 DOI: 10.3217/978-3-85125-467-9-178

Efficient Transfer Learning in Brain Computer Interfaces using Spectral Meta Learning

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Introduction: Recent advances in signal processing and machine learning techniques have enabled the application of Brain-Computer Interface (BCI) technologies to fields such as medicine, industry and recreation.. Despite the recent progress, the non-stationary nature of EEG, as well as user-to-user and session-to-session variability require most BCI systems to employ time-consuming and costly calibration sessions. The use of transfer learning techniques to minimize or eliminate this need for calibration data is an area of on-going interest for the development of practical BCI systems. This study aims to eliminate the need for calibration sessions and develop a user-independent BCI using an unsupervised ensemble technique called the Spectral Meta-Learner (SML) [1]. We apply the SML as a fusion algorithm to combine the predicted outputs of several training subjects subject whose individual classifier models were developed using information geometric classifiers (Minimum Distance to the Riemannian Mean- MDRM [2]). The effectiveness of this approach is demonstrated in a single-trial ERP detection for a rapid serial visual presentation (RSVP) task.

Material, Methods and Results: Thirty-two subjects were analyzed with a leave-one-out method where 31 subjects were used as training data to transfer to the left-out subject. MDRM models from the 31 training subjects made individual predictions to the test subject and the SML algorithm was used to fuse the output of the ensemble in an unsupervised fashion. Figure 1 shows the balanced accuracy (the average of sensitivity and specificity) of the SML as a BCI transfer method compared to several other ensemble based transfer learners. Figure 1 also shows the ceiling performance of traditional within-subject learner where 10 minutes of training data are used to build an MDRM model and the rest of the remaining data from that subject is used for testing.

The pairwise transfer method, where the model from a single training subject is transferred to the test subject performed the worst from all the methods analyzed with an average balanced accuracy of 61%. The SML method achieved performance comparable to the within subject classifier and outperformed all of the tested transfer methods including the traditional un-weighted (majority vote) and the Riemannian-distance based ensemble where the Riemannian distance was used to weight the individual models in the ensemble.

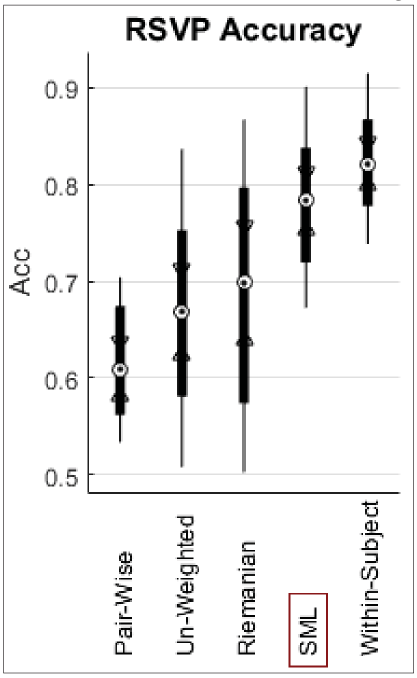

Figure 1. *Single trial RSVP balanced accuracy for the proposed SML method compared to other ensemble learners and the traditional calibration learner.*

Discussion: The proposed SML ensemble technique for transfer learning was able to achieve single trial ERP detection with a performance that is comparable to traditional within-subject calibration. Additionally, this method outperforms existing ensemble techniques for BCI transfer including the traditional majority voting scheme and the recently developed Riemannian distanced based transfer learning technique.

Significance: This study shows that unsupervised transfer learning for single-trial detection in ERP based BCIs can be realized to achieve practical performance levels that are comparable to within-subject classification. This represents a step-forward in the goal to completely eliminate the need for BCI calibration for a user-independent BCI system.

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