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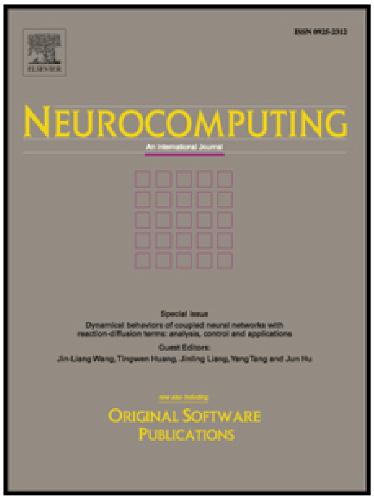

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Multiclass Support Matrix Machine for Single Trial EEG Classification

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Abstract

We propose a novel multiclass classifier for single trial electroencephalogram (EEG) data in matrix form, namely multiclass support matrix machine (MSMM), aiming at improving the classification accuracy of multiclass EEG signals, and hence enhancing the performance of EEG-based brain computer interfaces (BCIs) involving multiple mental activities. In order to construct the MSMM, we propose a novel objective function, which is composed of a multiclass hinge loss term and a combined regularization term. We first formulate the multiclass hinge loss by extending the margin rescaling loss to support matrix-form data. We then devise the regularization term by combining the squared Frobenius norm of tensor-form model parameter and the nuclear norm of matrix-form hyperplanes extracted from the model parameter. While the Frobenius norm prevents over-fitting when training the model, the nuclear norm captures the structural information within the matrix data. We further propose an efficient solver for MSMM based on the alternating direction method of multipliers (ADMM) framework. We conduct extensive experiments on two benchmark EEG datasets. Experimental results show that MSMM achieves much better performance than state-of-the-art classifiers and yields a mean kappa value of 0.880 and 0.648 for dataset IIIa of BCI III and dataset IIa of BCI IV, respectively. To our best knowledge, MSMM is the first classifier that supports multiclass classification for matrix-form EEG data. The proposed MSMM enables easier and more efficient implementation of robust multi-task BCIs, and therefore has potential to promote the wider use of BCI technology.

Keywords: Brain computer interface (BCI), electroencephalograph (EEG), support vector machine (SVM), support matrix machine, multiclass classification, alternating direction method of multipliers (ADMM)

1. Introduction

Brain computer interfaces (BCIs) have emerged as a new and promising communication mode between human and computers with the development of neuroscience and engineering over the last 20 years [1]. They capture brain signals associated with mental activities and transform them into commands to communicate with or control external machines. BCIs not only benefit people with severe motor impairments caused by various neuromuscular disorders through restoring their communication and movement ability [2, 3], but also find a lot of applications for healthy individuals, such as virtual reality systems [4, 5] and games [6, 7]. The brain signals employed in BCIs can be measured by several techniques, mainly including electroencephalogram (EEG), magnetoencephalogram (MEG), functional magnetic response imaging (fMRI) and functional