University Institute of Diagnostic and
Interventional Neuroradiology

Master's Thesis Proposal:
Brain morphometry with contrast enhanced MRI

Brain morphometry is a computational method that enables statistical assessment of brain structure based on *native* T1-weighted magnetic resonance imaging (MRI) by extracting variables like local cortical thickness, surface area, gyrification indices and the contrast between grey and white matter along the cortical band. Originally developed for scientific group studies, variants are more and more utilized also to support clinical diagnostics in individual patients.

Recently, we have developed Deep Learning (DL) based algorithms for brain segmentation and thickness estimation. **DeepSCAN** (McKinley et al., 2021) segments healthy brain structures and lesions of patients with multiple sclerosis at the same time. This helped to reduce the false positive rate considerably and led to accuracies similar to inter-rater agreement of human experts. **DL+DiReCT** (Rebsamen et al., 2020) builds upon a variant of DeepSCAN and delivers cortical thickness within minutes (as opposed to hours). It also outperforms traditional software in terms of accuracy and within-subject reproducibility.

In clinical reality morphometric questions often arise **retrospectively**, also for cases where the most appropriate sequences are not available. When run on **contrast-enhanced MRI** traditional software for brain morphometry may fail dramatically. We have scans from patients with multiple sclerosis and epilepsy, where native *and* post-contrast images were acquired during the same session (>500 datasets, different scanners and different field strengths).

We propose to use post-contrast MRI to **enhance the training data** together with labeling from co-registered pre-contrast images of the same session. Weak labels for the contrast agent can be generated by thresholding the difference image if required. We hypothesize that this will suffice already to make our DL-based segmentation algorithm robust to the presence of contrast agent.

If time allows, we propose to use pairs of pre- and post-contrast MRIs to train autoencoder CNNs or generative adversarial networks (GAN) to **synthesize a native image** out of one with contrast agent. We will evaluate, if this kind of "image normalization" can be used to enable reliable evaluation of contrast-enhanced MRI with traditional software for brain morphometry.

The student's tasks are:

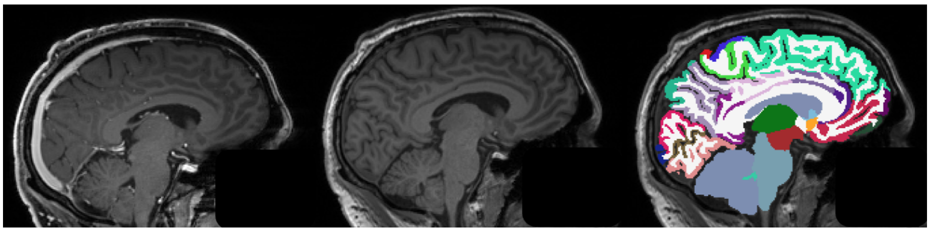
- review the literature on brain morphometry and DL
- extend training data by adding patients where native *and* contrast-enhanced MRI are available
- retrain existing DL models
- evaluate performance

Specific requirements:

- programming skills in Python
- skills in data engineering
- basics in Deep Learning
- basic statistics

Nature of the master thesis:

- literature study: 10%
- implementation: 30%
- data exploration: 40%
- documentation: 20%



Sagittal view of a contrast-enhanded (left) and native (middle) T1-weighted MRI.
Segmentation (right) was performed on the native MRI and usually fails on post-contrast MRI.

References:

- McKinley R, Wepfer R, Aschwanden F, Grunder L, Muri R, Rummel C et al. (2021). Scientific Reports 11, 1087.
- Rebsamen M, Rummel C, Reyes M, Wiest R, McKinley R (2020). Hum Brain Mapp 41, 4804-4814.

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