Master 2 Internship - 2024

Signal processing of EEG recorded during EEG-fMRI acquisition

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Scientific environment: Empenn U1228, IRISA, Campus de Beaulieu, Rennes - https://team.inria.fr/empenn/

Duration: 5-6 months

Starting date: début 2024

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

Context:

This stage will be co-supervised by researchers between Rennes University Hospital, Empenn lab (Rennes, France) and the University of Geneva. You will have the possibility to participate to the acquisition of EEG-fMRI data at the Neurinfo platform.

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 training for brain rehabilitation. It allows 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 by artefacts from the pulsatile motion of scalp arteries and cardiac activity, among others. Gradient artefacts can be fairly corrected by a hybrid mean and median moving average [Grouiller et al. 2016] or Optimal Basis Sets [Niazy et al. 2005] approaches. Other MR-related artefacts, notably cardiac activity artefacts are more difficult to correct, in particular in the case of arythmic subjects. Also, the evaluation of artefact correction methods' performance is not trivial.

Aims of the internship:

The goal of this internship is 1/ to implement several different state-of-the-art approaches found in the literature that allow reducing artefacts related to cardiac activity on EEG signals when recorded under fMRI. 2/ to estimate connectivity matrices from corrected and non-corrected EEG signals in order to compare them 3/ to study the variability in connectivity matrices to identify the most robust approach to correct for cardiac activity artefacts. 4/ to compare EEG and fMRI connectivity matrices within the different correction scenarios. 5/ to explore the dynamic of bimodal connectivity in order to achieve advanced self-regulation of brain 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

Location:

The recruited person will work at Inria/IRISA, UMR CNRS 6074, among the Empenn U1228 team. The work will be in close link with the research MRI platform Neurinfo (http://www.neurinfo.org) and clinicians working on depression.

Requirements:

We look for candidates strongly motivated by challenging research topics in neuroimaging. The applicant should present a good background in applied mathematics and/or computer science. Basic knowledge in image processing would be a plus.

References :

Perronnet, L., Lécuyer, A., Mano, M., Bannier, E., Lotte, F., Clerc, M., & Barillot, C. (2017). Unimodal versus bimodal EEG-fMRI neurofeedback of a motor imagery task. Frontiers in Human Neuroscience, 11, 193.

Grouiller, F., Jorge, J., Pittau, F., van der Zwaag, W., Iannotti, G. R., Michel, C. M., ... & Lazeyras, F. (2016). Presurgical brain mapping in epilepsy using simultaneous EEG and functional MRI at ultra-high field: feasibility and first results. Magnetic Resonance Materials in Physics, Biology and Medicine, 29, 605-616.

Nuttall R, El Mir A, Jäger C, Letz S, Wohlschläger A, Schneider G. Broadly applicable methods for the detection of artefacts in electroencephalography acquired simultaneously with hemodynamic recordings. MethodsX. 2023 Sep 14;11:102376. doi: 10.1016/j.mex.2023.102376.