

Image Denoising for Undersampled Magnetic Resonance Imaging

Motivation:

In magnetic resonance imaging (MRI), the raw data that is needed to generate images is directly sampled in the spatial frequency domain. There exist various paradigms to sample the 3D spatial frequency volume, one such being a trajectory of several 3D radial spokes (1), akin to a kooshball. The benefit of such a strategy is that there can be significant undersampling that can be performed without aliasing artifacts, compared to the minimum sampling density prescribed by the Shannon-Nyquist sampling theorem (2). However, the undersampling does incur a signal-to-noise-ratio (SNR) penalty as a function of the undersampling ratio (2). In addition to visually corrupting the recovered images, noise can be a large hindrance in performing quantitative imaging where voxels with low SNR can significantly bias the quantitative parameter being measured (3).

Related Work:

Image denoising has been used in research applications in MRI (4-6), however, clinical application of such methods is almost non-existent. The acceptance of such methods typically lags the inventions of new methods. For example, non-local means denoising is currently one of the state of the art implementations of denoising currently. One potential reason for this might be that, to my knowledge, there is no comprehensive study that analyzes the pros and cons of varying of various denoising methods for specific hypotheses. Since the extent of SNR is entirely relevant on the application of the specific MRI scan, it is vital to evaluate various denoising algorithms for specific questions in MRI.

Project Overview:

In this project, I plan on evaluating the efficacy of various denoising algorithms as it relates to obtaining high-fidelity quantitative MRI measurements. More specifically, I will optimize and evaluate the pros and cons of block-matching and 3D filtering (7), non-local means filtering (4), and bilateral filtering (9). I will evaluate these methods qualitatively and quantitatively. Qualitatively, I will assign a score on the overall visual appeal of the image (I have over four years of experience viewing clinical MRI scans) and quantitatively, I will evaluate SNR improvements, convergence times, autocorrelations of the residual noise, and accuracy of the quantitative maps.

Timeline, Milestones, and Goals:

The major goals of this project in the context of this class would be to have functional metrics on at least 3 different denoising methods. As far as timelines go, I will plan on spending one week each (roughly) on implementing the algorithms, optimizing the algorithms, and quantifying their efficacies. The above three would also be the milestones for my project. Simulating and/or sampling a gold-standard dataset to test this algorithm, though outside the scope of this class, will also take a little bit of time. (~5-6 hours). I will reserve around 5 hours for writing the final report also.

References:

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