Performance Enhancement by Sparse Representation of EEG Signals for Motor Imagery Based BCI systems

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Abstract. We evaluate a sparse representation based classification (SRC) scheme which was proposed in our previous work [Younghak et al., 2012] as a high performance classification method for motor imagery (MI) based BCI systems. For the comparison of classification accuracy, we use two widely used classification methods, linear discriminant analysis (LDA) and support vector machine (SVM). We analyze eight different data sets acquired from our motor imagery based BCI experiment. We use a CSP filtering for feature extraction. From the results, the SRC method shows improved classification accuracy than the other two classification methods.

Keywords: EEG, BCI, Motor Imagery, SRC, CSP, LDA, SVM

1. Introduction

In BCI systems, classification algorithm is needed to transform extracted features of a user's intention into computer commands to control the external device. In the EEG based BCIs, widely used classification methods are linear discriminant analysis (LDA) and support vector machine (SVM) [Lotte et al., 2007]. In our previous study, the sparse representation based classification (SRC) method has been introduced and applied with high classification accuracy to the EEG based BCI application [Younghak et al., 2012]. In the SRC method, dictionary design is very important. To make the uncorrelated dictionary for different classes, the CSP filtering has been used [Younghak et al., 2012]. In this study, we aim to compare the BCI classification accuracy of the SRC method with that of LDA and SVM, which are most widely, used classification methods in the BCI field. We use the same feature extraction setup using the CSP filters for the three classification methods. To evaluate classification accuracy, we collect data sets from eight different subjects. Each subject data set obtained from our own motor imagery (MI) based BCI experiments.

2. Material and Methods

2.1. Experimental data

In this study, we use eight data sets. These data sets acquired from four healthy male and four female subjects (average age = 24.63 and SD = 4.37). These data sets contain EEG signals generated from the left and the right hand motor imagery experiments. There are 5 runs. One run consists of 20 trials for each class. The number of total trials is 100 for each instruction (class). One trial consisted of 4-6 s resting time period (blank screen) and 3 sec instruction time period. The resting time period is randomly selected between 4 and 6 s. Instructions are represented at the center of the monitor screen. These experimental data sets were recorded by active electrodes in a cap. We use Active Two EEG measurement system made by Biosemi, Inc. The sampling rate of these data sets is 512 samples per second and the number of EEG channels is 64. The channel positions are selected from international 10/20 standard.

2.2. Methods

After collecting EEG data sets, we use a band pass filtering with 8-15 Hz frequencies to extract the frequencies which are related to motor imagery signals. For a feature extraction, we use a band power of 8-15 Hz signals after applying a spatial filtering. We use a common spatial pattern (CSP) as a spatial filtering, which is a widely used method for motor imagery based BCI applications [Blankertz et al., 2008]. To compare classification accuracy of the SRC method, we use two most widely used classification methods in the BCI field, namely, linear discriminant analysis (LDA) and support vector machine (SVM). To evaluate the classification accuracy for each subject, we use the leave-one-out (LOO) cross-validation which is useful for increasing the number of independent classification tests with a given limited data trials.

3. Results

We have analyzed eight data sets. Table 1 shows the classification results. We compare the classification accuracies of LDA, SVM and the SRC method. For each subject, we compute average accuracy for different numbers of CSP filters (The CSP filters varied from 1 to 64). From the result, the SRC method shows the best classification accuracy for seven data sets. For subject A, SVM shows the best accuracy. However, the accuracy difference is very small e.g., 0.41%. In addition, the SRC has the best mean classification accuracy and the smallest standard deviation for eight datasets. To confirm our results statistically, we use a paired *t*-test. We performed the *t*-test using paired SVM (or LDA) and SRC classification results for all subjects. The obtained *p*-values of the *t*-test represented in the last row of Table 1. All the *p*-values are less than 0.01. This means that the difference between the SRC method and the SVM (or LDA) is statistically significant.

Table 1. *Classification accuracies of LDA, SVM and SRC for eight data sets*

Subject	*Average accuracy (%)*		
	LDA	*SVM*	*SRC*
A	91.25	**93.47**	93.06
B	76.78	79.17	**84.39**
C	94.09	95.34	**95.81**
D	80.95	82.58	**85.40**
E	82.36	86.72	**89.84**
F	89.73	90.38	**92.92**
G	91.36	93.97	**96.03**
H	80.55	81.17	**85.42**
Mean (Std.)	85.88 (6.43)	87.85 (6.33)	**90.36 (4.79)**
p-value	0.0007	0.0063	

4. Conclusions

In this study, we compare the classification accuracies of the SRC and widely used LDA and SVM methods. Specifically, SVM has been well known for robust classification performance in many BCI researches. To evaluate the classification accuracy, we use our motor imagery based BCI experimental data sets acquired from eight different subjects. We use a CSP filtering to extract feature vectors for the three classification methods. We compare the classification accuracies of SRC, LDA and SVM methods. From the results, the SRC method is shown to provide the best classification accuracy regardless of the number of CSP filters.

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