## INTERNSHIP: Deep learning based segmentation of the brainstem using neural networks pre-trained on other areas of the brain

### Basic information

Place of internship: ISEP campus at Issy-Les-Moulineaux (92130, subway "Corentin Celton" on line 12). Laboratoire d'Imagerie Biomédicale (LIB; Sorbonne Université, Inserm, CNRS), Sce de Rééducation, Hôpital de la Pitié-Salpêtrière (75013, subway "St Marcel" on line 5 or "Chevaleret" on line 6).

Internship beginning: As early as late February 2023

Internship duration: 5 to 6 months

Remuneration: internship stipend

Contacts: Dr. Jérémie Sublime (jsublime@isep.fr), Dr. Véronique Marchand-Pauvert (veronique.marchand-pauvert@inserm.fr)

Remarks: This internship may lead to a PhD grant.

### Required background

Cursus: Ongoing M2 or ING3 in artificial intelligence, machine learning, or applied statistics

Skills: Image processing, image segmentation, machine learning (supervised or unsupervised), a practical experience with deep neural networks (using pyTorch or Tensorflow) will be strongly appreciated (CNN, YOLO, U-Nets, or W-Nets)

### Project

Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease affecting motor neurons in the central nervous system, leading to progressive paralysis and death within 2-5 years after the first symptoms, most often due to respiratory failure. There is no therapy with a satisfactory effect on survival and quality of life. The diagnosis is usually long (12-18 months), thus delaying a proper follow-up and possible inclusion in clinical trials. Furthermore, assessing the prognosis of patients (rapid or slow progression, response to innovative therapies) is difficult with current tools used in clinical routine. However, several studies have shown that multimodal magnetic resonance imaging (MRI) gives rise to valuable metrics for patients evaluation and prognosis[1,2].

Among the structures of the central nervous system, the brainstem is of particular interest in ALS. It is located between the brain and the spinal cord, and englobes motor neurons that are crucial for patient survival (respiratory control). Accordingly, it has been shown that atrophy of the brainstem lower part, quantified using anatomical MRI, helps to predict respiratory failure (before the first symptoms) and anticipate its clinical management[3]. However, to date, no methodology exists for a fine segmentation of brainstem structures, especially to distinguish between white (myelinated axons –emerging from neuron somi– supporting structural connectivity between populations of neurons) and grey matter (structures grouping neuron somi, called nuclei). The objective of the internship is therefore to study whether deep learning applied to multimodal MRI data would enable a precise segmentation of the brainstem and the delineation of brainstem nuclei and white matter.

### Challenges

While the brainstem has been identified as one of the areas primarily affected by ALS, it remains difficult to segment using multimodal MRI data due to the poor spatial resolution and the low contrast of the images. For these reasons, in this internship, we propose to train deep neural networks on subcortical brain areas such as the thalamus and the basal ganglia, for which annotated information (in terms of distinction between grey and white matter) are more easily available. We expect that what the algorithm learned in higher regions of the brain can be re-used in lower regions of the central nervous system such as the brainstem, assuming that both kinds of regions contain the same types of tissues and structures.

The challenges and scientific barriers for this project are numerous. First, multimodal MR images include many artifacts (e.g. geometric distortions due to eddy currents, magnetic susceptibility effects or subject motion) and present between-subjects and between-modalities registration issues, which make them difficult to use without proper preprocessing. Second, when going down from the brain towards the spinal cord, structures tend to get smaller and harder to detect. Finally, in the brainstem the limits between white and grey matter get blurred since neuronal density in brainstem nuclei is lower than that in subcortical brain nuclei.

A multimodal MRI dataset acquired in 26 patients with ALS and 27 healthy volunteers is available in LIB. The dataset comprises conventional structural images (so-called T1-weighted and T2-weighted images, enabling grey vs. white matter distinction), diffusion-weighted images (enabling to further characterize the structure of the axons in white matter), and atlas images of subcortical regions. The image preprocessing has already been done in LIB using conventional methodology and the trainee will be informed about the pipeline used.

This internship will have several goals:

- proposing deep learning methods for the segmentation of the different types of tissues (grey vs. white matter) in the brain.
- assessing the hypothesis that what can be learned in subcortical brain regions can be re-used to segment other regions of the central nervous system such as the brainstem.
- If possible, using the two above points to propose a segmentation of the brainstem in both healthy controls and patients.

It is worth mentioning that while the internship's main field is computer science, this project may lead to breakthroughs in neurosciences and neurology, and specifically in the evaluation of patients with ALS. Therefore, the intern will be working within a mixed team of medical doctors, neuroscientists, experts in MRI data processing and specialists in deep learning.

## References

1. Querin G. et al. Multimodal spinal cord MRI offers accurate diagnostic classification in ALS. J Neurol Neurosurg Psychiatry. 2018;89(11):1220-1221.

2. Grolez G. et al. The value of magnetic resonance imaging as a biomarker for amyotrophic lateral sclerosis: a systematic review. BMC Neurol. 2016;16(1):155.

3. Grolez G. et al. MRI of the cervical spinal cord predicts respiratory dysfunction in ALS. Sci Rep. 2018;8(1):1828.

## Collaborations

This project relies on a collaboration between ISEP and a team of LIB at Pitié-Salpêtrière Hospital in Paris.