Title: A fresh look at functional link neural network for motor imagery-based brain-computer interface

Author: Imali T. Hettiarachchi Toktam Babaei Thanh Nguyen Chee P. Lim Saeid Nahavandi

PII: S0165-0270(18)30131-6
DOI: https://doi.org/doi:10.1016/j.jneumeth.2018.05.001
Reference: NSM 7996

To appear in: *Journal of Neuroscience Methods*

Received date: 12-12-2017
Revised date: 18-4-2018
Accepted date: 3-5-2018

Please cite this article as: Imali T. Hettiarachchi, Toktam Babaei, Thanh Nguyen, Chee P. Lim, Saeid Nahavandi, A fresh look at functional link neural network for motor imagery-based brain-computer interface, *<![CDATA[Journal of Neuroscience Methods]]>* (2018), https://doi.org/10.1016/j.jneumeth.2018.05.001

A fresh look at functional link neural network for motor imagery-based brain-computer interface

Imali T. Hettiarachchi*, Toktam Babaei, Thanh Nguyen, Chee P. Lim, Saeid Nahavandi

Institute for Intelligent Systems Research and Innovation, Deakin University

Abstract

Background: Artificial neural networks (ANN) is one of the widely used classifiers in the brain computer interface (BCI) systems-based on noninvasive electroencephalography (EEG) signals. Among the different ANN architectures, the most commonly applied for BCI classifiers is the multilayer perceptron (MLP). When appropriately designed with optimal number of neuron layers and number of neurons per layer, the ANN can act as a universal approximator. However, due to the low signal-to-noise ratio of EEG signal data, overtraining problem may become an inherent issue, causing these universal approximators to fail in real-time applications.
New Method: In this study we introduce a higher order neural network, namely the functional link neural network (FLNN) as a classifier for motor imagery (MI)-based BCI systems, to remedy the drawbacks in MLP.
Results: We compare the proposed method with competing classifiers such as linear decomposition analysis, naïve Bayes, k-nearest neighbours, support vector machine and three MLP architectures. Two multi-class benchmark datasets from the BCI competitions are used. Common spatial pattern algorithm is utilized for feature extraction to build classification models.
Comparison with Existing Method(s): FLNN reports the highest average Kappa value over multiple subjects for both the BCI competition datasets, under similarly preprocessed data and extracted features. Further, statistical comparison results over multiple subjects show that the proposed FLNN classification method yields the best performance among the competing classifiers.
Conclusions: Findings from this study imply that the proposed method, which has less computational complexity compared to the MLP, can be implemented effectively in practical MI-based BCI systems.

Keywords:
Motor imagery, Brain computer interface, Functional link neural network, Multi-class, Classification

1. Introduction

The goal of a brain-computer interface (BCI) system is to translate brain signals to a control command of an external device (Fig. 1). The most widely used input to the BCI systems is the brain activity recorded via Electroencephalography (EEG). EEG is a non-invasive brain imaging technique, which records the brain's electrical signals using scalp mounted passive electrodes. The popularity of EEG over other imaging techniques is due to its non-invasiveness, low cost, portability and superior time resolution suitable for real-time applications [1].

BCI systems-based EEG inputs are characterised with different signatures of the recorded signal. The brain responses such as P300 event related potential (ERP), steady state visual evoked potentials (SSVEP), event related synchronization/ desynchronization (ERS/ ERD) and slow cortical potentials (SCP) are such characteristics that can be tracked and detected from an EEG signal [2]. Among them, our focus will be on the BCI systems which are referred to as motor imagery (MI)-BCI, operating on the ERS/ERD characteristics [3].

MI-based BCI uses movement imagery related brain signals to control different assistive devices and for rehabilitation purposes. The success of the MI-BCI system relies on extracting features that reliably describe the different MI states. Spectral domain features such as fast Fourier transform (FFT) [4], wavelet transform (WT) [5, 6] and autoregressive (AR) have been widely used for MI-BCI systems. To handle inherent non-stationarity issues of the EEG signals, extensions of the aforementioned methods, including short-time FFT [7], adaptive autoregressive (AAR) [8, 9], multivariate adaptive autoregressive modelling [10, 11] have also been proposed. Common spatial pattern (CSP) algorithm is identified by the BCI community as a powerful tool in extracting features for MI. The CSP features are widely accepted for MI-based BCIs owing to its resemblance to the ERS/ERD phenomenon in MI [12, 13]. In the present study, we use CSP algorithm to extract the features from the MI EEG recordings.

Improving the performance of MI-BCI systems with respect to classification accuracy is a key topic widely discussed among the BCI research community. The performance of the pattern recognition system depends on the features that describe a signal, as well as the embedded classification algorithm. To this end, a wide variety of classification algorithms and their strengths

*Corresponding author
URL: imali.hettiarachchi@deakin.edu.au (Imali T. Hettiarachchi)