Improving EEG Neurofeedback with Advanced Machine Learning and Signal Processing tools from Brain-Computer Interfaces Research

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Workshop Title:

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What methodology or tool would you like to introduce?

In this workshop we would like to present various machine learning and signal processing tools that we and others developed to process EEG signals in real-time, and that could be used to substantially improve current standard EEG-based NeuroFeedback (NF) training processes. The tools we will present were mostly designed to build EEG-based Brain-Computer Interfaces (BCIs), i.e., systems that can decode users' mental states in real-time from their EEG signals. As such, their signal processing tools promise to be very useful for EEG-NF research and practice as well. We notably plan to present various adaptive EEG spatial and temporal filters, which would enable NF practionners to find robust subject-specific NF features, in individually, and functionally relevant brain areas and frequency bands. Such tools notably include spatio-spectral filters such as inverse solutions (e.g., LORETA), common spatial patterns (CSP) and variants (RCSP, FBCSP, etc), Independent Component Analysis (ICA) or Source Power Comodulation (SPoC). We will also present briefly some more advanced, state-of-the-art processing tools such as Riemannian geometry-based EEG analysis or Tensor analysis and notably Tensor Regression. All these tools have the potential to extract much more specific and robust EEG signatures and features for EEG-NF.

Why is this tool important for neurofeedback research?

Most typical EEG-NF use very basic processing tools, typically the power in a single channel and single fixed frequency band as target NF feature. However, it is known that the EEG signal a single EEG channel reflects the brain activity from multiple brain areas and not a single one. Moreover, the spatial and spectral signature of a given cognitive function (e.g., attention, used for Attention Deficit Hyper Activity Disorder NF for instance) is known to vary substantially from one patient to the next. Thus using a fixed and single EEG channel and frequency band must be suboptimal, possibly not relevant for the current patient, and cannot be specific to the target cognitive function only. Thus, using more advanced signal processing and machine learning tools would make it possible to 1) really extract spatial and spectral features that are specific to the target cognitive function and not to another one, using dedicated spatial and spectral filters; and 2) to identify from EEG data (examples) the individual EEG signature of this target cognitive function for each user.

What imaging modalities does this apply to?

Most of the tools we plan to describe are specific to EEG signal processing. Some of them though, such as ICA, Riemannian geometry or Tensors and Tensor Regression, could be applied to any modality, including fMRI. Most of our examples will be on EEG.

Is this a commercially available product, potentially commercially available, or open source?

This is an ensemble of machine learning and signal processing tools. Most of them are actually freely available in open-source toolboxes (e.g. ICALab, EEGLab, etc) and real-time EEG processing software (e.g., OpenViBE). We will mention where to find them.

What is the proposed schedule of speaker(s)?

- 0-15min (Fabien Lotte)
    - Introduction: presentation of EEG-BCI, EEG-NF, their similarities and differences
    - Limitations of standard EEG-NF processing tools
    - The BCI signal processing and machine learning approach
- 15-45min (Fabien Lotte)
    - Basic spatial filters for EEG (Laplacian, Bipolar)
    - Inverse solutions
    - Common Spatial Patterns (CSP)
    - CSP and spatio-spectral optimization variants
    - Source Power Comodulation (SPoC)
- 45min-1h15 (Andrzej Cichocki)
    - Independent Component Analysis (ICA)
    - Tensors and Tensor Regression
- 1h15-1h30 (Fabien Lotte)
    - Riemannian Geometry
    - Conclusion and perspectives