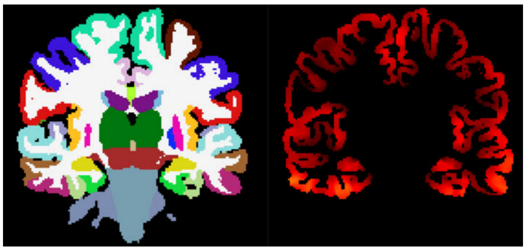

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Master's Thesis Proposal: Training deep neuronal networks to handle lesional MRI

Brain morphometry is a computational method that enables statistical assessment of brain structure based on 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 cortical 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.

An obstacle for clinical applications of brain morphometry can be that patient data may significantly deviate from the expectation of "normal appearing brains". For example, patients can have **brain tumors** or prior **brain surgery** or **stroke**. In such cases morphometry estimation may become unreliable even outside the lesional area (e.g. in the contra-lateral hemisphere).

We propose to adapt this methodology to **better handle brains with large lesions** stemming from stroke, tumors or surgery. For this purpose the training data for DeepSCAN will be enriched by datasets from patients with MRI before and after epilepsy surgery. Optionally we will increase the sample size by data augmentation (i.e. randomly generating synthetic resections from MRI of healthy subjects). A resection-agnostic model will allow to estimate morphometry also from MRI with stroke lesions and tumors in two steps: First, existing manual lesion annotations or software from other projects of our group (Meier et al., 2016; Rebsamen et al., 2019) will be used to identify the lesion. Second, after masking the tumor in the original MRI, the resulting images can be used as input similar to a post-surgery MRI.

The student's tasks are:

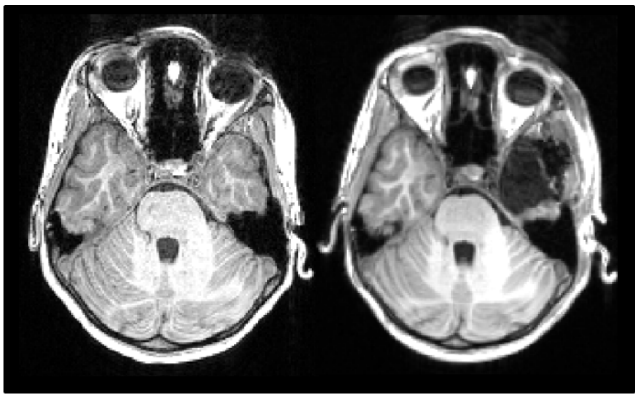
- review the literature on brain morphometry and DL
- extend training data by adding pre- and post-surgical MRI and data augmentation
- retrain existing DL models to become lesion-agnostic
- evaluate performance

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: 20%
- data exploration: 50%
- documentation: 20%



Example of pre- and post-surgical MRI of a patient with temporal lobe epilepsy. The idea is to train brain segmentation and morphometry estimation on both images with ground truth taken only from the pre-surgical MRI.

References:

- McKinley R, Wepfer R, Aschwanden F, Grunder L, Muri R, Rummel C et al. (2021). Scientific Reports 11, 1087.
- Meier R, Knecht U, Loosli T, Bauer S, Slotboom J, Wiest R, Reyes M (2016). Scientific Reports 6, 23376.
- Rebsamen M, Knecht U, Reyes M, Wiest R, Meier R, McKinley R (2019). Frontiers Neurology 13, 1182.
- Rebsamen M, Rummel C, Reyes M, Wiest R, McKinley R (2020). Hum Brain Mapp 41, 4804-4814.

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