Internship Title:

Unsupervised Domain Adaptation in Neuroimaging

The case of White Matter Lesions Segmentation

Keywords: image processing, medical imaging, machine learning, deep learning, domain adaptation, optimal transport

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Duration: 6 months

Starting date: end 2021 - beginning 2022

Location: Empenn research Lab, Inria-Irisa Rennes, Campus de Beaulieu

Context of the internship:

We are looking for a highly motivated candidate for an internship of up to 6 months.

The selected candidate will join the research lab Empenn in Inria-Irisa, located in Rennes, France. Our research lab consists of more than 20 researchers, faculty members, PhD students, engineers and interns, working in the field of neuroimaging.

The team has access to several computing facilities (e.g. IGRIDA cluster) and established collaborations with other Inria/Irisa research teams in the field of machine learning, including Obelix. The partnership with the Neurinfo imaging platform and the collaboration with neurologists at the Rennes University Hospital are an asset for this project.

Depending on the candidate aspirations and skills, this internship could lead to a PhD.

Detailed description:

Magnetic Resonance Imaging (MRI) data can have high or subtle variations across individuals, MR scanners, and data acquisition protocols i.e. intensity, contrast, signal-to-noise, and resolution. Robustness to such variations is a critical requirement when deploying a model as part of an automated analysis.

In recent years, deep Convolutional Neural Networks (CNNs) have demonstrated outstanding performances in a wide range of computer vision and image analysis applications in the medical domain [1]. In particular, CNNs have achieved state-of-the-art results for segmentation tasks, including the segmentation of multiple sclerosis lesions, ischemic stroke, or infant brain on MRI images. Nevertheless, a fundamental limitation of CNNs is their sensitivity to dataset shift, i.e. the source training data distribution differs from the target data distribution, causing recurrent and significant failures when a model is deployed to a new clinical site or dataset.

Domain Adaptation (DA) approaches aim to address the shift between the source and target dataset [2]. They assume access to samples of the target, while they restrict access to their labels. Their relevance is two-fold: they may ease not only the adoption of deep models in the clinical workflow, but also the exploitation of increasingly large imaging datasets, where data acquisitions are often not standardized and only a subset of the images is annotated.

This internship concerns the investigation of a solution to the problem of domain shift suitable for a white matter lesion segmentation task and that does not require annotations of target data i.e. unsupervised domain adaptation.

Recently, we have proposed a framework that jointly learns a segmentation task, i.e. white matter lesion segmentation from multi-contrast brain MRI images, and addresses the domain shift problem using a solution based on Optimal Transport [3, 4] i.e. this approach explicitly minimizes a distance between source and target distributions in the feature space [Figure 1]. While results are encouraging, some aspects need further investigation, such as the major issue of class imbalance between source and target domains.

Research impact:

In this internship, you will work with public and private Multiple Sclerosis (MS) MRI datasets. MS is a chronic inflammatory-demyelinating disease of the central nervous system. Magnetic Resonance Imaging (MRI) is fundamental to characterize and quantify MS lesions; the number and volume of lesions are used for MS diagnosis, to track its progression and to evaluate treatments [5].

Current MRI protocols in MS consist of Fluid-Attenuated Inversion Recovery (FLAIR) and T1-weighted (T1-w) images, offering complementary contrasts that allow identification of different types of lesions. Accurate identification of MS lesions in MRI images is extremely difficult due to variability in lesion location, size, and shape, in addition to anatomical variability across patients. Since manual segmentation requires expert knowledge, it is time consuming and prone to intra- and inter-expert variability, several methods have been proposed to automatically segment MS lesions. Nevertheless, the challenge remains to provide techniques that work regardless of the type of lesion or MRI protocol.

Finally, the clinical significance of this internship is broad, as implemented methods can be easily transferred to various pathologies or traumas visible on medical imaging, such as tumours, oedema, and traumatic brain injuries. Moreover, they can be applied to other imaging modalities, including PET and CT modalities.

Required or desirable skills:

We are seeking a highly motivated candidate currently enrolled in a master in computer science, engineering or a closely related discipline.

We require understanding of common machine learning methods (e.g. Convolutional Neural Networks) and statistical analysis. Knowledge in computer vision or image processing is desirable.

We require experience working with Linux/Ubuntu, Python language, and common deep learning libraries such as PyTorch or TensorFlow.

Curiosity, motivation, and good communication skills are critical. Proficiency in English is required.

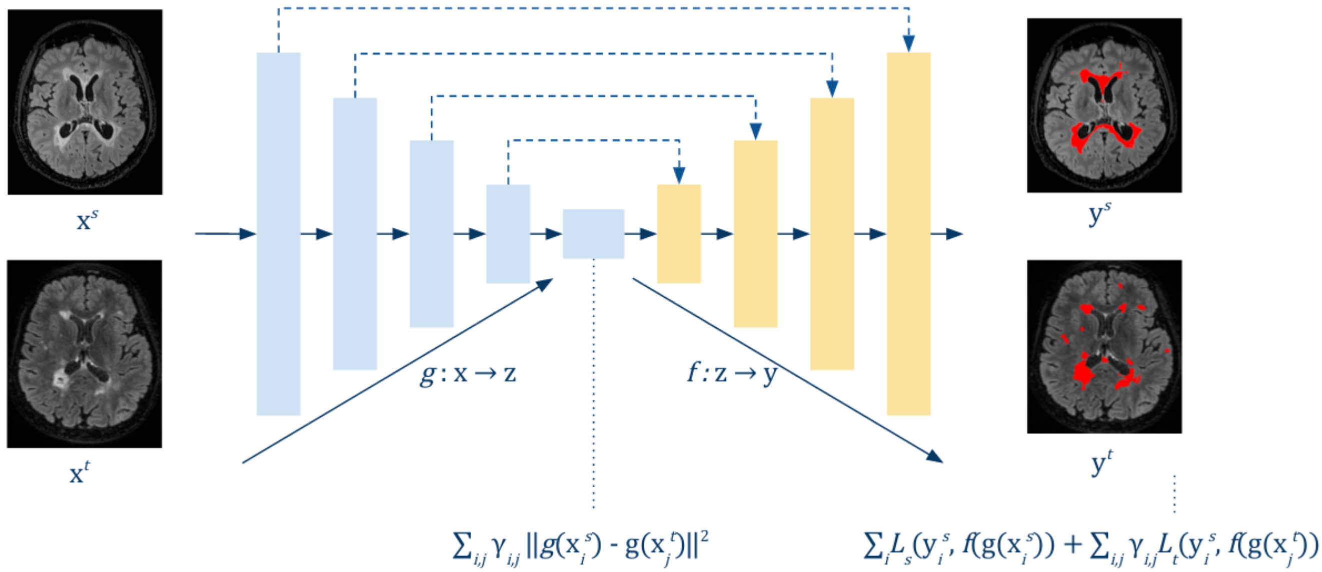

Figure 1. Domain Adaptation of source dataset *s* towards target dataset *t*. The global loss comprises a representation loss computed in the latent space *z*, and a segmentation loss computed at the final output layer.

References:

[1] Greenspan, H., Van Ginneken, B., & Summers, R. M. (2016). Guest editorial deep learning in medical imaging: Overview and future promise of an exciting new technique. *IEEE transactions on medical imaging*, *35*(5), 1153-1159.

[2] Choudhary, A., Tong, L., Zhu, Y., & Wang, M. D. (2020). Advancing medical imaging informatics by deep learning-based domain adaptation. *Yearbook of medical informatics*, *29*(01), 129-138.

[3] Courty, N., Flamary, R., Habrard, A., & Rakotomamonjy, A. (2017). Joint distribution optimal transportation for domain adaptation. *arXiv preprint arXiv:1705.08848*.

[4] Ackaouy, A., Courty, N., Vallée, E., Commowick, O., Barillot, C., & Galassi, F. (2020). Unsupervised multiple sclerosis lesions from domain adaptation with optimal transport in multi-site segmentation of MRI data. *Frontiers in computational neuroscience*, *14*, 19.

[5] Commowick, O., Istace, A., Kain, M., Laurent, B., Leray, F., Simon, M., ... & Barillot, C. (2018). Objective evaluation of multiple sclerosis lesion segmentation using a data management and processing infrastructure. *Scientific reports*, *8*(1), 1-17.