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Performance Prediction in Motor Imagery BCI

M. Ahn[1], H. Cho[1], S. Ahn[1], S. C. Jun[1,2]

[1]*School of Information and Communications, GIST, Gwangju, South Korea*

[2]*Wadsworth Center, New York State Department of Health, Albany, New York, USA*

Correspondence: S. C. Jun, School of Information and Communications, GIST, Buk-gu, Gwangju, South Korea 500-712.
E-mail: scjun@gist.ac.kr

Abstract. We propose a strategy for predicting user's performance in motor imagery BCI. It is composed of four band powers (theta, alpha, beta, gamma) of resting state; it comes from the recent investigation of neurophysiologcal characteristics that alpha and beta powers are positively correlated, and theta and gamma are negatively correlated with BCI performance in motor imagery. Our proposed predictor yielded the correlation value of r = 0.59 for 61 motor imagery subject datasets, and the correlation reached to r = 0.7 when 7 outliers (determined by Whisker length of 1.5) were excluded. Our predictor is far simpler and comparabale (or slightly better) to Blankertz's.

Keywords: BCI, subject variability, session variability, performance predictor

1. Introduction

Motor imagery has been commonly used as a control paradigm in BCI research and development since ERD (event related desynchronization) is known to be a generally notable feature. However, a significant number of subjects experience some trouble in generating detectable ERD. In [Blankertz et al., 2010], it was reported that α and β bands of resting state are positively correlated with BCI performance, and a predictor was proposed using potential decrease of α power, which can be estimated through an iterative fitting algorithm. Recently, the influence of γ on sensory motor rhythm was revealed in [Grosse-Wentrup et al., 2011]. In addition, four band powers of resting state were investigated by [Ahn et al., 2012], reporting the existence of significant positive (α or β) and negative (γ) correlations with BCI performance. Further, they found that θ had negative correlation with BCI performance as high as α (up to $r = 0.5$). From their findings, we propose a performance predictor yielding potential performance (PP), as formulated in equation (1). It is composed of four band powers and corresponding coefficients. To see its practicability, and 61 motor imagery subject datasets acquired from two different EEG systems were used.

$$PP = \frac{c_1 a + c_2 b}{c_3 q + c_4 g}. \qquad (1)$$

2. Material and Methods

2.1. Data 1: Offline data (52 subjects)

For each of 52 subjects, 100 motor imagery trials for each class (left/right) were acquired using Biosemi Active 2 (64 channels, sampling rate: 512 Hz). To estimate performance (off-line), each dataset was spectrally (8-30 Hz) and temporally filtered (0.4–2.4 s after cue onset) since this zone is most informative for motor imagery [Ahn et al., 2012], then 10-fold cross-validation using CSP (common spatial pattern) and FLDA (Fisher linear discriminant analysis) was applied. For the analysis of PP, resting state (open eyes) signal was recorded during 1 minute and bandpass filtered (1-100 Hz).

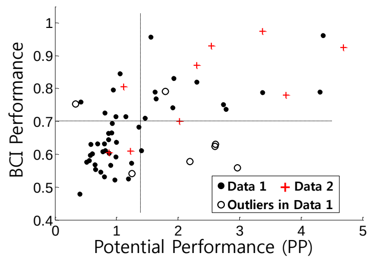
2.2. Data 2: Online data from BCI competition 2008 dataset 2b (9 subjects)

Second group of datasets was acquired from BCI Competition site, in which users conducted motor imagery (left/right hand) with feedback [Leeb et al., 2007]. The data was digitized at 250 Hz and bandpass (0.5-100 Hz) and notch (50 Hz) filters were applied. Only 3 channels (C3, Cz and C4) were available; we could not apply CSP and FLDA to get BCI performance. Actual performance was estimated from the competition winner's result, which was expressed in kappa value ($\kappa = (P_o - P_h)/(1 - P_h)$, P_o: expected performance, P_h: hypothetical probability of chance agreement). Assuming theoretical chance agreement in 2 class problem yields $P_h = 0.5$, the kappa value was converted into an estimate of expected performance P_o. This estimate was used as a BCI performance in this work.

Resting state (open eyes) signal (1 minute) before online session was bandpass filtered (1-100 Hz) for further investigation of PP.

2.3. Resting state and potential performance (PP) calculation

It was reported from [Ahn et al., 2012] that significant correlations with BCI performance occurred on mainly central area in the brain, and θ and α focused notably near C3 and C4 channels. Thus, two channels (C3 and C4) were selected for target channels in this work. From the resting state, the four band powers (θ: 4-8 Hz, α: 8-13 Hz, β: 13-30 Hz, γ: 30-70 Hz) were estimated for each of two channels. Each band power was averaged over these two target channels. For simplicity, all coefficients (C_i) in equation (1) were set to 1. In Fig. 1, PP and BCI performance were plotted for all 61 subjects and the detailed statistics were described.



	Data1	Data2	All
r	0.48	0.69	0.59
r^2	0.23	0.48	0.34
p	3.3372e-004 **	0.0396 *	6.5700e-007 **

After outliers are rejected

	Data1	Data2	All
r	0.64		0.70
r^2	0.41		0.50
p	2.1194e-006 **		2.8352e-009 **

* < 0.05, ** < 0.001

Figure 1. *Two dimensional plot of PP and BCI performance (left) and its correlation analysis result (right). Two cases of inclusion and exclusion of 7 outliners were statistically compared.*

3. Results

Data 1 yielded a correlation of r = 0.48 between PP and BCI performance. Data 2 (red + in Fig. 1) yielded higher value of r = 0.69. Combining Data 1 and Data 2, r = 0.59 (61 subjects) was observed. The correlation got increased up to r = 0.70 (54 subjects) when 7 outliers determined by the boxplot of the band power distribution with Whisker length of 1.5 were excluded. Our proposed potential performance predictor using two channels C3 and C4 only showed comparable (or slightly higher) result than that (r = 0.53) of Blankertz. One interesting thing from Fig. 1 is that the relationship between PP and performance may not be linear; its distribution is denser near 1 as PP.

4. Discussion

There may exist other factors affecting BCI performance variability. This means that neurophysiological factor could innate the limitation to estimate user's performance. Thus, the combination of our proposed potential performance (PP) with other existing factors or more channels will facilitate better prediction of BCI performance. In addition, it could be improved further if the coefficients in equation (1) are optimized in a proper manner. Our predictor is greatly advantageous in that it requires simply four kinds of band powers of resting state, which enables us to easily apply for predicting a user's potential performance in motor imagery BCI.

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