Can transfer learning across motor tasks improve motor imagery BCI?

Fabien Lotte, Andrzej Cichocki

Can transfer learning across motor tasks improve motor imagery BCI?

Fabien Lotte[1,2], Andrzej Cichocki[2,3]

1 Inria, LaBRI (Univ. Bordeaux, CNRS, Bordeaux-INP), France

2 RIKEN BSI, Wakoshi, Japan

3 SKOLTECH, Moscow, Russia

Introduction:

Motor Imagery (MI)-BCIs are among the most used types of BCIs, and proved useful for multiple applications including assistive technologies, gaming or stroke rehabilitation, among others [1]. However, in practice, their performances are limited and a substantial proportion of users fail to control them [2]. One of many potential causes could be that for many first time users, performing MI is new and difficult, and can thus lead to unclear MI EEG patterns. Therefore, calibrating an MI-BCI on such unclear EEG examples can lead to suboptimal EEG features and BCIs. In this work, we explored whether we could improve such features and BCI by using EEG from other motor tasks, e.g., executed or observed movements, for which the resulting EEG motor activity pattern may be clearer. In particular, we proposed a machine learning method to take into account such data into spatial filters optimization.

Material, Methods and Results:

We recorded EEG data (64 channels, Biosemi) from 12 subjects who performed 4 types of foot motor tasks. They imagined (imagined walking), executed (feet dorsiflexion), observed (watched a video of someone walking, first person view) or simultaneously observed and imagined foot movements. Each motor task was performed both slowly and quickly (fast movements being twice faster than slow ones). Subjects also performed resting state trials. For each subject, there is on average 22.7 trials for each motor/rest task and each speed, after rejecting noisy trials.

We aimed at improving foot MI classification (here, MI vs Rest) by using EEG from another foot motor task for calibration. To do so, we designed a new regularized variant of the common spatial patterns (CSP) spatial filter [3], which aims at finding spatial filters w that can maximize the discriminability of rest EEG versus foot MI and another foot motor task at the same time. In other words, we look for spatial filters targeting a common brain source between foot MI and another foot motor task. We expect this could ease the identification of good subject-specific motor-related EEG features. Formally, we optimize spatial filters w so that they extremise the function $w' ((1-a)C_{mi} + aC_o) w / w' C_r w$, where C_{mi}, C_o and C_r are the covariance matrices of foot MI, another foot motor task and rest EEG respectively. Variable 'a' is the regularization strength, optimized using MI vs Rest inner cross-validation (CV) classification accuracy (CA) on the training set. We used this method to optimize CSP filters in the 8-30Hz band, applied this filter on MI vs Rest EEG data, and trained a Linear Discriminant Analysis to classify the resulting band power features from MI and Rest. Training and testing was done using leave-one-run-out CV.

The standard CSP+LDA approach on MI vs Rest led to an average CA of 71.9%, while the proposed transfer learning method reached a CA of 74.4% when using executed foot movements as regularizer. A two-way repeated measure ANOVA with factors speed (slow vs fast movement) and method (standard vs regularized CSP) showed a trend towards significance for the performance difference between methods (p=0.07). The other two motor tasks did not seem to help when used as regularizer though (CA observed: 71.4%, observed+imagined: 72.6%).

Discussion:
This study needs to be extended by including more subjects, to confirm or infirm the usefulness of executed foot movements in improving foot MI BCI. We could also explore additional motor tasks, such as passive movements. Nonetheless, we proposed a new method to incorporate EEG from additional motor tasks. On a small subjects set (N=12), this method could improve average decoding performances, with a trend towards statistical significance.

Significance:
Although further analysis and confirmation is required (more subjects are being included), this study suggested a new way to improve MI-BCI design, by exploiting additional, non-MI, motor tasks and proposed a new machine learning method to do so.

Acknowledgment: We acknowledge support from the Japanese Society for the Promotion of Science, the European Research Council (grant ERC-2016-STG-714567) and the French national Research Agency (grant ANR-15-CE23-0013-01).

References:

[1] Clerc et al, Brain-Computer Interfaces 2, ISTE-Wiley, 2016

[2] Alison & Neuper, Brain-Computer Interfaces, Springer, 2010

[3] Lotte & Guan, IEEE TBME, 2011