Master 2 Internship – EEG signal processing of signal recorded during EEG-fMRI acquisition.

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Duration: 5 to 6 months, starting in 2023

Keywords: Signal processing, EEG, bi-modal, Neurofeedback

Context:

Electroencephalography (EEG) directly measures changes in electric potentials occurring in the brain in real-time with an excellent temporal resolution (milliseconds), but a limited spatial resolution (around a centimetre), due to cortical currents volume conduction through head tissues, and the ill-posed inverse problem of source localisation. On the other hand, functional magnetic resonance imaging (fMRI) offers a better spatial resolution (a few millimetres) but has slow dynamics (one or two seconds) as it measures hemodynamic activities, which occur in general, a few seconds after a neural event. Both EEG and fMRI are non-invasive methods that are indirectly coupled and measure complementary aspects of human brain activity.

Simultaneous EEG-fMRI recording has been used to understand the links between EEG and fMRI in different states of brain activities and has received recognition as a promising multi-modal measurement of brain activity. Furthermore, recent studies [Perronnet et al. 2017] have shown the high potential of combining EEG and fMRI in a bimodal Neurofeedback training (i.e., feeding back in "real-time" a subject with a score reflecting his or her own brain activity to self-regulate brain areas or networks, targeted by a neural rehabilitation) to achieve advanced self-regulation, by providing a more specific estimation of the underlying neural activity.

However, EEG-fMRI analysis is limited by the corruption of EEG signals under the MRI environment. During EEG-fMRI acquisition, EEG signals are altered by extremely strong gradient artefacts and, as the motion of a closed electrical circuit in a magnetic field induces an electric current (Lenz-Faraday law), the signal is also affected by artefacts induced by any motion or vibration in the strong static magnetic field (MR motion-related artefacts) such as head motion, the pulsatile motion of scalp arteries, the vibration of the ventilation system, and cardiac activity. Gradient artefacts can be fairly by a hybrid mean and median moving average corrected [Grouiller et al. 2016] or Optimal Basis Sets [Niazy et al. 2005] approaches. For MR motion-related artefacts, methods were proposed based on Optimal Basis Set [Wu et al. 2016] or ICA [Mayeli et al. 2016]. However, the evaluation of artefact correction

methods' performance is not trivial since the true EEG signal without artefacts is unknown. Also, most studies evaluate the reduction of the artefacts but without addressing the problem of signal preservation, and it has been shown that over-filtering degrades the EEG signal [Steyrl et al. 2019].

Objectives:

The goal of this internship is first, to implement and compare the different state of the art approaches found in the literature that allows to reduce the noise on EEG signals when recorded under fMRI. Then to explore different metric related to the EEG signal that can help to assess the quality of the EEG signal correction, and determine the metrics or the combination of metrics that best describe the quality of the corrected EEG signal. We will focus on the artefact correction related to the cardiac activity.

Main activities:

- Bibliographic research
- Processing EEG signals with different software
- Implementation of a state-of-the-art method
- Designing an EEG signal processing pipeline
- Definition of adapted metric to measure the EEG signal quality

additional activities:

- Take part in the acquisition of EEG-fMRI data (with or without neurofeedback training)
- Present the work progress during lab seminar
- Interact with other researchers

Requirements:

- Good knowledge in applied mathematics and/or computer science.
- Strong interest in neuro-imaging.
- Knowledge in signal processing.

How to apply?

Please send us the following information and documents:
- Updated CV
- Your grades and ranking of your master degree
- A motivation letter
- A recommendation letter, or the contact of a teacher or a supervisor who could recommend your application.
- The 6 months during which you are due to complete your master internship.