Accelerated Cardiac Diffusion Tensor Imaging via Graph Neural Networks Based Multi-Modality Magnetic Resonance Restoration

Supervisor(s):

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Project description:

Background

In vivo cardiac diffusion tensor imaging (cDTI) is an emerging Magnetic Resonance Imaging (MRI) technique that has the potential to describe the micro-structure of myocardial tissue in the living heart. However, cDTI faces challenges such as low resolution, low signal-to-noise ratio nature and prolonged scanning time. During routine cardiac MR scanning, radiologists tend to acquire images with different modality to comprehensively evaluate patients' conditions. The purpose of multi-modality image restoration is to use a high-quality (or fully-sampled) reference image with a shorter acquisition time to enhance the quality of images (or reconstruct images) with a longer scanning time. However, most existing multi-modality methods required registered image pairs, which limits their applicability to cDTI data due to the movement derived from the heartbeat and human breath.

Main Goal

This main goal of this study is to develop GNN-based unregistered multi-modality MR restoration model for cDTI reconstruction, denoising and super-resolution, guided by fully sampled high-quality modality, such as cine MRI. In contrast to conventional methods that treat MR images as pixel arrays, this approach transforms MR images into patch-based graphs. The relationship between unregistered modalities can be learning from the graph connection rather than aligned pixel array.

Experiment Approach

1. We will develop a GNN-based single-modality restoration model as the baseline.
2. We will simulate the misalignment on multi-contrast brain dataset (e.g., BraTS), and develop a GNN-based multi-modality restoration model.
3. We will exploit this GNN-based multi-modality methods on cDTI (target) dataset and cine (reference) dataset.

Outcome

The outcome of this work is developing advanced GNN-based multi-modality methods for unregistered cDTI reconstruction, super-resolution and denoising. We hypothesise that the proposed model can provide high-quality cDTI restoration leveraging the information from unregistered reference modality.

Timeline (tentative):

(1) 31/10/2024:1-page plan agreed with student on the project.
(2) 30/11/2024: data curation, paper reading.
(3) 31/12/2024: training baseline segmentation model of GNN-based single-modality cDTI restoration.
(4) 31/1/2025: simulated R&D reports.
(5) 31/3/2025: develop GNN-based unregistered (simulation) multi-modality restoration on brain dataset.
(6) 31/5/2025: develop GNN-based unregistered multi-modality restoration on cDTI dataset.
(7) 31/8/2025: final thesis submission.

Minimum viable thesis:

We will develop a novel GNN-based multi-modality model on registered brain dataset. The backbone of the proposed multi-modality model can be existing Vision GNN.

Required background & skills:

Excellent interpersonal communication; Superb reading and written skills in English; Good basis of mathematic theory; Skilful at programming, e.g., Python, Pytorch, DGL, etc.

Representative References:

[1] C.-M. Feng et al., ‘Multimodal Transformer for Accelerated MR Imaging’, IEEE Transactions on Medical Imaging, vol. 42, no. 10, pp. 2804–2816, Oct. 2023, doi: 10.1109/TMI.2022.3180228.
[2] Q. Lyu et al., ‘Multi-Contrast Super-Resolution MRI Through a Progressive Network’, IEEE Transactions on Medical Imaging, vol. 39, no. 9, pp. 2738–2749, Sep. 2020, doi: 10.1109/TMI.2020.2974858.
[3] J. Huang et al., ‘Deep Learning-based Diffusion Tensor Cardiac Magnetic Resonance Reconstruction: A Comparison Study’. arXiv, Apr. 04, 2023. doi: 10.48550/arXiv.2304.00996.
[4] K. Han, Y. Wang, J. Guo, Y. Tang, and E. Wu, ‘Vision GNN: An Image is Worth Graph of Nodes’, Advances in Neural Information Processing Systems, vol. 35, pp. 8291–8303, Dec. 2022.
[5] J. Huang, A. Aviles-Rivero, C.-B. Schonlieb, and G. Yang, ‘ViGU: Vision GNN U-Net for Fast MRI’. arXiv, Jan. 23, 2023. Accessed: Jun. 13, 2023.