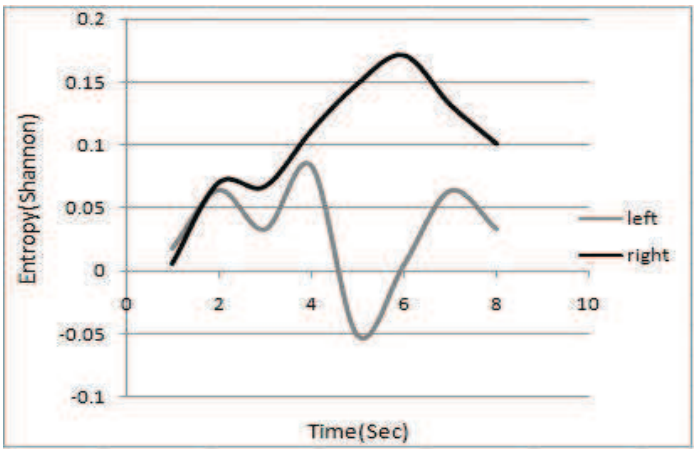

Fig 3(b): Entropy of C4 for left and right imagination where maximum ERD can be found in 5th second means in the 5th second left imagination for C4 electrode has been initiated.

When cortical areas are not specifically engaged in a given mode of activity at a certain moment of time, an amplitude enhancement or **Event Related Synchronization (ERS)**. Rhythmic EEG components are being used as neural input signals for establishing a BCI as planning or preparation of a specific movement causes desynchronization of alpha rhythms. During preparation of a specific movement, a different spatial localization is shown by the ERD which depends on the side (i.e. right or left) of the movement which is being planned. There is proof that imagination of hand movements and actual execution of the movement produces similar characteristic ERD patterns.

Conclusion: Features like bandpower and entropy were extracted using these techniques. In the frequency band of EEG, spectral changes were examined. There was a significant difference seen in the bandpower and entropy for C3 and C4 electrode positions. During the right hand motor imagination, the region near C3 electrode becomes active and there is an amplitude attenuation called ERD found in right hand imagination curve suggesting right hand imagination task in progress. Similarly, amplitude enhancement or ERS is found in left hand imagination curve suggesting inactivity in that particular electrode position. The region near C4 electrode position is activated due to left imagination, so ERD is found for left imagination and ERS for right imagination. The C3 and C4 are mostly responsible for motor movements either for actual movement or for imagined movement. C3 and C4 follows contralateral concept which means, during the right hand imagination region near C3 electrode is active and during left hand imagination region near C4 electrode is active. This shows that the signals produced by the brain during an execution of a particular task is same as the signals produced during the imagination of the same task i.e. same ERD is produced during execution or imagination of a particular task. Classification was performed using Naive Bayes classifier and a maximum classification accuracy of 77 % was obtained in the C3 and C4 region of brain.

References:

1. Akin M, Kiymik MK. Application of periodogram and AR spectral analysis to EEG signals. Journal of Medical systems.2000; 24(4):247-256.
2. Cincotti F, Mattia D, Babiloni C, Carducci F, Salinari S, Bianchi L, Marciani MG, Babiloni F. The use of EEG modifications due to motor imagery for brain computer interface. IEEE trans. on Neural Syst. and Rehab. Engg.2003; 11(2):131-133.
3. Fang Y, Chen M, Zheng X, Harrison RF. Feature Extraction of Motor Imagery in BCI with approximate entropy. Journal of computational information sys. 2012; 8(6):2485-2491.
4. Herman P, Prasad G, McGuinnity TM, Coyle D. Comparative analysis of spectral approaches to feature extraction for EEG based motor imagery classifications. IEEE trans. on Neural Syst. and Rehab. Engg.2008; 16(4):317-326.
5. Kamousi B, Amini AN, He B. Classification of Motor Imagery by means of cortical current density estimation and von neumann entropy. Journal of Neural Engg.2007; 4: 17-25.
6. Pregenzer M, Pfurtscheller G. Frequency component selection for an EEG based Brain to Computer Interface. IEEE trans. on Rehab. Engg.1999; 7(4):413-419.
7. Pfurtscheller G, Neuper C, Schlogl A, Lugger K. Separability of EEG signals recorded during right and left motor imagery using adaptive autoregressive parameters. IEEE Trans. on Rehab. Engg.1998; 6(3):316-325.
8. Pfurtscheller G, Neuper C, Guger C, Harkam W, Ramoser H, Schlogl A, Obermaier B, Pregenzer M. Current trends in Graz brain computer interface(BCI) research. IEEE trans. on Rehab. Engg. 2000; 8(2):216-219.
9. Pfurtscheller G, Neuper C. Motor imagery and direct brain computer communication. Proceedings of IEEE. 2001; 89(7):1123-1134.
10. Pfurtscheller G, Brunner C, Schlogl A, Lopes da Silva FH. Mu rhythm (de)synchronization and EEG single trial classification of different motor imagery tasks. Neuroimage.2006; 31:153-159.
11. Ramoser H, Gerking JM, Pfurtscheller G. Optimal spatial filtering of single trial EEG during imagined hand movement. IEEE trans. on rehab. engg. 2000; 8(4):441-446.

Ranjita Dutta, Birla Institute of Technology
Pillutla Soma Sunder, Accendere Knowledge Management Services Pvt. Ltd.
Rakesh Kumar Sinha, Birla Institute of Technology's.