BCILAB: A Toolbox for Rapid Development of Advanced BCI Designs

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Abstract. BCILAB is a new open-source MATLAB-based toolbox aimed at helping advance the state of the art in designing and building Brain-Computer Interfaces (BCIs) and Cognitive Monitoring systems with a focus on electrophysiological signals. These systems translate, in real time, brain and/or other biosignals into control signals useful to computer applications, thereby offering communication and control pathways to their users that extend the brain's natural motor output channels. To address the challenges of accurately and robustly translating a person's brain signals into estimates of cognitive/affective state, and of solving the related inverse problems given the least amount of (relatively costly-to-acquire) data, BCILAB includes an extensible component framework for advanced signal processing, machine learning and related probabilistic inference, optimization and system evaluation, which covers over 100 methods and method variants. To validate the toolbox implementation we present analysis results for several data sets (17 subjects total) pooled from the BCI Competitions III and IV.

Keywords: BCI, EEG, Toolbox, MATLAB, CSP, Motor Imagery

1. Introduction

Here we present BCILAB, a new open-source toolbox for MATLAB (The Mathworks, Natick, MA) that attempts to facilitate both the development of new BCI approaches and implementations as well as comparisons with methods already published in the scientific literature.

The main design aim of BCILAB is to assist practitioners in the experimental neurosciences, the computational and mathematical sciences, and in application design and engineering in efficiently developing and testing new brain-computer interface (BCI) models. Both a graphical user interface (GUI) shown in Fig. 1 and a scripting interface are provided to allow researchers to perform analysis and online experiments. A complementary set of plug-in frameworks allow methods developers to rapidly implement new methods and make them available for later re-use in numerical and real-time experiments, as well as to test new methods against already existing approaches.

2. Material and Methods

To validate the overall toolbox implementation we replicate a part of the analysis performed in [Lotte and Guang, 2011], which itself is a comprehensive re-analysis of publicly available data sets from the BCI Competitions III and IV, together comprising data from 17 subjects. The underlying task is a variant of the well-established motor imagery scenario (cf. [Pfurtscheller and Neuper, 2001]), which is one of the two most frequently used experimental designs in the clinical BCI field and a widely accepted benchmark. An analysis of event-related potential phenomena as relied on, for example, by P300 spellers [Farwell and Donchin, 1988] is omitted here due to space limitations.

3. Results

The mean and median classification accuracy of all algorithms across the data from all subjects is summarized in Table 1. Chance level here is 50%. In agreement with the reference analysis by [Lotte and Guang, 2011], the highest accuracy across all the data is attained by the three regularized variants of the basic Common Spatial Pattern (CSP) algorithm: using Tikhonov regularization (TRCSP), diagonal loading regularization (DLCSPcv) and the recently-proposed DLCSPauto which uses regularized shrinkage estimators for the covariance matrices on which CSP is based. We also present results for the Spectrally Weighted Common Spatial Patterns (Spec-CSP) approach by [Tomioka et al., 2006] as a representative method that learns its spectral filter adaptively.

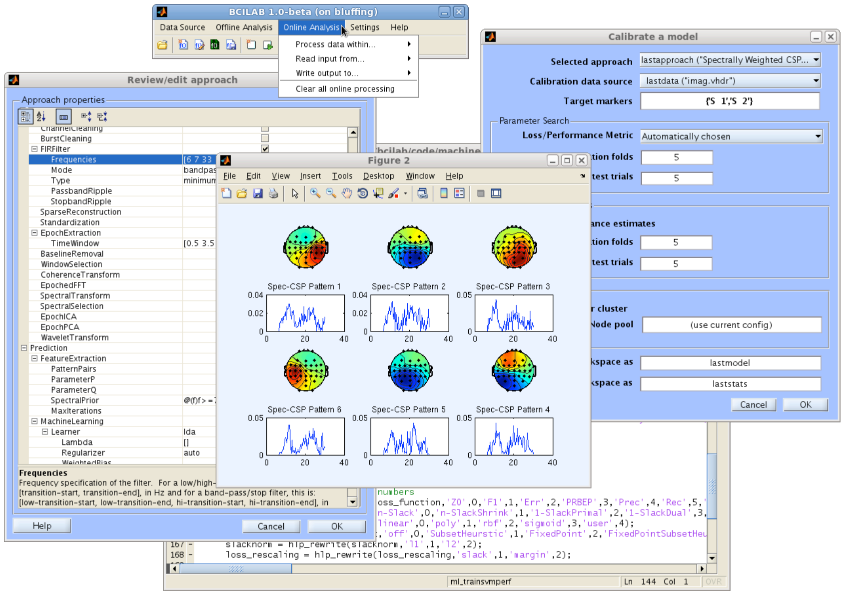

Figure 1. *A sample subset of BCILAB's graphical user interface panels showing the main menu, a model visualization, a model configuration dialog, an evaluation setup dialog, and the script editor.*

Table 1. *Classification accuracy of a representative sample of algorithms for oscillatory processes applied to motor imagery data across 17 subjects from the BCI Competitions III and IV.*

Algorithm	*Median Accuracy (%)*	*Mean/Std. Dev. Accuracy*
CSP	75.8	75.8±15.3
TRCSP	75.8	75.2±15.4
DLCSPcv	76.2	75.9±16.0
DLCSPauto	**78.2**	**75.9±16.3**
Spec-CSP	77.4	75.3±17.1

4. Discussion

The results of the presented method comparisons show that state-of-the-art BCI performance can be achieved by applying BCILAB to a representative BCI task. The methods used in the analysis support online processing and are part of the open-source toolbox and available at ftp://sccn.ucsd.edu/pub/bcilab/.

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