

# A Prior Neurophysiologic Knowledge Free Tensor-based Scheme for Single Trial EEG Classification

Jie Li, Liqing Zhang, Dacheng Tao, Han Sun and Qibin Zhao

**Abstract**—Single trial EEG classification is essential in developing brain-computer interfaces (BCIs). However, popular classification algorithms, e.g., common spatial patterns (CSP), usually highly depend on the prior neurophysiologic knowledge for noise removing, although this knowledge is not always known in practical applications. In this paper, a novel tensor-based scheme is proposed for single trial EEG classification, which performs well without the prior neurophysiologic knowledge. In this scheme, EEG signals are represented in the spatial-spectral-temporal domain by the wavelet transform, the multi-linear discriminative subspace is reserved by the general tensor discriminant analysis (GTDA), redundant indiscriminative patterns are removed by Fisher score, and the classification is conducted by the support vector machine (SVM). Applications to three datasets confirm the effectiveness and the robustness of the proposed tensor scheme in analyzing EEG signals, especially in the case of lacking prior neurophysiologic knowledge.

**Index Terms**—Electroencephalogram (EEG), General Tensor Discriminant Analysis (GTDA), Single trial classification.

## I. INTRODUCTION

Electroencephalogram (EEG) is a measurement of electrical activity in the brain collected using non-invasive electrodes attached to the scalp. Over the years, EEG has been applied in a very wide variety of clinical and research contexts. Now, in computing, it is the most exploited sensory signal in brain computer interface (BCI) which aims to use brain activity to translate human intention and provide a new directly communication channel between brain and computer. The potential applications of BCI are vast and range from an

interesting gadget in computer games to a useful tool for persons with severe motor disabilities. A number of EEG based BCI systems have been developed recently [14] [21] [22][23] [29] in which patterns of EEG in different mental states can be discriminated for information transmission by feature extraction and classification algorithms. Research [1] [8] has shown their effectiveness and efficiency depend on the quality of EEG feature representation and the accuracy of pattern classification of the recorded single trial EEG.

In a BCI system, the subject is required to perform different tasks according to predefined mental control paradigms, which would induce the biofeedback based on specific responses to stimulus or event-related rhythm modulation, e.g., P300 speller paradigm[7], self-regulation of rhythm[22], and motor imagery [2][26], and then the subject's intention is conveyed by the pattern changes of the recorded EEG. The most commonly used mental control paradigm in BCI is the motor imagery. This is because the motor imagery produces the attenuation of brain oscillatory activity within particular frequency bands over sensorimotor cortex (ERD: event-related desynchronizations) [12], and depending on the part of the body imagined moving, the recorded EEG exhibits a distinctive pattern.

One of the most successful algorithms for single trial EEG classification, evidenced by the 2003 BCI Competition [9], is termed the common spatial patterns (CSP) [16]. CSP detects the spectral discriminations between two classes of tasks by calculating discriminative spatial patterns that maximize the variance of one class and at the same time minimize the variance of the other, wherein the variance of the band-pass filtered EEG signals directly reflects the spectral power of the band frequency. For the classification of two classes of motor imageries, CSP achieves the accuracy above 90% on single trials EEG samples [16]. Therefore, most existing BCI systems [2][15] use the CSP algorithm to characterize EEG patterns achieving reasonable results in on-line discrimination of the motor imagery task. Extensions of CSP for the multi-class classification [11] and integrations with other forms information [10][27][35] have also received increasing attention recently.

Although the CSP algorithm proves to be highly successful, it is not optimized for the EEG classification problem. The performance of CSP severely depends on the prior neurophysiologic knowledge for noise removing, i.e., the

Manuscript received March 11, 2008; revised July 2, 2008. This work was supported by the National High-Tech Research Program of China (Grant No.2006AA01Z125), the National Natural Science Foundation of China (Grant No. 60775007) and the Shanghai Committee of Science and Technology, China (Grant No.08511501700).

J. Li, L.Q. Zhang, H. Sun and Q.B. Zhao are with the Department of Computer Science and Engineering, Shanghai Jiao Tong University, Shanghai 200240, P.R. China (e-mail: lijie1216@sjtu.edu.cn; zhang-lq@cs.sjtu.edu.cn; jeremiah@sjtu.edu.cn; qbzhao@sjtu.edu.cn).

D.C. Tao is with the School of Computer Engineering, Nanyang Technological University, 50 Nanyang Avenue, Blk N4, Singapore, 639798 (e-mail: dacheng.tao@gmail.com).

Copyright (c) 2006 IEEE. Personal use of this material is permitted. However, permission to use this material for any other purposes must be obtained from the IEEE by sending a request to pubs-permissions@ieee.org.