 DOI:10.3217/978-3-85125-260-6-112

Predicting the Performance of a MI-Based BCI Based on Pre-Cue EEG Data

A. Bamdadian[1], C. Guan[1], K. K. Ang[1], J. Xu[2]
[1]Institute for Infocomm Research (I^2R), Singapore; [2]National University of Singapore (NUS), Singapore

Correspondence: A. Bamdadian, Institute for Infocomm Research, Singapore, 1 Fusionopolis Way, #21-01, Connexis, Singapore 138632.
E-mail: stuab@i2r.a-star.edu.sg

Abstract. One of the main problems in motor imagery based brain-computer interface systems is that some users cannot perform motor imagery (MI) well. Hence, it will be useful to have prior knowledge about the capability of the users in performing MI. This study proposed a novel predictor to evaluate the performance of the users based on the pre-cue EEG data. Group level analysis on $N = 17$ healthy subjects shows that there is a significant correlation $r = 0.49$ between the proposed coefficient and the cross validation accuracies of the subjects in performing MI. The results suggest that having higher frontal theta and lower posterior alpha prior performing MI may enhance the BCI performance. This finding may help in designing a new experiment to improve motor imagery performance.
Keywords: Motor imagery, performance predictor, EEG rhythms

1. Introduction

Motor imagery-based (MI-based) BCI system is widely used for both therapeutic and non-therapeutic applications. It had shown that some users cannot perform motor imagery well and there is a big variation in performance of the users [Blankertz et al., 2010]. One of the possible reasons may be the inability of users in modulating their electroencephalogram (EEG) rhythms. EEG rhythms modulations typically occur during motor imagery. Studies had shown that EEG rhythms have significant role on BCI performance and hence can be used to predict the performance [Blankertz et al., 2010; Grosse-Wentrup et al., 2012; Maeder et al., 2012]. So far none of performance predictors was widely used in different BCI experiments. Predicting the performance of the patients prior to the experiment may be useful; moreover, it may lead to better understanding of the possible reasons of performance variation in different subjects. In this study, we aim to predict the performance of the users based on the pre-cue EEG data. Studies had shown that pre-stimulus alpha activity over occipital and parietal area and theta activity over frontal area contains useful information about attention of the users [Mazaheri et al., 2009]. Hence, we hypothesized that a coefficient based on EEG rhythms from different brain regions be informative in predicting the performance of the users. A novel coefficient $P_\theta/(P_\alpha+P_\beta)$ was proposed of which P_θ, P_α, and P_β are the average EEG band power of theta (4-8 Hz), alpha (8-13 Hz), and beta (13-22 Hz) bands over frontal (F_3, F_z, F_4), central (C_z, Cp_z) and parietal area (P_7, P_3, P_z, P_4, P_8) respectively. To study the effectiveness of the proposed coefficient, we performed a correlation analysis between this coefficient and performance of the 17 healthy subjects. The coefficient was calculated based on the pre-cue EEG data (i.e., 1 second before providing the cue for the subjects).

2. Material and Methods

2.1. Experimental setup

In this work, EEG data from the 17 healthy subjects were collected. Two of the subjects were left-handed, the rest were right-handed. The EEG data from each subject were collected on two separate days, two non-feedback sessions on the first day and three non-feedback sessions on the second day were recorded. During these sessions, the subjects were instructed to perform kinaesthetic motor imagery of their chosen hand or rest right after a visual cues displayed on the computer screen in each trial. Each session comprised of 40 trials of motor imagery and 40 trials of background rest condition and lasted about 16 minutes. Each trial comprised a preparatory segment of 2 s, the presentation of the visual cue for 4 s, and a rest segment of at least 6 s. Each trial lasted approximately 12 s, and a break period of at least 2 minutes was given after each session of EEG recording.

2.2. Pre-processing and Analysis

The recorded EEG data are filtered over θ, α, and β frequency bands. Local average reference filtering was then applied to spatially filter the data by subtracting the average activity of the neighboring electrodes from each single electrode. EEG band power for all the trials were calculated and then averaged in 1 second before the presentation of

the visual cue. The EEG powers were finally normalized across all trials. For estimating the performance of the users the Filter Bank Common Spatial Pattern (FBCSP) algorithm [Ang et al., 2012] with support vector machine (SVM) classifier was used. A group level analysis was done to study the correlation between mean of coefficient $P_\theta/(P_\alpha+P_\beta)$ over all trials and accuracies of subjects.

3. Results

Fig. 1 shows the correlation between the proposed coefficient $P_\theta/(P_\alpha+P_\beta)$ and off-line accuracies of the 17 healthy subjects. The Pearson's correlation coefficient of ($r = 0.49$, $p = 0.04$) was obtained. The result of linear regression analysis is shown as a black solid line. As shown, the subjects can be clustered into high performance users (pl, s, ks, lj, kk, hj, ab, zy) and low performance users (hh, hd, wy, kx, ly, at). The three subjects (jh, yz, ad) which are shown in red circles in Fig. 1 are considered as outliers. Higher correlation ($r = 0.68$, $p = 0.006$) was achieved by excluding them from our analysis. The dashed red line is the result of new regression analysis. Performing Mann-Whitney U-test also shows that there is a significant difference ($p = 0.001$) between the coefficient of users with high and low performance. The results suggested that high performance users have higher values of defined EEG rhythm-based coefficient and vice versa.

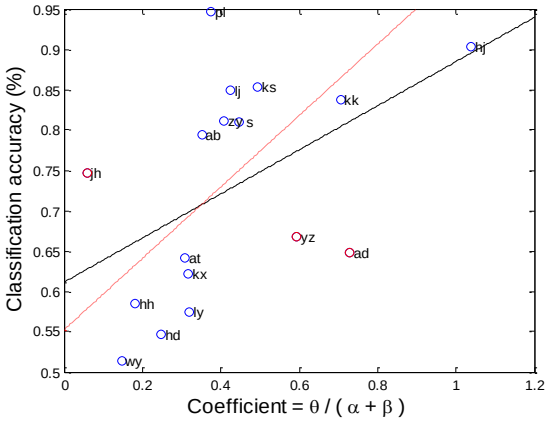

Figure 1. *Correlation of the EEG rhythm-based coefficient $P_\theta/(P_\alpha+P_\beta)$ with BCI classification accuracy. Each circle represents a healthy subject. The black (slope=0.28) and red (slope=0.44) lines are linear regression results considering all the users and all except three users shown in red circles, respectively.*

4. Discussion

Results showed the proposed coefficient $P_\theta/(P_\alpha+P_\beta)$ computed from 1 second of pre-cue EEG data is successful in predicting the performance of the users. The results of correlation analysis suggested that an increase in frontal theta along with a decrease in posterior alpha correlated with an increase in motor imagery performance. In conclusion, monitoring the EEG rhythms over frontal and parietal area before cue may help in improving the user's performance. To have a better understanding about the effectiveness of the defined coefficient, further analysis has to be done on single trial basis.

References

Blankertz B, et al. Neurophysiological predictor of SMR-based BCI performance. *NeuroImage*, 51:1303-1309, 2010.

Grosse-Wentrup M, Schölkopf B. High gamma-power predicts performance in sensorimotor-rhythm brain–computer interfaces. *J Neural Eng*, 9: 046001, 2012.

Maeder CL, et al. Pre-Stimulus Sensorimotor Rhythms Influence Brain-Computer Interface Classification Performance. *IEEE Trans Neural Sys Rehab Eng*, 20:653-662, 2012.

Mazaheri A, et al. Prestimulus alpha and mu activity predicts failure to inhibit motor responses. *Hum Brain Map*, 30:1791-1800, 2009.

Ang KK, et al. Filter Bank Common Spatial Pattern algorithm on BCI Competition IV Datasets 2a and 2b. *Front Neurosci*, 6, 2012.