Offre n°2024-07532

PhD Position F/M Machine learning for efficient bimodal EEG-fMRI neurofeedback

Le descriptif de l'offre ci-dessous est en Anglais

Type de contrat : CDD

Niveau de diplôme exigé : Bac + 5 ou équivalent

Fonction : Doctorant

A propos du centre ou de la direction fonctionnelle

The Inria Centre at Rennes University is one of Inria's nine centres and has more than thirty research teams. The Inria Centre is a major and recognized player in the field of digital sciences. It is at the heart of a rich R&D and innovation ecosystem: highly innovative PMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute, etc.

Contexte et atouts du poste

The project lies at the interface of signal and image processing, behavioural neuroscience and neurofeedback. Neurofeedback approaches (NF) (see [1] for a complete and actual introduction), also known as restorative brain-computer interface (restorative BCI), consist in providing real-time feedback to a patient about his or her own brain activity in order to learn how self-regulate specific brain regions and help him or her perform a given task. The estimation of neurofeedback scores is done through online brain functional feature extraction relying for the majority on electroencephalography (EEG) or functional magnetic resonance imaging (fMRI). Recent studies [2, 3, 4] have shown the high potential of combining EEG and fMRI in a bi-modal NF training (i.e., NF scores are estimated in real-time from features of both modalities) to achieve an improved self-regulation, by providing a more specific estimation of the underlying neural activity. NF is a very promising brain rehabilitation technique for psychiatric disorders, stroke and other neurological pathologies.

Measures of brain activity through fMRI or EEG are ground solutions in the context of NF for brain rehabilitation protocols and EEG is currently the only modality used by NF clinical practitioners. EEG, which directly measures changes in electrical potential occurring in the brain in real time, has an excellent temporal resolution (hundreds of milliseconds), but has a limited spatial resolution (around centimeter) due to cortical currents volume conduction through head tissue. On the other hand, fMRI offers a better spatial resolution (few millimeters) but has slow dynamics (one or two seconds) as it measures neuro-vascular (i.e. changes in the blood oxygenation level) activities, which occurs in general, a few seconds after a neural event [5, 6]. Moreover, using a MRI scanner is costly, exhausting for patients (since staying perfectly still when suffering is challenging), and time-consuming.

Although exceptional progress has been obtained during the past decades to explore the human brain, researches based on different neuro-imaging modalities are crucial to shed light on the variety of human brains, as well as understanding the complex link between anatomical and functional properties of the brain [7, 8].

References :

[1] Sitaram, R., Ros, T., Stoeckel, L., Haller, S., Scharnowski, F., Lewis-Peacock, J., Weiskopf, N., Blefari, M. L., Rana, M., Oblak, E., Birbaumer, N., and Sulzer, J. Closed-loop brain training: the science of neurofeedback. Nature Reviews Neuroscience 18, 2 (Feb. 2017), 86–100.

[2] Zotev, V., Mayeli, A., Misaki, M., and Bodurka, J. Emotion self-regulation training in major depressive disorder using simultaneous real-time fMRI and EEG neurofeedback. NeuroImage: Clinical 27 (2020), 102331.

[3] Zotev, V., Phillips, R., Yuan, H., Misaki, M., and Bodurka, J. Self-regulation of human brain activity using simultaneous real-time fMRI and EEG neurofeedback. NeuroImage 85 (Jan. 2014), 985–995.

[4] Perronnet, L., Le�cuyer, A., Mano, M., Bannier, E., Lotte, F., Clerc, M., and Barillot, C. Unimodal Versus Bimodal EEG-fMRI Neurofeedback of a Motor Imagery Task. Frontiers in Human Neuroscience 11 (Apr. 2017).

[5] Friston, K. J., Jezzard, P., and Turner, R. Analysis of functional MRI time-series. Human Brain Mapping 1, 2 (1994), 153–171.

[6] Logothetis, N. K., Pauls, J., Augath, M., Trinath, T., and Oeltermann, A. Neurophysiological investigation of the basis of the fMRI signal. Nature 412, 6843 (July 2001), 150–157.

[7] Sui, J., Adali, T., Yu, Q., Chen, J., and Calhoun, V. D. A review of multivariate methods for multimodal fusion of brain imaging data. Journal of Neuroscience Methods 204, 1 (Feb. 2012), 68–81.

[8] Sui, J., Jiang, R., Bustillo, J., and Calhoun, V. Neuroimaging-based Individualized Prediction of Cognition and Behavior for Mental Disorders and Health: Methods and Promises. Biological Psychiatry 88, 11 (Dec. 2020), 818–828.

[9] Pinte, C., Fleury, M., Maurel, P. Deep learning-based localization of EEG electrodes within MRI acquisitions. Frontiers in Neurology, 2021.

Mission confiée

Relying on this context, the goal of this thesis is to investigate and propose methods to provide more specific and efficient NF training to participants. This thesis will seek to address the following two challenges 1/ Machine learning for EEG electrods detection on T1 MRI, the most standard acquisition sequence.
2/ This will help to consider new EEG features and to predict fMRI activity using EEG signals.

EEG electrodes detection:
The localization of EEG electrodes in the 3D MRI volume is key information for optimizing neurofeedback protocols and developing more precise EEG targets. As these electrodes are designed to be the least visible possible on MRI, we have developed a first automatic method [9] for detecting them in particular MRI sequences (PETRA sequences). This method has very good results but requires additional acquisition time, and the sequence is not always available on all MRI scanners. In this thesis, the first task will be to develop a new automatic algorithm for detecting electrodes on anatomical MRI scans (systematically acquired during neurofeedback protocols).
In particular, we will study the possibility of having a mixed model based on a real physical model of the EEG headset on the one hand, and on a term learned on residuals by an AI model on the other.

Prediction of fMRI activity using EEG signal :
The main idea is to model EEG and fMRI signals to understand the link between those signals and optimise the feature extraction from EEG when used alone. This objective lies in the data fusion domain, as it is of great interest for neuroscience studies and, as said, to understand the link between measures extracted from both signals. This understanding will allow us to propose models to extract fMRI information using EEG signals. A first step would be to predict fMRI activity lying right under an EEG channel using its positioning, and then extend the model to the brain regions targeted by the NF training. Such a predictive model will make it possible to envisage lighter neurofeedback rehabilitation protocols (relying less on the cumbersome use of MRI) by enriching EEG-only sessions with information learned during simultaneous sessions.

Medical imaging data :
The particularity of medical imaging data such as EEG and fMRI, is that the ground truth of brain activity is not known and the signals are noisy. It will be important to integrate apriori in the model and to build a "ground truth" that would be the most plausible. Data used for this PhD will come from existing datasets.

Principales activités

- Analyse and process EEG and fMRI data
- Propose methods for EEG electrods detection
- Develop document and integrate developed methods in a software
- Propose models to link EEG and fMRI signals
- Write scientific paper for conferences and journals
- Co-supervise master student's internship

Compétences

The candidate must have a strong background in computer science and applied mathematics, and show an interest in medical images.
The candidate must be fluent in English.

Avantages

- Subsidized meals
- Partial reimbursement of public transport costs
- Possibility of teleworking (90 days per year) and flexible organization of working hours
- Partial payment of insurance costs

Rémunération

Monthly gross salary amounting to 2100 euros for the first and second years and 2190 euros for the third year

Informations générales

- **Thème/Domaine :** Neurosciences et médecine numériques
  Calcul Scientifique (BAP E)
- **Ville :** Rennes
- **Centre Inria :** Centre Inria de l'Université de Rennes
- **Date de prise de fonction souhaitée :** 2024-10-01
- **Durée de contrat :** 3 ans
- **Date limite pour postuler :** 2024-05-31

Contacts

- **Équipe Inria :** EMPENN
- **Directeur de thèse :**
  Cury Claire / claire.cury@inria.fr

A propos d'Inria

Inria est l'institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 215 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3900 scientifiques pour relever les défis du numérique, souvent à l'interface d'autres disciplines. L'institut fait appel à de nombreux talents dans plus d'une quarantaine de métiers différents. 900 personnels d'appui à la recherche et à l'innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 200 start-up. L'institut s'efforce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l'économie.

L'essentiel pour réussir

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Consignes pour postuler

Please submit online : your resume, cover letter and letters of recommendation eventually

Sécurité défense :
Ce poste est susceptible d'être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L'autorisation d'accès à une zone est délivrée par le chef d'établissement, après avis ministériel favorable, tel que défini dans l'arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l'annulation du recrutement.

Politique de recrutement :
Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.