Project Proposal: Incorporating Image Priors into GRAPPA

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Motivation: Magnetic Resonance Imaging (MRI) utilizes parallel imaging techniques such as GRAPPA and SENSE to accelerate image acquisition by undersampling in Fourier space. GRAPPA is preferred for its robustness, particularly in noisy or low-signal environments. Unlike SENSE, it cannot optimize SNR or incorporate image priors. While SENSE excels at SNR optimization and allows for prior incorporation, it is less robust in the presence of artifacts and noise.

Project Description: This project seeks to combine the robustness of GRAPPA with the flexibility of SENSE, with a stretch goal of incorporating image priors into the GRAPPA reconstruction process. Our goal is to identify the most effective image priors that enhance both image quality and artifact reduction. We will investigate various types of image priors and evaluate their impact on the robustness and quality of GRAPPA reconstructions. The goal is to discover and implement the priors that most effectively improve reconstruction and the feasibility of incorporating priors with GRAPPA.

Related Work: Previous studies have highlighted the potential benefits of incorporating prior information into GRAPPA reconstruction. One approach integrates prior information from Autocalibrating Signal (ACS) data into GRAPPA using the Tikhonov prior. This demonstrates promise in enhancing GRAPPA's robustness and image quality, aligning with our project's objectives of improving denoising and artifact removal in GRAPPA reconstructions [1].

Another study proposes a Bayesian framework that combines GRAPPA and SENSE by incorporating prior distributions derived from k-space arrays. The inclusion of this prior information improves estimating missing spatial frequency values, reducing aliasing, and reconstructing full-field-of-view images without aliasing artifacts. This approach is relevant to our project, as we aim to incorporate such prior information to develop a more robust GRAPPA reconstruction [2].

Additionally, research has shown that when generative priors are integrated into reconstruction algorithms, image quality is improved due to reduced artifacts and better reconstructions from undersampled k-space data. This work demonstrates the importance of image priors in MRI reconstruction [3].

[1] https://cds.ismrm.org/protected/06MProceedings/PDFfiles/03656.pdf
[2] https://pubmed.ncbi.nlm.nih.gov/39424209/
[3] https://arxiv.org/pdf/2308.02340

Milestones:

- Research image prior methods relevant to MRI reconstruction (week 1)
- Select two image prior methods to incorporate into our GRAPPA reconstruction method (week 1)
- Implement the standard GRAPPA reconstruction method (week 2)
- Implement the standard SENSE reconstruction method (week 2)
- Develop a method to incorporate image priors into GRAPPA reconstruction (week 2)

Final Goals:

- Develop a GRAPPA-based reconstruction algorithm that integrates image priors for improved noise reduction and artifact removal
- Compare the performance of our proposed method against standard GRAPPA and SENSE reconstructions to evaluate improvements in image quality and robustness