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Recruiting Neural Field Theory for Motor Imagery Data Augmentation

Daniel Polyakov[1*], Oren Shriki[1]
[1]Ben-Gurion University, Beer Sheva, Israel
*P.O. Box 653, Beer Sheva, Israel. E-mail: polydani@post.bgu.ac.il

Introduction:

Brain-computer interfaces (BCIs) allow for controlling computer and robotic applications directly with brain activity. A common problem in BCI systems is poor classification accuracy due to a lack of diverse training data, which is typically collected during exhausting calibration sessions. A possible solution to increase the amount of training data is augmenting them with a computational model of neural dynamics. Here, we focus on Neural Field Theory (NFT), a powerful technique for constructing physiologically-inspired models of large-scale brain activity. These models can be fitted to experimental EEG spectra and generate artificial EEG time series accordingly [1].

Materials, Methods and Results:

We fitted NFT models to common spatial patterns (CSP) of each MI class, jittered the fitted parameters, and augmented trials by generating CSP signals from the models. We computed the total power (TP) of the CSPs as well as their Higuchi Fractal Dimension (HDF) and applied Linear discriminant analysis (LDA) to classify MI states based on these features. We used the "2a" dataset from BCI competition IV to test the accuracy improvement. To imitate a small training set, we randomly split the dataset into 3 equal folds and used the first fold for training and NFT augmentation, and the other 2 folds for validation (see Figure 1). Using the TP feature, we reached a classification accuracy of κ=0.82 (Cohen's Kappa) for the full training set, κ=0.79 for the small training set, and κ=0.83 for the augmented training set. In comparison, an augmentation that was based on adding Gaussian noise to the features yielded κ=0.76 for the augmented training set. HDF feature didn't present an improvement in accuracy.

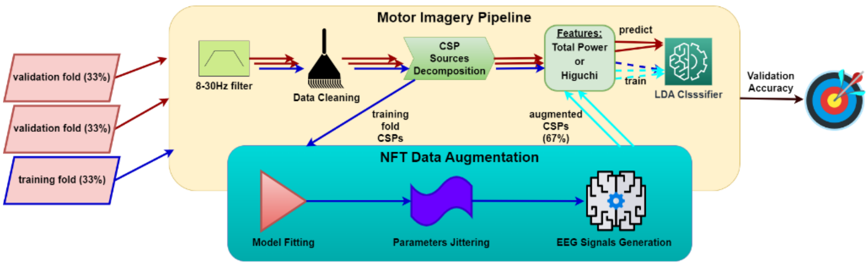

Figure 1: Data augmentation experiment flow

Discussion:

NFT-based data augmentation successfully improved classification accuracy to the level of a full training set. It performed much better than noise-based augmentation suggesting that NFT generates a signal with a more realistic distribution. The improvement was present for TP-based classification but not for HFD-based, implying that NFT generates EEG signals that better encompass spectrum-based features rather than time-domain-based features.

Significance:

Our findings demonstrate that data augmentation using a physiological model (here NFT) can improve the accuracy of BCI classifiers when the number of training samples is limited. This approach provides biophysical meaning to the generated signals and can improve accuracy to the level of a large, diverse training set.

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References:

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