Offline Analysis of Motor Imagery EEG Signals for Brain Computer Interface

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***Abstract*—Brain-Computer Interface (BCI) is an interface between brain and devices that enables electrical signals from the brain to direct external activity for disabled patients. Motor imagery is the mental representation of movement without any body movement. Motor imagery based BCI, is considered as the most effective way for direct brain computer communication. In awake people, primary sensory or motor cortical areas often display 8-12 Hz EEG activity called 'Mu' rhythm. Imagery left and right hand movements of 15 subjects were recorded using 64 channel EEG acquisition system. In this paper the reactive patterns of EEG rhythms of imagery hand movements are analyzed using in EEGLAB toolbox in MATLAB. The EEG data is sampled at 160 samples per second, band pass filtered between 0.1 Hz to 50 Hz. Epochs corresponding to left and right hand movements are extracted followed by baseline removal. After pre-processing the epoch files are analyzed using power spectral plots and event related potential plots. This analysis shows that an imagination of moving hand causes decrease in the activity at sensory motor cortex particularly contralateral side of the brain. This is shown as a desynchronization of Mu rhythm. The results imply that EEG phenomena can be utilized in Brain Computer Interface operated by motor imagery and can be used for classifier development.**

Keywords*—Brain Computer Interface (BCI), Electroencephalography (EEG), motor imagery, Event Related Desynchronization (ERD), Event Related Synchronization (ERS).

I. INTRODUCTION

Research in the field of neuroscience has helped to understand the human brain in recent years. Advancements in biomedical signal processing have led BCI in diagnosis of brain diseases and to achieve real time processing using EEG signals. Studies on BCI concentrate on developing communication and control technology for patients suffering from severe neuromuscular disorders [1]. This study involves brain science, neural engineering and rehabilitation [2]. BCI performs recording, processing, analyzing and classifying the brain signals as shown in Fig. 1. They are generated by mental task without the need of any muscular performance.

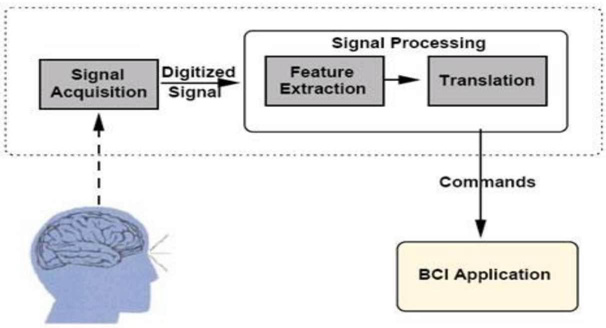


Fig. 1. Basic design and operation of any BCI system

The primary sensory or motor cortical areas often display 8–12 Hz EEG activity in awake people. Mu and beta rhythms recorded from the scalp at motor cortex area are translated in real-time into commands that operate a computer display or other device [1].

The mu rhythms are usually associated with 18–30 Hz beta rhythms. Motor imagery is mainly described as the mental rehearsal of a motor act without any movement by muscular activity, is assumed to involve to a large extent the same cortical 15areas that are activated during actual motor preparation and execution [3].

Movement or preparation of movement is typically accompanied by decrease in mu and beta rhythms on opposite side of the brain. This decrease is described as "Event Related Desynchronization" (ERD). In contrast, rhythm increase, or "Event-Related Synchronization" (ERS) is followed after the movement and with relaxation [4]. They do not require actual movement; and occur also with motor imagery. The hand area of motor cortex of the scalp represents the contralateral hand movements as mu rhythm which is considered to be the prominent rhythm [5].

II. METHODOLOGY

In this study, the motor imagery signals of 15 subjects are analyzed after taking their consent. The motor imagery EEG signals were collected using 64 channel EEG acquisition system. The methodology consists of pre-processing and analysis steps for both hand movements of imagery. Fig. 2 shows the flow chart of offline analysis of motor imagery EEG signals.

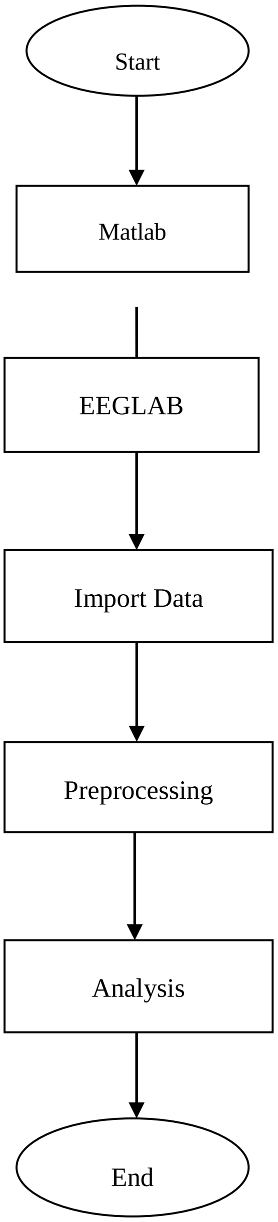


Fig. 2. Flow chart of offline analysis of Motor Imagery EEG signals

A. Preprocessing of EEG Data

In this study, an open source tool box EEGLAB running under MATLAB is used for pre-processing and analysis. Each EEG sample is referenced to Cz electrode. After channel locations are imported the information about the recording electrodes is necessary for plotting EEG scalp maps to estimate source locations for data components. The data is sampled at 160 Hz and is band pass filtered between 0.1 Hz to 50 Hz. This bandpass filtering of data using linear FIR filter eliminates the power line noise, EOG and EMG artifacts. To study the event related EEG dynamics of recorded data, the data epochs of interest are extracted from the filtered data followed by the removal of epoch baseline offsets. Epochs of events: onset motion of left hand (event 1) and onset motion of right hand (event 2) are extracted for EEG data for 'imagery' study. After pre-processing, each epoch file was studied by plotting channel Power spectral maps, Event Related Potential (ERP) plots and comparing ERP averages [6].

B. Analysis of EEG Signals

Since the event-related desynchronization and synchronization (ERD/ERS) can be quantified in time and space and can be displayed in the form of time courses or maps, the EEG data is analyzed in the following ways:

1. Power Spectrum Analysis

Spectral plot displays a colored trace that represents the spectrum of the activity and measures magnitude of signals at measurement points [7]. EEGLAB shows the power spectrum on the brain model at some chosen frequencies. Therefore, it is easy to identify the active area in the brain. Our study involves, power spectrum at 4, 8, 10, 12, 14, 20, 22 and 40 Hz frequencies of epoched data for both hand imaginary movements.

2. Event Related Potential (ERP) plots

Analysis of epoched data can be achieved using ERP images. ERP averages are used to compare the event related potentials of left and right hand motor imagery movements.

a) Channel ERP Image plots

Data averaging collapses the dynamic information in the data. In order to have a better understanding and the causes of ERP effects, ERP image is plotted which gives trial by trail views of a set of data epochs. An ERP image is a colored rectangular image in which each horizontal line represents a potential time series during a single experimental trial [8].

Instead of plotting activity in single trials, trials are represented as horizontal lines whose changing color values indicate the potential at each time point in the trial. The color-sequence lines for all trails in a dataset are stacked above each other to form an ERP image.

b) ERP Comparisons

Comparing the ERP averages of electrodes C3 and C4 provides the exact information about the event related changes occurring in brain during each hand imagery movement.

III. RESULTS

All the above analysis was done for the data pertaining to 15 subjects. But the results of one subject are only shown. The results show that power spectral plots (Fig. 3 and 4), channel ERP images (Fig. 5 and 6) and comparison of ERP images (Fig. 7) of right and left imaginary hand movements with different colour patterns in different image plots. In power spectral plots the reactive patterns are represented by high and low colour intensities. Desynchronization and synchronization are indicated as blue color and red color respectively.

Desynchronization of mu rhythm (8-12 Hz) and central beta rhythm (18-26 Hz) at sensory motor cortex of right hand imagery is represented as blue colour on left side of the brain (Fig. 3). Desynchronization of mu rhythm and central beta rhythm at sensory motor cortex of left hand imagery is represented as blue colour on right side of the brain (Fig. 4).

The synchronization pattern on right side of the scalp during right hand imagery shows more red colour on right side electrodes C2, C4, C6 than left side electrode positions C1, C3, C5(Fig. 5). The synchronization pattern on left side of the scalp during left hand imagery shows more red colour on left side electrodes C1, C3, C5 than right side electrode positions C2, C4, C6 (Fig. 6).

The comparison of ERP averages of right and left imagery at electrode positions C1, C2, C3, C4, C5 and C6 shown in (Fig. 7).Green line represents the average ERP of right hand imagery and blue line represents the average ERP of left hand imagery. At left side electrode positions C1, C3 and C5 the potential of average ERP of right hand imagery is more than the left hand imagery. At right side electrode positions C2, C4 and C6 the potential of average ERP of left hand imagery is more compared to right hand imagery (Fig. 7).

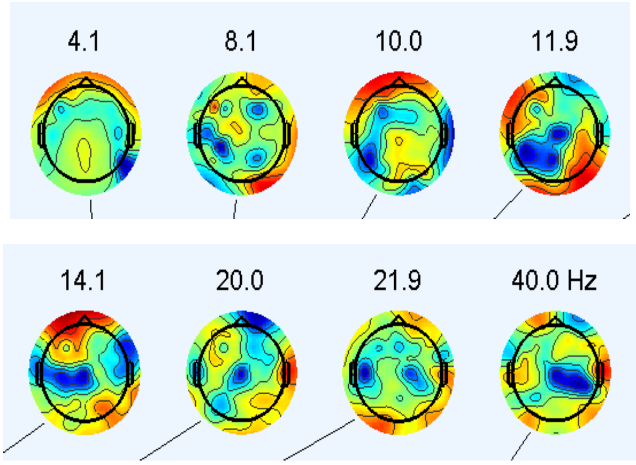


Fig. 3. Power spectral plots during right hand imagery at various frequencies

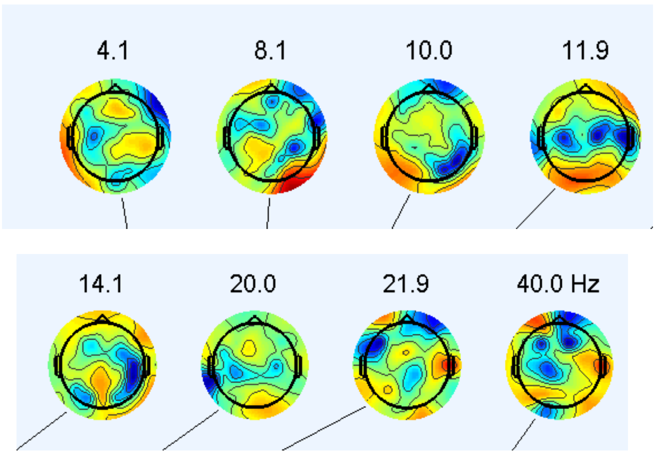
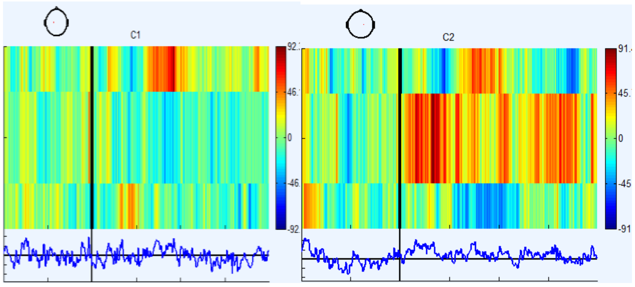


Fig. 4. Power spectral plots during left hand imagery at various frequencies



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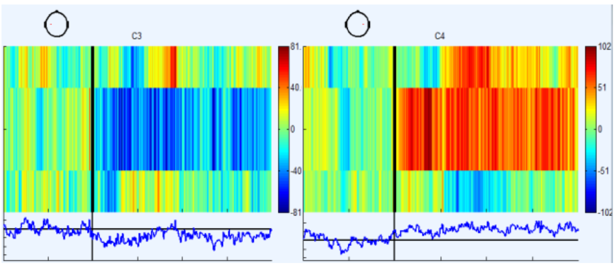

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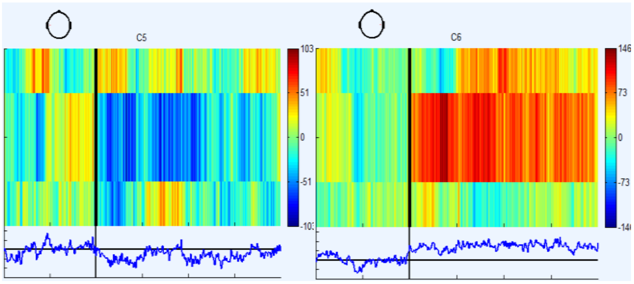
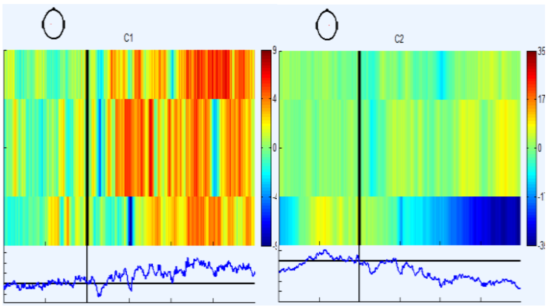


(c)

Fig. 5.Channel ERPs at electrode positions (a) C1, C2, (b) C3, C4 and (c) C5, C6 during right hand imagery



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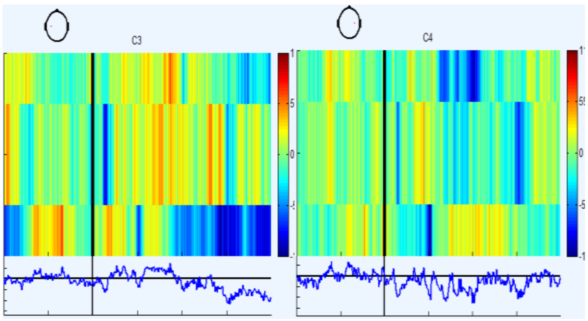

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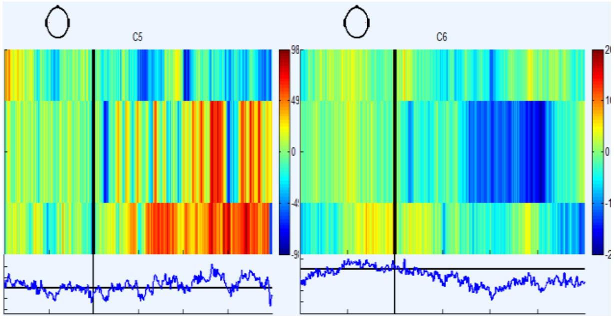
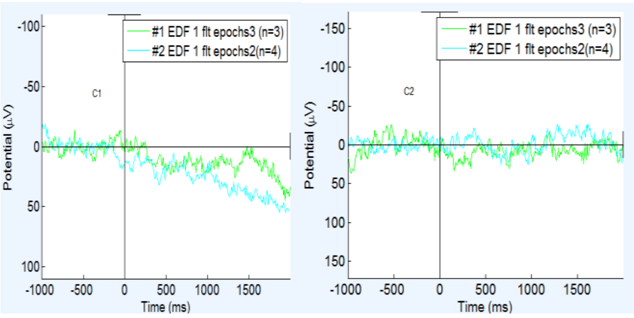


(c)

Fig. 6. Channel ERPs at electrode positions (a) C1, C2, (b) C3, C4 and (c) C5, C6 during left hand imagery



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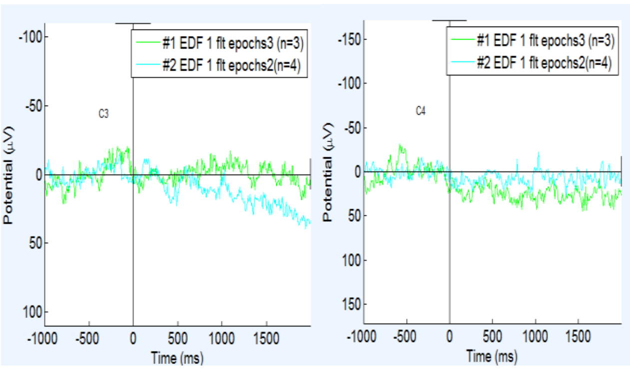

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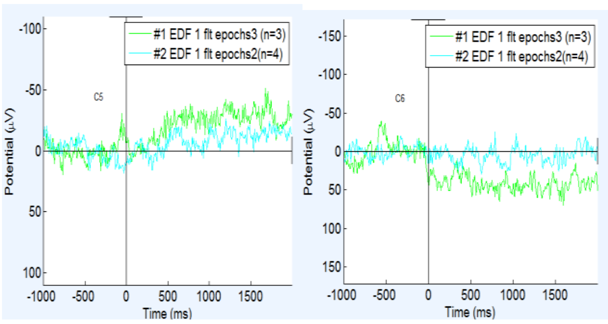

(c)

Fig. 7. Comparison of ERP averages of right and left imagery at electrodes positions C1, C2, (b) C3, C4 and (c) C5, C6

(Green trace represents the average ERP of right hand imagery and Blue line represents the average ERP of left hand imagery)

IV. DISCUSSION

From the spectral plot results (Fig. 3 and 4), it is observed that the spectral plot of right hand imagery shows decrease in spectral power near the C3 electrode position (left side sensory motor area which is responsible for the right hand movement) at 8 Hz-20 Hz and that of left hand imagery shows decrease in the spectral power near the C4 electrode position (right side sensorimotor area which is responsible for the left hand movement) at 8-14 Hz. This shows that desynchronization of mu rhythm (8-12 Hz) and central beta rhythm (16-30 Hz) at sensory motor cortex the imagination of hand movements.

The channel ERP image (Fig. 5) shows decrease in the event related potentials (blue colour) on left side of the sensorimotor area and an increase in event related potentials on the right side (red colour) during the right hand imagery. Also the channel ERP image (Fig. 6) of left hand imagery shows decrease in the event related potentials on right side of the sensorimotor area and an increase in event related potentials on left side which indicates the desynchronization of the sensorimotor rhythms during imagination of hand movements. The comparison of the channel ERPs (Fig. 7) strengthens the result obtained from ERP image.

V. CONCLUSIONS & FUTURE SCOPE

The results show that an imagination of right hand movement of any subject will desynchronize the mu rhythm and central beta rhythms in the sensory motor hand area of left side of the particular subject’s brain (since brain takes charge of opposite side of the body) and imagination of left hand movement will desynchronize the mu rhythm (8-12 Hz) and central beta rhythms (18-26 Hz) in the sensory motor hand area of right side brain.

Feature extraction and classification algorithm are not aimed in our work, but the results obtained can be used in the development of classifiers which will improve the speed and accuracy of EEG based BCIs.

VI. REFERENCES

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