A New BCI Classification Method based on EEG Sparse Representation

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***Abstract*—Motor imagery based Brain Computer Interface (BCI) systems provide a new communication and control channel between the human and an external device with only imagination of limbs movements. Because Electroencephalogram (EEG) signals are very noisy and non-stationary, powerful classification methods are needed. We propose a new classification method based on sparse representation of EEG signals and ell-1 minimization. This method requires a well constructed dictionary. We show very high classification accuracy can be obtained by using our method. Moreover, our method shows improved accuracy over a well known LDA classification method.**

I. Introduction

Motor imagery based EEG signals are very sensitive to noise and artifacts, for example caused by unwanted eye movements. Thus, powerful signal processing methods are needed. In this paper, we are interested in developing a new classification method for the BCI system. Using right hand 'R' and foot 'F' of motor imagery data sets, we propose a new sparse representation based classification (SRC) method. The SRC method is motivated from compressed sensing (CS) theory. SRC works by finding a sparse representation of the test signal in terms of the training signals included in the dictionary. To make a proper dictionary, we use a common spatial pattern (CSP) which has distinguishable property for different classes. CSP is a powerful signal processing technique suitable for EEG-based BCI system [1]. After CSP filtering, We use sensorimotor rhythms (Mu and Beta rhythm) as a feature of BCI system [2].

II. Methods

Let N_t be the total training signals. We define a dictionary matrix $\mathbf{A}_i = [\mathbf{a}_{i,1}, \mathbf{a}_{i,2}, ..., \mathbf{a}_{i,N_t}]$ for class $i = R, F$, where each column vector $\mathbf{a} \in \mathbb{R}^{m\times 1}$ is obtained by CSP filtering, FFT of the time domain signal in a training trial. By combining the two matrices, we form the complete dictionary, $\mathbf{A} := [\mathbf{A}_R; \mathbf{A}_F]$. We apply the same procedure done to obtain the columns of the dictionary to the test signal. Then, this test signal can be sparsely represented as a linear combination of some columns of $\mathbf{A}$. We can represent this as a matrix algebraic form: $\mathbf{y} = \mathbf{A}\mathbf{x}$.

We use certain FFT coefficients (Mu and Beta rhythms) as a feature, and the linear equation becomes under-determined ($m < 2N_t$). CS theory has shown that the ell-1 norm minimization can solve this under-determined system well in polynomial time [3]. Unlike the conventional ell-2 norm minimization, the ell-1 norm minimization gives a sparse representation result. In this study, we use the basis pursuit method, one of the standard linear programming methods [4].

III. Results

We have analyzed five data sets, which have same 140 trials for each class. Figure 1 shows the SRC classification accuracy of all subjects. We can see the SRC method shows good performance when the number of training signals is large enough. For all subjects, average accuracy grows when the number of training signals increases.

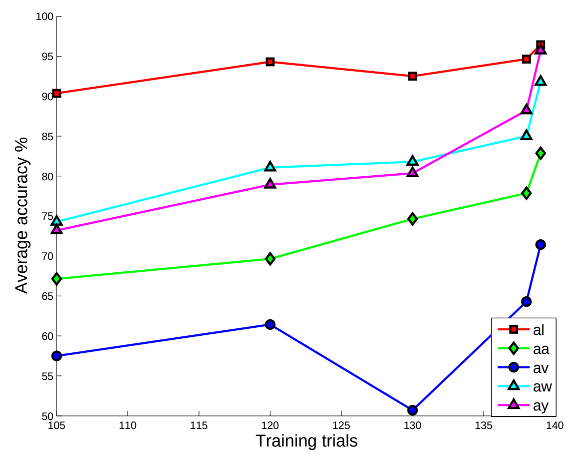

Fig. 1. Average accuracy of SRC with different number of training signals

IV. Conclusions

We apply the idea of sparse representation as a new classification method to the motor imagery based BCI. The sparse representation method needs a well designed dictionary composed of training data. We use the CSP filtering and the FFT to produce the columns of the dictionary. We have shown that a good classification result can be obtained by the proposed method. In addition, we have compared with the conventional approach such as linear discriminant analysis (LDA) method, which is well known for robust performance for the BCI system. Our result shows proposed method better than LDA.

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