Volume-based Translation of phase-cycle balanced Steady State Free Precession MRI to Diffusion Tensor

Thesis submitted in partial fulfilment of the requirements for the degree

Master of Science

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Disclosures

- I affirm that I have written the dissertation myself and have not used any sources and aids other than those indicated.
- I affirm that I have not included data generated in one of my laboratory rotations and already presented in the respective laboratory report.

Tübingen, March 2024 _____

Abstract:

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Contents

1. Introduction

- Largest multi modal data set of its kind
- bSSFP now feasible with new HW
- Speeds up scanning times potentially yielding multiple modalities with one scan
- Limited data available for ML applications

2. Related Work

2.1. MRI Sequences

2.1.1. phase-cycle balanced steady-state free precession MRI

Some bla bla about qMRI development in the past.
In depth description of sequence, profile, banding

2.1.2. Diffusion-weighted MRI

2.2. Deep Learning

2.2.1. Architecture & Training

UNet, challenges, impact of transformers, ...

2.2.2. Image-to-Image Synthesis

2.2.3. Deep Learning in Medical Imaging

3. Methods

3.1. The Dove Dataset

Some stats on size

3.1.1. Participants & Study Design

briefly describe participants, task, scanning times (of the day)

3.1.2. Recorded Sequences

cf gais doc. Details on acquisitions

3.2. Data Processing

requirements

3.2.1. bSSFP

3.2.2. DWI

TODO ask svenja what was done

3.2.3. Augmentation

3.3. Machine Learning-based DWI Tensor estimation from bSSFP data

MONAI, torchio, pytorch lightning.

3.3.1. Architecture

UNet + some extra layers to fit output dim.

3.3.2. Training

Pre-training, transfer & fine-tuning

Sparse data, small batch sizes. => Augmentation not enough => Pre training

AutoEncoder PreTraining As auto encoder. train autoenc for bssfp only

ExtraHead Transfer and Fine tuning freeze autoenc, add head. transfer then unfreeze all and fine tune Unet + extra head

4. Results

4.1. Direct bSSFP to DWI Tensor Training

4.2. Pre-Training & bSSFP Transfer-Learning

4.3. Comparison of Voxel-wise to Volume-wise Regression

4.4. Modality Comparisons

4.4.1. Quantitative comparison of Quality differences between Auto-Encoding and pc-bSSFP Image to Image Translation

4.4.2. pc-bSSFP is more suitable than single-volume Structural Images

4.4.3. Phase-cycles contain relevant the Information

4.4.4. Asymmetry Index Maps distill phase-cycle Information

5. Discussion

5.1. Limitations

voxel- patch - volume pro-con
Statistical power
model size/speed
learned vs. closed-form/deduced/analytical transformation

5.2. Future Work

5.2.1. Modular Deep Learning

Pretrain autoenc for both.
Use enc of bssfp (or conv transf. for enc) and dec of DWI/specialized for modality
LDM for latent translation
GAN & Stable diffusion, control flow matching, latent diffusion models

5.2.2. Conv Transf.

New kid on the block

5.2.3. Neural Arch Search

DiNTS

6. Acknowledgements

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Appendix

A. Supplementary Material

Figure .1. ***A. & B.*** *SNc and projections to the dorsal striatum in healthy subjects and patients with PD. In the healthy subject, the SNc is still highly pigmented due to the melanin-containing dopamine-producing cells being intact. The SNc projects to the striatum and delivers normal amounts of DA into the basal ganglia (BG) circuit. If the dopamine-producing neurons undergo apoptosis, the pigmentation decreases and so does the amount of dopamine adimnistered to the striatum.* ***C.*** *Photomicrographs of Lewy bodies.*