Project 1 – Domain adaptation and generalization techniques for AI medical image analysis

Machine learning and specifically **deep learning** techniques are promising tools in medical image analysis and they have demonstrated very good performances in many tasks such as image segmentation. These techniques are though data demanding and as such they need large-scale cohorts, often multi-centric datasets. In this context, **Domain Adaptation** (DA) has recently raised strong interests in the medical imaging community as the **generalization** of algorithms to unseen data (domain shift) or different input data domains (missing modalities) still remains an open problem. In this project we will investigate different approaches for DA of MR image analysis in order to improve the applicability of machine learning approaches to various clinical settings (eg. transfer learning, image synthesis). Specifically, we will explore the DA issues in the context of **deep learning for MRI segmentation** in two different applications: multiple sclerosis and fetal brain.

Related publications: (1) La Rosa F., et al (2021) "*MPRAGE to MP2RAGE UNI translation via generative adversarial network improves the automatic tissue and lesion segmentation in multiple sclerosis patients"*. Computers in Biology and Medicine, 104297. (2) Payette, K.; de Dumast, P. et al (2021) *"A comparison of automatic multi-tissue segmentation methods of the human fetal brain using the FeTA Dataset"*, Nature Scientific Data. (3) La Rosa F., et al (2020) *"Multiple sclerosis cortical and WM lesion segmentation at 3T MRI: a deep learning method based on FLAIR and MP2RAGE"*. NeuroImage. Clinical.

Project 2 - Advanced machine learning for assessing the in-vivo thalamic nuclei magnetic resonance imaging

The thalamus has a key role in brain function as it is the central relay of many cortical areas. Given their functional importance, the ability to non-invasively map and differentiate the thalamic nuclei is of extreme value in a wide range of neuroscience research areas as well as in clinical practice. For instance, having a direct visualization of thalamic nuclei would be crucial in a better understanding of the pathophysiology and psychopathology of many brain disorders. The major challenge of a precise image analysis of the thalamus is related to its high complex architecture, made of small nuclei of a few millimeters only, connected to many cortical regions and, at the same time, to other grey matter nuclei and brain areas like the cerebellum. However, there is today the ability to in-vivo image the thalamus through advanced magnetic resonance imaging modalities at both 3T and 7T. In this project we will explore how to exploit this **MRI**, including multiple modalities, and further develop them with **machine learning** tools to quantify the thalamic nuclei. We will also explore the translation of current techniques for imaging the **developing thalamus of newborns and children**.

Related publications: (1) "*Robust thalamic nuclei segmentation method based on local diffusion magnetic resonance properties",* Battistella G., Najdenovska E., et al. Brain structure & function, 222 (5), 2017. (2) "*In-vivo probabilistic atlas of human thalamic nuclei based on diffusion- weighted magnetic resonance imaging"***,** Najdenovska E., Alemán-Gómez Y., et al., Scientific data, 5, 2018. (3) J.Jorge, et al M. Bach Cuadra, "*Improved susceptibility-weighted imaging for high contrast and resolution thalamic nuclei mapping at 7T*", Magnetic Resonance in Medicine, 2020.