The Inria Rennes - Bretagne Atlantique Centre is one of Inria's eight centres and has more than thirty research teams. The Inria Center is a major and recognized player in the field of computer science and more specifically in the construction of a rich and lively innovation ecosystem, highly innovating PMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute, etc.

A propos du centre ou de la direction fonctionnelle

Key words: EEG, fMRI, Signal processing, Brain imaging, Machine learning, Neurofeedback

Context and motivation

The project lies at the interface of signal and image processing, behavioural neuroscience and neurofeedback. Neurofeedback approaches (NF) (see [7] 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 on the relativity on electroencephalography (EEG) or functional magnetic resonance imaging (fMRI). Recent studies [13, 12, 6] 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 [12].

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 potentials occurring in the brain in real time, has an excellent temporal resolution (hundreds of milliseconds), but has a limited spatial resolution (around centimetre) due to cortical currents volume conduction through head tissue. On the other hand, fMRI offers a better spatial resolution (few millimetres) 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 [3, 4]. 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 healthy and disordered human brains, as well as understanding the central question is to identify the origin of a failure [1, 8]; it can be due to (1) the complex link between anatomical and functional properties of the brain [9, 10].

Before providing NF training of improved quality and adaptable to the participant, one central question is to identify the origin of a failure [1, 8]; it can be due to (1) the signals feature extraction, (2) a too difficult task, (3) the patient’s inability to learn via NF [11], or (4) a lack of attention from the patients (are they actively trying to change their brain activity?) during the task [2]. Also, motivation should be enhanced, if possible, and the prevailing attention of the participants should be monitored [5]. As highlighted in [1], to obtain the best success in NF sessions, it is suggested to personalise and adapt NF session to the participant, which is the main objective of this PhD thesis.

Methodological Objectives:

Relying on this context, the goal of this thesis is to investigate and propose methods to provide improved and adaptable NF trainings to participants. This thesis will seek to address 2 of the following challenges, regarding the candidate profile:

1. Monitoring and analysing participant’s motivation in real time during NF training. This objective will require to design a new protocol for NF training using eye-tracking and skin conductance devices, to first monitor signal, before analysis. Then optimal feature extraction will be studied to detect drops and increase in motivation.

2. Investigating adaptable targets to avoid the too difficult task issue, by proposing new NF scores computation and determining a hierarchy between different NF scores computations based on EEG and fMRI signals. This objective will focus on the differences and complementarity aspects of measures extracted from EEG and fMRI signals. New bi-modal EEG-fMRI NF target will be proposed and combinations between both modalities and different measures extracted will be analysed.

3. Modelling of EEG and fMRI signals to understand the link between those measures.
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 for the previous objective to understand the link between measures extracted from both signals. This understanding will allow developing models to extract fMRI information using EEG signal.

References:


Mission confiée Supervision

The PhD candidate will be supervised by Dr Pierre Maurel (pierre.maurel@inria.fr) and Dr Claire Cury (claire.cury@inria.fr)

Job environment

The successful candidate will join the Unit/Project Empenn - U1228. This research team is jointly affiliated with Inserm (national institute of health and medical research), Inria (national institute of computer science and applied mathematics research) and belongs to the IRISA Institute (UMR CNRS 6074, University of Rennes 1). The team is located in Rennes, France and has offices in both the medical and the physical sciences campuses. More information can be found at: https://team.inria.fr/empenn. The project will also benefit from transverse collaborations with clinical projects through the Neurinfo experimental platform located at the University Hospital in Rennes (cf. http://www.neurinfo.org/), one of the few imaging platform in the world equipped with bi-modal neurofeedback technology.

Principales activités

- Analyse NF training data (EEG, fMRI, NF scores,...)
- Propose learning / modeling / regression methods to adress different challenges
- Design experimental protocol for objective (1)
- Write scientific journal and conference papers

Compétences

- Signal and image processing
- Knowledge or strong interest in machine learning, modelling and statistics
- Knowledge or strong interest in neuroimaging or neuroscience
- Strong experience in programming, especially in Python and/or Matlab will also be valued
- Interest in data acquisition (for new NF training recording)
- Very good understanding of English

The candidate should feel at ease in an environment of scientific dynamics and should want to learn, explore, interact and listen.
Avantages
- Subsidized meals
- Partial reimbursement of public transport costs

Rémunération
Monthly gross salary amounting to 1982 euros for the first and second years and 2085 euros for the third year