Ph.D. position in Artificial Intelligence and Medical Imaging:

An Assembly of CNNs for the Prediction of Neurological Diseases

PhD Director: Dr. Pierrick Coupé / LaBRI UMR 5800 (pierrick.coupe@labri.fr)
Co-supervisor: Dr. Michael Clément / LaBRI UMR 5800 (michael.clement@labri.fr)

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Laboratory : Laboratoire Bordelais de Recherche en Informatique, Université de Bordeaux

Collaborators :

- **CHU de Bordeaux / Neurocentre Magendie** : Dr. Thomas Tourdias
- **Institut des neurosciences** (INCIA) : Dr. Gwenaëlle Catheline
- **Université polytechnique de Valence** (Espagne) : Pr. José Manjon

Context:

Magnetic resonance imaging (MRI) plays a crucial role in the detection of pathologies, the study of brain organization and clinical research. Every day, a large amount of data is produced and this amount is constantly increasing, preventing the use of manual approaches to analyse it. Thus, the development of reliable, robust and rapid techniques for the detection of neurological pathologies is becoming an important field in medical imaging. In this thesis project, the objective is to develop a new generation of MRI analysis methods that can automatically detect neurological diseases.

Objectives:

The first objective will be to develop new methods of pathology detection by addressing the current limitations of deep learning (DL) in medical imaging. DL is a rapidly growing field in computer vision thanks to its many successes. However, the results obtained by deep learning in computer-aided diagnosis of neurological diseases are still quite limited [1].

In this thesis, the candidate will therefore propose a new generation of methods capable of overcoming the current limitations of DL for computer-aided prognostic. In particular, She/He will build on our recent work based on the use of a large number of DL networks (more than 200 in parallel) to segment MRI scans of the brain. Until now, Artificial Intelligence (AI) methods have not been able to extract the brain structures (more than 100) from an MRI. Indeed, the complexity of the problem but also the lack of available training data prevent DL methods to achieve this task [2].

In order to solve this problem, we have recently developed a method based on an assembly of artificial intelligences (AIs) [3]. Inspired by the functioning of a parliamentary system, in our approach AIs can exchange information and participate in decision-making by voting. The use of a large number of AIs organized in an assembly allows to simplify the problem because each AI only process a sub-part of the brain. Moreover, this strategy enables to obtain a better final decision because it is based on the consensus of 250 AIs working together. If many works exist on the improvement of the architecture of AIs inspired by biology and neurosciences, we are forerunners in the use of a large number of AIs inspired by the human society.

The first results obtained show an improvement of more than 30% in the quality of segmentation compared to the use of a single AI. However, many questions remain open in this new and very promising research path. What is the optimal organization of this large number of AIs? How to make them communicate effectively? How to improve their learning by using non-labelled data through semi-supervised learning? The candidate will study these different questions and propose solutions adapted to the problem addressed.

The second objective will focus on the development of specific tools for two pathologies: multiple sclerosis (MS) and Alzheimer's disease (AD). These two diseases account for approximately 2.5 million people with MS and 46.8 million people with AD

worldwide. For AD alone, the associated global cost is estimated at $605 billion. The candidate will work closely with our collaborators at the Bordeaux University Hospital, the Neurocentre Magendie and the Institute of Neuroscience (INCIA). She/He will therefore have access to experts in these two pathologies. By developing methods for an earlier and more precise diagnosis, this project will allow a better management of the patient, a better treatment and thus a reduction of the associated costs. Thus, our project could play a major role in the transition to P4 (predictive, personalized, preventive and participatory) medicine: the proactive medicine of the next decade.

Finally, the candidate will integrate the tools developed within our volBrain platform (http://volbrain.upv.es) [4]. This platform offers a free and open-access service to the entire scientific community. It has more than 3800 users worldwide and has already processed more than 190,000 MRI scans, one of the largest databases in the world. Today, it has become one of the most recognized international platforms in the field. This unique environment will give international visibility to this thesis work.

Environment

The applicant will be part of a consortium of international experts in medical imaging [5], artificial intelligence [3], neurological diseases [6-7] or neuroscience [8]. The candidate will benefit from the hardware environment of the Laboratoire Bordelais de Recherche en Informatique (GPU servers, computing platform, etc...). She/He will also be in permanent collaboration with the clinicians and neuroscientists involved in the project. Moreover, this project is part of a longstanding collaboration with the Polytechnic University of Valencia (Spain) around the volBrain platform. The candidate will therefore have the opportunity to carry out missions in Spain during the integration of its methods into the web platform.

Candidate profile

The candidate (engineering degree or Master 2) must have a solid foundation in deep learning and machine learning. She/He must also have skills in image processing and programming. A good command of Python, Keras, Pytorch and tensorflow is highly recommended. A good level of English in reading and writing is also a key element. An interest in medical imaging is a plus.

To apply, send a file containing a CV, a covering letter, your transcripts, the list of your publications (if available), the contact of 2 referees who can attest to your skills as well as any document likely to strengthen your application.

References

[1] Wen, Junhao, et al. "Convolutional Neural Networks for Classification of Alzheimer's Disease: Overview and Reproducible Evaluation." arXiv preprint arXiv:1904.07773 (2019).

[2] Huo, Yuankai, et al. "3d whole brain segmentation using spatially localized atlas network tiles." NeuroImage 194 (2019): 105-119.

[3] P. Coupé, B. Mansencal, M. Clément, R. Giraud, B. Denis de Senneville, V.-T Ta, V. Lepetit, J. V. Manjon. AssemblyNet: A Novel Deep Decision-Making Process for Whole Brain MRI Segmentation. MICCAI'19, 2019.

[4] J. V. Manjon and P. Coupé. volBrain: an online MRI brain volumetry system. Frontiers in Neuroinformatics, 30:10, 2016

[5] P. Coupé, J. V Manjon, V. Fonov, J. Pruessner, M. Robles, D. L. Collins. Patch-based Segmentation using Expert Priors: Application to Hippocampus and Ventricle Segmentation. NeuroImage, 54(2): 940–954, 2011.

[6] V. Planche, I. Koubyr, J. E. Romero, J. V. Manjon, P. Coupé, M. Deloire, V. Dousset, B. Brochet, A. Ruet, T. Tourdias. Regional hippocampal vulnerability in early multiple sclerosis: a dynamic pathological spreading from dentate gyrus to CA1. Human Brain Mapping, 39(4), 1814-1824, 2018.

[7] P. Coupé, J. V. Manjon, E. Lanuza, G. Catheline. Lifespan changes of the human brain in Alzheimer's disease. Nature Scientific Report, 2019.

[8] P. Coupé, G. Catheline, E. Lanuza, J. V. Manjon. Towards a unified analysis of brain maturation and aging across the entire lifespan: A MRI analysis. Human Brain Mapping, Human Brain Mapping, 38 (11), 5501-5518, 2017