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TSMNet for BCI: online, unsupervised adaptation

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Introduction: Besides generalization across days (=sessions) and subjects, brain-computer interfaces (BCIs) for healthcare require a high degree of interpretability while being robust to scarce data. Recent works [1-3] indicate that geometric deep learning, combing deep learning with Riemannian geometry, has the potential to meet this demand for EEG-based BCI systems. In [1], we proposed a geometric deep learning framework to learn typical tangent space mapping (TSM) models [4] end-to-end. With an intrinsically interpretable neural network architecture, denoted TSMNet, we obtained state-of-the-art performance in EEG-based BCI inter-session and -subject unsupervised domain adaptation (UDA) problems. Here, we propose an unsupervised adaptation scheme to extend our framework to data stream settings (i.e., online BCI).

Methods and Results: TSMNet [1] relies on domain-specific batch normalization (DSBN) on the symmetric positive definite (SPD) manifold to align the first and second order moments across domains in latent space. To extend DSBN on the SPD manifold to a data stream setting, we evaluate several initialization and online algorithms to estimate the Fréchet mean and variance of unseen domains. Using BCI competition dataset 4a, we found (Figure 1) that (1) the initialization and adaptation methods quickly converge to the performance of the oracle (=TSMNet with UDA on entire target domain data), (2) the previous session's mean and variance drastically improve initial performance upon standard normal (identify matrix and unit variance) initializations, and (3) in inter-subject transfer, finetuning the classification layer to session 1 of the target subject performs as well as inter-session transfer.

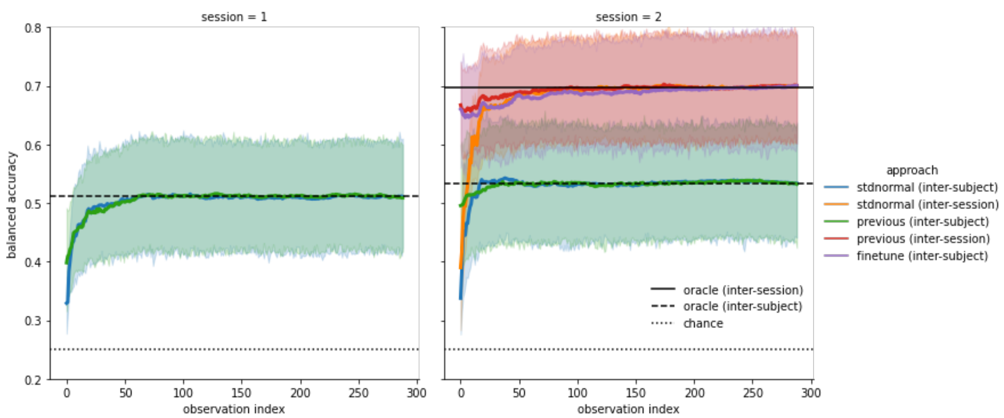

Figure 1. Session 1(left panel) and 2 (right panel) test set performance (balance accuracy score) over the observations index (1 to 288) as a function of the considered initialization schemes and unsupervised transfer learning settings (inter-session and -subject).

Discussion and Significance: Our simulation results with a single dataset suggest that TSMNet can be readily adapted to unseen sessions and subjects without retraining the entire model.

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