Master student training course

Apprentissage profond pour la détection de foyers épileptiques en imagerie IRM-TEP
Deep Learning for epilepsy lesion detection based on PET and MR imaging.

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Key-words: multimodality (PET and MRI) medical imaging, neuroimaging, machine learning (deep learning)

Summary
For patients suffering from drug resistant epilepsy, surgical removal of the epileptogenic zone offers the possibility of a cure. The analysis of neuroimaging data (MRI, PET..) is increasingly used in the presurgical work-up of patients to localize the epileptogenic zone. We are currently developing a software based on statistical machine learning that will automatically process these medical imaging data so as to provide maps highlighting abnormal regions in the image. We recently prototyped a first system based on features automatically learned from magnetic resonance imaging (MRI) based on the deep learning methodology (see figure 1 for illustration). The objective of this master project is to improve the diagnostic performance of this system by accounting for the information provided by a nuclear imaging modality referred to as positron emission tomography (PET) (see figure 2). The successful candidate will explore different ways to incorporate this new data modality into the pipeline. The first step will consist in building the MRI-PET image database, and more specifically processing the PET data. This task will be supervised by the CERMEP team. The second step will consist in designing and evaluating different fusion strategies of the PET and MR data within the deep feature learning architecture. This task will be supervised by the CREATIS team. Dr Julien Jung who is a neurologist at HCL and CRNL (Centre de Recherche en Neurosciences de Lyon) will also actively contribute to this project by providing his strong clinical expertise in the evaluation of the epilepsy lesion maps that will be generated by the software as well making the MR and PET data available.

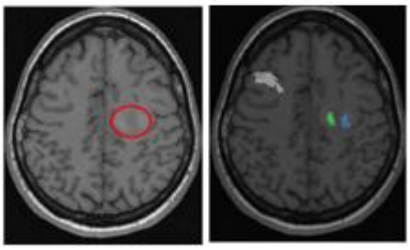

Figure 1. Example Maximum intensity projection (MIP) of a cluster map estimated by a deep learning network overlaid on the MRI transverse slices of a patient. The epilepsy lesion location is highlighted in red circle on the left figure. The grey cluster corresponds to a false detection.

Skills
Strong knowledge in at least one of the following fields is required:

- machine learning (deep learning/ outlier detection);
- Image processing
- Applied mathematics

The available code is written in Matlab (SPM toolbox) for the image database processing and Python for the machine learning part.
The successful candidate is expected to be autonomous and show motivation and interest in multidisciplinary research (image processing and machine learning in a medical context).

Applications
Interested applicants are required to send a cover letter, CV and any other relevant documents (reference letter, recent transcripts of marks,...) to **carole.lartizien@creatis.insa-lyon.fr** and **nicolas.costes@cermep.fr**

Gratuity : ~550 euros/mois.

Detailed description of the project

Scientific context:
For patients suffering from drug resistant epilepsy, surgical removal of the epileptogenic zone offers the possibility of a cure. The analysis of neuroimaging data (MRI, PET..) is increasingly used in the presurgical work-up of patients to localize the epileptogenic zone. However, the detection of malformative lesions, which is based on a visual analysis of these massive 3D image datasets, is very challenging. Neurologists may greatly benefit from software that automatically process these data so as to provide probability maps highlighting abnormal regions in the image. Such software are referred to as computer aided diagnostic (CAD) tools.

A common pipeline in the existing CAD systems is to perform binary or multi-class classification at voxel level based on features extracted from normal and pathological locations on patient scans. This often requires a huge amount of annotated samples which is hard to achieve in the medical context. As an alternative, we proposed to treat this lesion localization task as an outlier detection problem, which, in our context, consists in learning a description of the normal brain pattern and detecting which new observations fit into the learned description and which do not.
We recently prototyped two different systems based on information provided by MRI (T1 weighted acquisitions), one based on manually extracted features that capture the specificity of malformative epileptogenic lesions in T1 weighted MRI [El Azami, 2016], and one based on features (representation) learnt from a deep architecture consisting of stacked convolutional autoencoders [Alaverdyan, 2017].

Objective
The objective of this master project is to improve the CAD detection performance by accounting for the information provided by a nuclear imaging modality referred to as positron emission tomography (PET), which is part of the presurgical evaluation protocol of epilepsy patients in some clinical centers. We hypothesize that the PET information will increase the discriminant power of features learned by the unsupervised deep feature models.

The successful candidate will explore different ways to incorporate this new data modality. We indeed may consider early fusion strategies that consists in extracting deep features based on the combination of the PET and MR data as input of the network, as performed by Havaei et al in the supervised configuration [Havaei, 2017]. Another way would be to explore different configurations of multi-view learning [Chang, 2013] in the specific context of one-class classification problem.

This project is part of collaboration with Dr Julien Jung from CRNL (Centre de Recherche en Neurosciences de Lyon) as part of project recently funded by FFRE (Fédération Française de Recherche sur l'Epilepsie). Dr Jung is responsible for the construction of a database of MR and PET brain acquisitions of healthy subjects and epilepsy patients that will be made available for this project. The successful candidate will also strongly interact with Nicolas Costes and Caroline Bouillot from CERMEP for the preprocessing of the PET and MRI data.

Program outline
The candidate will need to address the following tasks:

- Reviewing the state of the art literature in the domain of unsupervised deep learning algorithms and multi-view learning.
- Perform the preprocessing and quality control analysis of the patients and normal subjects PET data. This task will be supervised by the CERMEP team. It mainly consists in normalizing and coregistering the MR and PET exams. We also plan to perform a mass univariate analysis of these PET data that will serve as basis for comparison with the multivariate analysis performed by the deep architecture. This task will be performed within the framework of the SPM toolbox.
- Designing and implementing different fusion strategies of the PET and MR data within the deep unsupervised feature architecture.
- Evaluating the performance of these multimodality architectures based on the PET-MRI epilepsy patients datasets.

Collaboration
The candidate will be supervised by Carole Lartizien from CREATIS as well as Nicolas Costes and Caroline Bouillot from CERMEP. He (She) will be part of the collaboration with Julien Jung from CRNL and HCL as part of the FFRE project. The successful candidate will share his time between CERMEP (for processing the PET-MRI database) and CREATIS (for the machine learning part).

References

[El Azami, 2016] El Azami, M., A. Hammers, J. Jung, N. Costes, R. Bouet and C. Lartizien. *Detection of Lesions Underlying Intractable Epilepsy on T1-Weighted MRI as an Outlier Detection Problem*. PLoS ONE, 11(9): e0161498, 2016.

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[Chang, 2013] Chang Xu, Dacheng Tao, and Chao Xu. A survey on multi-view learning. CoRR, abs/1304.5634, 2013.

[Havaei, 2017] M. Havaei, A. Davy, D. Warde-Farley, A. Biard, A. Courville, Y. Bengio, C. Pal, P. M. Jodoin et H. Larochelle (2017). Brain tumor segmentation with Deep Neural Networks. Medical Image Analysis, 35: 18-31.

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