APOGEE BIO -POSTDOC GENOPOLE/IBISC

Titre : Apprentissage profond et décomposition tensorielle pour l'analyse de l'imagerie multimodale en imagerie cérébrale et advisable IA.

Title: Deep learning and tensor decomposition for the analysis of multimodal imaging in brain imagery and advisable AI.

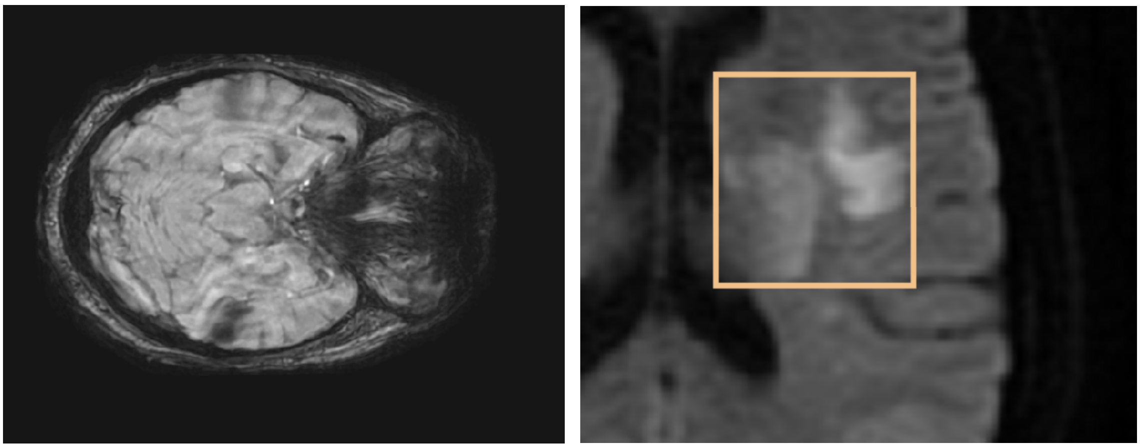
Partners : IBISC (univ Evry, université Paris-Saclay), centre hospitalier sud-francilien (CHSF)
Basic AI and Data Science : statistical training in big dimensions
Specialized ML and AI : signal, image, vision
Application domain : precision medecine, imagery by MR
Mots-clés deep learning, imagerie multi-modale, weekly supervised learning, self-attention
Key-words machine learning, deep tech, neuroimaging, precision medicine, stroke
total duration of postdoc 24 months
Working period : 2024/09/01 to 2026/09/01
€3000 net monthly salary for 24 months.

Deadline for submission: February 28, 2024

Context and objectives

According to the World Health Organization, **stroke** is the second cause of death and the leading cause of chronic functional disability in adults, with 17 million victims, 31% of whom were under the age of 65. More than 6 million people die from stroke worldwide each year.
In France, each year around 150,000 people are hospitalized for a stroke, one every 4 minutes with an average cost of 19 k€. It is estimated that 750,000 people have survived a stroke, two thirds of which will have disabling consequences, which represents a financial burden for the state of around 2.8 billion €/year… in reality 10 billion over 5 years due to the cost of handicap.

The ischemic stroke is caused by a blood clot (thrombus) that blocks a brain artery causing lack of oxygen brain tissue supplied by that artery (Fig. 1). There is an urgent need to diagnose and determine if a treatment with thrombolytic drugs (anti-coagulants) can "reverse" the stroke. The response time is limited and should not exceed 3 to 4 hours after the onset of symptoms. Confronted with the management of a stroke, the doctor then asks 3 questions to which the imagery provides particularly relevant answers: is it really a stroke? Is the stroke ischemic or hemorrhagic in nature? If thrombolysis is considered, are there any radiological contraindications to this treatment? There is consensus that **magnetic resonance imaging (MRI)** is the gold standard for eliminating non-vascular diagnoses because of its sensitivity and specificity in acute ischemia.



(a) Image de SWAN

(b) Lesion showing an intensity comparable to that of normal tissue

Figure 1: (a) Visualization of a lesion on a diffusion MRI showing the different stages of development. Most publications deal only with well-developed lesions that take advantage of high intensity boundaries (2b) For the hyperacute phase, weak or zero borders and low intensities complicate the task of segmentation.

Hospital reception therefore favors the speed of access to the neurovascular unit (NVU) and MRI to confirm the diagnosis of cerebral infarction or cerebral hemorrhage: early treatment (< 4,5 h) limits the severity of the sequelae. If MRI makes it possible to search for the cause of the lesion, it raises many **methodological difficulties** linked to the very progressive pathophysiology of stroke in the very first hours. There has not been until nom a complete automatic tool for the simultaneous segmentation of lesions to date.

Objectives

The solution that we implement is based on the automatic segmentation of the infarct's areas and ischemic tissues at risk. The application of AI and neural networks to the analysis of images makes it possible to work on a large amounts of data in a more relevant way than conventional image processing methods.
But the price to pay is in too long simulation time and interpretability globally. We propose several solutions.

First , the latent space of NN layers can be structured in **tensor form**, which provides very good performance [Pan21]. It has been shown that this allows a compromise in terms of performance and interpretability. However, this preliminary work leaves significant room for progress, and the properties of this type of hybrid model are still poorly understood.
Automatic learning on tensor data is classically carried out by linear tensor decomposition, for example CPD/PARAFAC or Tucker [Sid17]. Recently, tensor representations have been integrated into neural networks and have enabled significant developments in deep learning, particularly in the field of images, by reducing the number of parameters to be estimated.
To increase the **identifiability** and **interpretability** of deep neural models, constraints are added, for example non-negativity, classic in a matrix and tensor learning framework [Kol08].

Another issue is the confidence of the neurologist in the segmentation of the ROI. Doctors might choose to rely on their expertise until AI solutions prove to be consistently reliable and widely validated. Doctors can interpret the context of the entire patient case. They consider not only the imaging data but also the patient's medical history, symptoms, and other relevant clinical information. This **holistic approach** is crucial for accurate diagnosis and treatment planning. This is why advisable AI will help integrating AI into medical practice. Advisable AI recognizes the value of human clinical judgment and expertise. Instead of replacing doctors, it assists them by providing suggestions and insights. Advisable AI recognizes these variations due to factors like imaging equipment differences, patient characteristics, and variations in imaging protocols and acknowledges the potential limitations of automatic segmentation algorithms. Human experts can adjust their approach based on this understanding.

At last, **longitudinal studies** of stroke patients allow to observe the natural progression of stroke over time and gain comprehensive insights into the trajectory of the disease and its treatment. But also to evaluate the long-term impact of different treatments, rehabilitation strategies, medications and long-term complications, including cognitive decline, motor impairments, and psychological issues. Longitudinal studies enable the identification of biomarkers associated with stroke recovery. This knowledge is crucial for developing targeted therapies and precision medicine approaches tailored to individual patient profiles.

The objectives are to validate the results on **multi-center large patient databases** and to integrate the model into clinical application software.

Work program

The difficulty of obtaining a sufficient amount of reliable class-specific training data for a supervised automatic approach requires the study of new strategies.

First of all, we will establish a benchmark of the different approaches. Then we will modify the constraints which structure the tensor decomposition in an auto-encoder/Tucker decomposition type model. We will evaluate and compare the characteristics of several deep NN architectures.

The new architectures will be improved with an advisable **AI implementation**.

Then the longitudinal study will be set and biomarkers will be studied.

A solution suggested by very recent studies [Bra19] proposes to develop new generic salience functions or to use the data augmentation method to build a robust classification as well as other parameters such as texture or shape.
Evaluating the new procedure against a referenced procedure raises many methodological difficulties. The **performance indicators** are
1. the **repeatability** of the (deterministic) segmentation process in a degraded situation or not,
2. the **efficiency** of the tool to be tested on a ground truth basis and quantified with DICE [3] to measure performance in segmentation,
3. the **speed of inference**, including the **normalization** of the MR images.

References

[Kol08] Kolda, Bader, « Tensor decompositions and applications », in: SIAM review 51.3 (2009), pp. 455–500.

[Sid17] Sidiropoulos et al. « Tensor Decomposition for Signal Processing and Machine Learning »IEEE Transactions on Signal Processing, 2017.

[Pan21] Panagakis et al. « Tensor Methods in Computer Vision and Deep Learning » Proceedings of the IEEE, https://doi.org/10.1109/JPROC.2021.3074329

[Bra19] Ikram Brahim et al. Deep Learning Methods for MRI Brain Tumor Segmentation: a comparative study. In 9th IEEE International Conference on Image Processing Theory, Tools and Applications (IPTA 2019), Istanbul, Turkey, November 2019.

[Rie10] Christian H. Riedel et al. Assessment of thrombus in acute middle cerebral artery occlusion using thin-slice nonenhanced computed tomography reconstructions. Stroke, 41(8):1659–1664, 2010.

[San14] Emilie M. M. Santos et al., and on behalf of the MR CLEAN investigators. Development and validation of intracranial thrombus segmentation on ct angiography in patients with acute ischemic stroke. PLOS ONE, 9(7):1–8, 07 2014.

Profile and skills required
The recruited person will be a PhD in computer sciences/AI, able to understand and develop adaptive learning algorithms and to process medical datasets and use them in an operational system to achieve the mission described above.

Programming skills: A practice of Tensorflow and Pytorch is mandatory. French is not an issue. His(her) English is fluent. The work will be carried out at the IBISC Laboratory located on the Evry campus of the UPSaclay. IBISC develops multidisciplinary, theoretical and applied research in the field of information sciences and engineering, with a strong orientation towards health applications. The selected candidate will have the chance to work in an interdisciplinary team and with a consortium of data scientists and clinicians from the CHSF hospital. The project is multidisciplinary, at the interface of machine learning, computer science and medicine.

The call is open to researchers of any nationality. The candidate should have a PhD or four years of experience as a researcher; he/she must be among the first three authors for at least one manuscript, either published, in press or accepted for publication. Candidates can apply within the four years following the obtainment of their PhD or after four years of research experience.

Contact: send resume to

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