

Diffusion Models for Contrast Harmonization of Whole Head Magnetic Resonance Images

Magnetic Resonance (MR) Imaging is an important tool for the diagnosis and monitoring of pathological conditions such as Multiple Sclerosis (MS), a demyelinating disease of the central nervous system, often resulting in brain atrophy. The calculation of percentage brain volume change (PBVC) is crucial for the monitoring of MS progression and can be done by segmenting grey matter (GM), white matter (WM) and cerebrospinal fluid (CSF). However, numerous extrinsic and intrinsic factors, e.g. the magnetic field strength, influence the MR image contrast. Therefore, image harmonization is required to allow subsequent automatic segmentation of the images originating from different scanners.

Scanning of multiple sclerosis patients for the Swiss Multiple Sclerosis Cohort-Study [1] started in 2012. Longitudinal data of hundreds of patients has been obtained for more than ten years at eight different locations in Switzerland. At the University Hospital in Basel the 1.5 T scanner was replaced by a 3 T scanner in 2016. As this scanner change led to a change in image metrics, it was not possible anymore to longitudinally compare the data of the patients. A paired dataset of MR images acquired in both scanners was collected for healthy subjects and MS patients [2] with the aim of restoring image comparability by creating a contrast harmonization tool using this dataset.

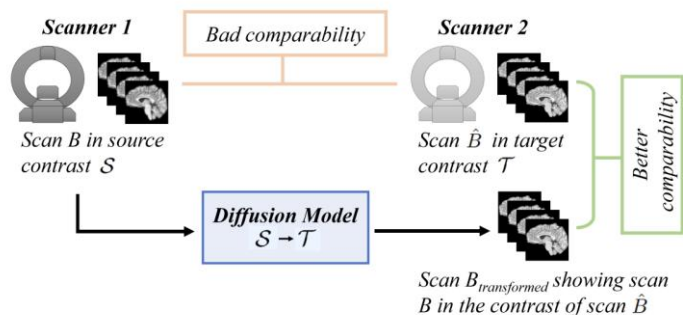


Fig. 1 Overview of the current contrast harmonization method using skull-stripped images.

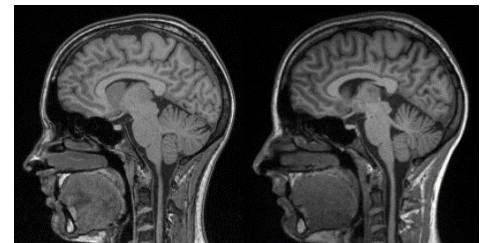
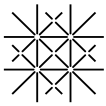


Fig. 2 Exemplary slices of whole head images, acquired with 1.5 T (left) and 3 T (right).

So far, a diffusion model for contrast harmonization was developed on a skull-stripped version of the dataset, i.e. the brains without their surroundings, illustrated in Fig. 1. It resulted in a reduction in differences between images acquired with different magnetic field strengths evaluated in the downstream segmentation of CSF, GM and WM. The next step is now the adaption of the existing diffusion model approach for whole head images, shown in Fig. 2. These images present further challenges, as the brain surrounding tissues and bones heavily influence the contrast differences. The goal of this master thesis is to develop a deep learning model that harmonizes contrasts of the whole head images and can reduce the differences in the results of downstream segmentation. Furthermore, we can also consider an unpaired dataset for image-to-image translation between the different scanners.



Nature of the Thesis

- Programming: 80%
- Documentation: 20%

Specific Requirements

- Programming skills in Python
- Basic deep learning knowledge

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References

[1] Giulio Disanto, Pascal Benkert, Johannes Lorscheider, Stefanie Mueller, Jochen Vehoff, Chiara Zecca, Simon Ramseier, Lutz Achtnichts, Oliver Findling, Krassen Nedeltchev, et al. The swiss multiple sclerosis cohort-study (smc): a prospective swiss wide investigation of key phases in disease evolution and new treatment options. *PloS one*, 11(3): e0152347, 2016.

[2] Tim Sinnecker, Sabine Schädelin, Pascal Benkert, Esther Ruberte, Michael Amann, Johanna M Lieb, Yvonne Naegelin, Jannis Müller, Jens Kuhle, Tobias Derfuss, et al. Brain atrophy measurement over a mri scanner change in multiple sclerosis. *NeuroImage: Clinical*, 36:103148, 2022.