2019-01487 - PhD Position F/M [Campagne CORDI-S] Network features for brain-computer interfaces

Type de contrat : CDD de la fonction publique
Contrat renouvelable : Oui
Niveau de diplôme exigé : Bac + 5 ou équivalent
Fonction : Doctorant
Niveau d'expérience souhaité : Jusqu'à 3 ans

Contexte et atouts du poste

Brain-computer interfaces (BCIs) are increasingly explored for control and communication, as well as for treatment of neurological disorders, particularly via the ability of subjects to voluntary modulate their brain activity through mental imagery (MI) [1].

Despite this technique has gained a wide territory in the last years, the community is still facing a critical issue in terms of performance as measured by the correct classification of the user's intent [2]. While much of the efforts to solve this problem have focused on the classification block of the BCI, the research of alternative features has been poorly explored and rather crude univariate measurements, such as the signal band power of single brain areas, have been used so far [3].

However, the brain is not just a collection of isolated pieces working independently, but it rather consists of a distributed complex network that integrates information across differently specialized regions [4]. It turns out that examining the signal of one specific region – while neglecting its interactions with other regions – oversimplifies the real phenomenon and one must instead obtain an understanding of the system's collective behavior to fully capture the brain functioning. This project aims to extract new features from brain connectivity networks derived from functional neuroimaging data during BCI-related tasks.

Mission confiée

The main goal of the project is to develop a methodological framework based on network science to derive innovative features that better discriminate BCI-related mental states [5].

Specifically, this project aims to:

- Introduce new connectivity features based on graph theory that explicitly take into account the spatial nature of the brain,
- Validate the network features in existing EEG datasets of MI tasks involving healthy subjects and stroke patients
- Test the potential in new EEG MI-based BCI experiments involving healthy subjects and, eventually, stroke patients

Principales activités

Development of network features

The main thrust consists in conceiving and designing new graph theoretic indices that are suitable to characterize the mental states in typical BCI scenarios. Starting from the state-of-the-art, different types of indices characterizing different topological scales of the network (eg, nodes, groups of nodes, entire network) will be developed. A particular attention will be devoted to the adaptation of these indices to the spatial nature of the brain network where the nodes correspond to specific brain regions/EEG sensors and this geometry needs to be incorporated into the graph index definition. The developed indices will be first validated on synthetic networks generated from known models and then tested on actual brain networks derived from functional connectivity estimated from EEG signals.

Data processing and BCI experiments

The second thrust consists in processing and analyzing EEG data from existing databases and from new ones to be acquired in the course of the project. This includes EEG preprocessing to improve the signal-to-noise ratio of the brain data, functional connectivity estimation to construct the brain networks' links, and the extraction of the brain network features by the application of the developed graph indices. The design and realization of new BCI experiments involving healthy subjects and stroke patients will mainly consist in organizing a series of EEG recording sessions and performing MI-based BCI tasks in collaboration with the PI's team and the neuroimaging core facility.

Result evaluation and report

The obtained results will be evaluated with respect to those obtained with standard approaches and interpreted from a methodological and neuroscience perspective. This procedure will allow to emphasize the strong aspects and identify the weak points that can be addressed in the future, and those that must to be solved in the course of the project. All the conducted research activity will be reported and shared with the PI's team and published in written documents and/or presented in appropriate international conferences.

References

[1] M. Hamedi, S.-H. Salleh, and A. M. Noor, "Electroencephalographic Motor Imagery Brain Connectivity Analysis for BCI: A Review," *Neural Computation*, vol. 28, no. 6, pp. 999–1041, May 2016.

[2] M. C. Thompson, "Critiquing the Concept of BCI Illiteracy,"*Sci Eng Ethics*, pp. 1–17, Aug. 2018.

[3] L. Bougrain, M. Clerc, and F. Lotte, *Brain-Computer Interfaces 1: Methods and Perspectives*. John Wiley & Sons, 2016.

[4] E. Bullmore and O. Sporns, "Complex brain networks: graph theoretical analysis of structural and

Informations générales

- **Thème/Domaine :** Neurosciences et médecine numériques
  Biologie et santé, Sciences de la vie et de la terre (BAP A)
- **Ville :** Paris
- **Centre Inria :** CRI de Paris
- **Date de prise de fonction souhaitée :** 2019-10-01
- **Durée de contrat :** 3 ans
- **Date limite pour postuler :** 2019-05-26

Contacts

- **Equipe Inria :** ARAMIS
- **Directeur de thèse :**
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A propos d'Inria

Inria, l'institut national de recherche dédié aux sciences du numérique, promeut l'excellence scientifique et le transfert pour avoir le plus grand impact. Il emploie 2400 personnes. Ses 200 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3000 scientifiques pour relever les défis des sciences informatiques et mathématiques, souvent à l'interface d'autres disciplines. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 160 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

This project will be realized in the Inria ARAMIS team "Algorithms, models and methods for images and signals of the human brain" at the Institut du Cerveau et de la Moelle (ICM) in Paris. The team has a privileged position within a unique scientific and technological environment with a strong program on neurofeedback and BCIs as well as with a comprehensive neuroimaging core facility (eg, M/EEG, fMRI, DTI, NIRS), including a powerful centralized cluster computer system to realize big-data analysis and simulation. All the MI-based BCI data needed to validate the methodology, as well as the authorization to perform new EEG experiments on stroke patients, are already available in the framework of existing research projects granted to the PI's team.

Consignes pour postuler

La candidature doit contenir :

CV
lettre de motivation
notes de master
Des lettres de recommandation peuvent être envoyées directement à la personne au recruteur.

The application must contain:

CV
cover letter
master's notes
Letters of recommendation can be sent directly to the recruiter.

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

functional systems," *Nature Reviews Neuroscience*, vol. 10, no. 3, pp. 186–198, Mar. 2009.

[5] F. De Vico Fallani and D. S. Bassett, "Network neuroscience for optimizing brain–computer interfaces," *Physics of Life Reviews*, Jan. 2019.

Compétences

The ideal candidate should have a solid background in data analysis and/or signal processing, enjoy high comfort levels when dealing with mathematical abstractions/modeling as well as programming (C++ or Octave-based preferably). The knowledge of BCI-related software (eg, OpenViBE, BCI2000) is welcome but not necessary. The ability and willingness to learn will do equally well. Written and spoken English is required.

Avantages

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Rémunération

1982 € la première et la deuxième année, 2085 € la troisième année.

1982 € during the first and second years, 2085 € the last year.

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.

Attention: Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d'autres canaux n'est pas garanti.