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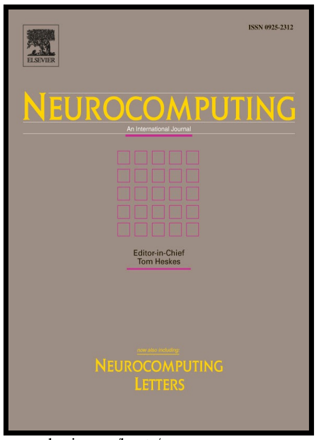

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Hidden-layer visible deep stacking network optimized by PSO for motor imagery EEG recognition

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Abstract:

A novel method called PSO optimized hidden-layer visible deep stacking network (PHVDSN) is proposed for feature extraction and recognition of motor imagery electroencephalogram (EEG) signals. A prior knowledge is introduced into the intermediate layer of deep stacking network (DSN) and the hidden nodes are expanded by the unsupervised training of restricted Boltzmann machine (RBM) for the parameter initialization. Then particle swarm optimization (PSO) is applied to optimize the input weights, aiming at alleviating the risk of being immersed in the curse of dimensionality. The performance of the proposed method is evaluated with real EEG signals from different subjects. Experimental results show that the recognition accuracy of PHVDSN is superior to some state-of-the-art feature extraction algorithms. Furthermore, on another benchmark data set where the EEG sessions for each subject are recorded on separated days, the proposed method is demonstrated to be robust against transferring from session to session.

Keywords: deep stacking network, restricted Boltzmann machine, particle swarm optimization, feature extraction, EEG recognition

1. Introduction

Brain computer interface (BCI) [1] has potential application value in many fields such as medical treatment, military and entertainment. In a BCI system, the key technology is the feature extraction and classification of EEG data. Electroencephalogram data are considered as time-series data consisting of sampled points taken from a continuous, real-valued process over time and there are some characteristics that distinguish it from other types of data. Firstly, high-dimensional EEG data are often mingled with noises. Secondly, it is not certain that there is enough information available to understand the process. Further, time-series have an explicit dependency on the time variable. Besides, EEG data are also non-stationary, which means the characteristics of the data, such as mean, variance, and frequency, change over time. In conclusion, high-dimensional and complex with unique properties, Electroencephalogram data are challenging to analyze and model.

Over past years a lot of studies have been focused on the feature extraction and recognition of EEG data. Wu S and Wu W [2] applied the common spatial pattern (CSP) to feature extraction and the linear discriminate analysis (LDA) to the classification of motor imagery EEG data and obtained an average recognition rate of 80% for two subjects. A discriminative criterion called extreme energy ratio (EER) is proposed by Sun S [23] to help people understand the intuitive signification and conceivable efficacy of the feature extraction method. The EER is demonstrated to be theoretically equivalent to CSP but much easier to understand and use. Extreme energy difference (EED) [24] holds a similar idea to EER but with a different objective function and it can be regarded as a beneficial complement to CSP. Suk et al. [3] proposed a novel Bayesian framework, in which the problem of simultaneous spatio-spectral filter optimization is formulated as the estimation of an unknown posterior probability density function and it was used for discriminative feature extraction of motor imagery EEG classification. In [4], a performance analysis on AdaBoost, LPBoost, RUSBoost, Bagging and Random Subspaces for classification of 3-class motor imagery EEG data was presented and the best classification