PhD position

Modeling brain structural and functional connectivity in neurodegenerative diseases

Supervisors: Julie COLOIGNER (julie.coloigner@irisa.fr)
Giulia LIOI (giulia.lioi@imt-atlantique.fr)

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

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Keywords : Neuroimaging, Neuroinformatic, Graph, Functional MRI, Diffusion MRI, tractography, Graph signal processing.

Context:

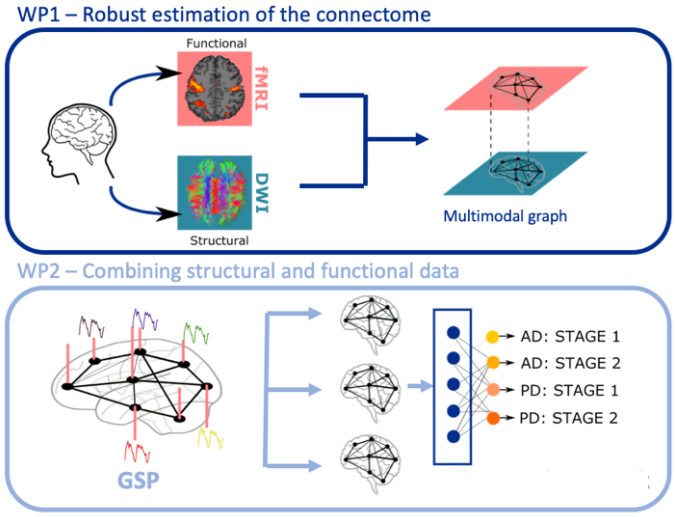
The neurodegenerative diseases like Alzheimer's (AD) and Parkinson's (PD) disease are the consequences of pathological processes that begin decades before the onset of the typical clinical symptoms [1][2]. However, current diagnosis comes quite late in the course of the disease, while evidences underline the multiple benefits that would be associated with earlier diagnosis [3]. An outstanding challenge for clinical neurosciences is therefore to provide reliable, non-invasive, affordable and easy-to-track biomarkers able to improve both the early detection and the monitoring of neurodegenerative diseases, that can be applied at an individual level. It is well acknowledged that AD and PD display a progressive multifactorial disruption of cerebral networks, all along the course of the diseases, which is highly related to the clinical phenotype [4].

In the search for those biomarkers, the introduction of non-invasive imaging techniques, such as functional magnetic resonance imaging (fMRI) and diffusion weighted imaging (DWI), prompted important discoveries to provide a comprehensive map of neural connections, known as the connectome. The field of network science for analyzing the connectome offers new insights into networks disruptions that are characteristic of specific brain disorders [5]. Mathematical modelling using graph theory, which appeared in neuroimaging at the beginning of this century, provides powerful quantitative tools and measures for the analysis of complex cerebral networks [6][7]. Undirected brain connectivity has been classified in two categories: (i) structural connectivity estimated by DWI, where links represent axons or neuronal fiber density or (ii) functional connectivity (measured for instance with fMRI) where links represent statistical dependencies between brain signals from different areas, such as correlations, coherence, or transfer entropy. However, prior studies have largely focused on the comparison between patients suffering from AD or PD versus healthy subjects. As a result, the relevance of the reported alterations in brain network may be limited due to a lack of specificity. Indeed, the extracted features that are sensitive to AD or PD may well reflect common neurodegenerative processes, therefore lacking specificity for the disease-related physiopathology at the individual level. Integrating simultaneously these modalities could yield a powerful tool, to expand the knowledge of our brain and to exhibit robust biomarkers of AD and PD, more sensitive to pathophysiological changes.

Scientific objectives:

The major scientific objective for this PhD will be to look at how the integration of these advanced MRI techniques may allow a better definition of the brain change patterns in different states of AD and PD. To do so, the PhD student will first evaluate methodologies to jointly analyze functional and structural neuroimaging data, such as a recent framework called Graph Signal Processing (GSP)[8], [9]. Indeed,

this approach is particular promising to shed new light on the complex interplay between brain function and structure, by jointly analyzing functional activity and the underlying structural connectome. Another approach is the multilayer networks to combine both structural and functional graphs [10].



After that, he will develop a new multimodal and multi-stage approach using **innovative machine learning (ML) methods,** adapted for multimodal features, to provide non-invasive, **reliable and easy-to-track candidate biomarkers** for each stage of AD and PD diseases. The PhD student will apply the developed approach on two large patients' cohorts and, then, assess the effectiveness of candidate disease-specific biomarkers on a new innovative local multimodal cohort including patients with and without cognitive impairment, at various stages of the diseases. The proposed PhD project is an part of a long-term project, funded by the French research agency (ANR).

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 Pierre-Yves Jonin, neuropsychologist in CHU Rennes and Neurologists working on Alzheimer's and Parkinson's diseases.

The candidate will also benefit of a multidisciplinary environment, as within the context this thesis, the Empenn team will closely collaborate with the BRAIn team, specialized in addressing key questions at the crossbreed of Artificial Intelligence, Deep Learning and Signal Processing.

IRISA is a French laboratory for research and innovation in digital science and technology and offers a PhD funding. Successful candidates will also benefits of annual paid holidays and social insurance.

Requirements:

We look for candidates strongly motivated by challenging research topics in machine learning and neuroimaging. The applicant should present a good background in machine learning and applied mathematics. Basic knowledge in image processing would be a plus. Good knowledge of computer science aspects is also mandatory, especially in Python and Matlab.

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.

References :

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