Compressed Sensing Reconstructions for Dynamic Contrast Enhanced MRI

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Motivation

Introduction

Dynamic contrast enhanced (DCE) magnetic resonance imaging (MRI) allows for the detection and characterization of lesions as well as examination of the renal system. The contrast agent uptake typically completes within a few minutes, about an order of magnitude faster than a conventional full acquisition.

Parallel Imaging: SPIRiT

Parallel imaging has long been used as a method for MRI acceleration, by acquiring data on multiple receiver coils, which creates data redundancy across the channels. The SPIRiT approach to exploiting this spatial data redundancy allows for a robust reconstruction capable of accelerations on the order of 2x to 4x. At higher accelerations, the quality of SPIRiT reconstructions degrades rapidly.

Compressed Sensing

In combination with parallel imaging (and SPIRiT), compressed sensing techniques can be used in order to achieve the temporal resolution necessary for DCE imaging. Accelerations on the order of 20x can be achieved by aggressively undersampling the volume during data acquisition. Projection onto convex sets (POCS) type algorithms are used to exploit both spatial and temporal sparsity, enabling successful SPIRiT reconstructions.

Acknowledgements

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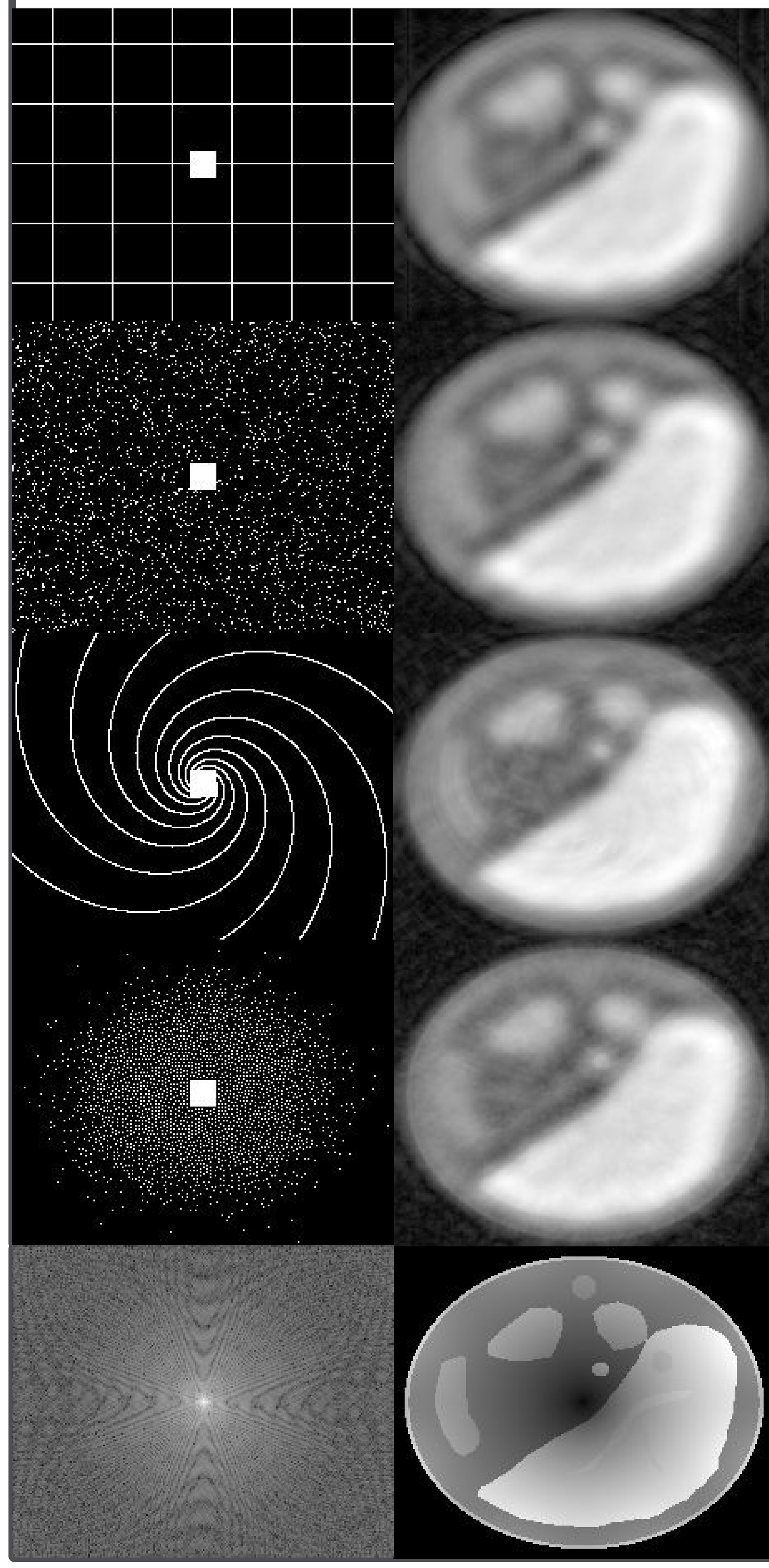
Michael Lustig, for code contributions implementing SPIRiT and the wavelet transform

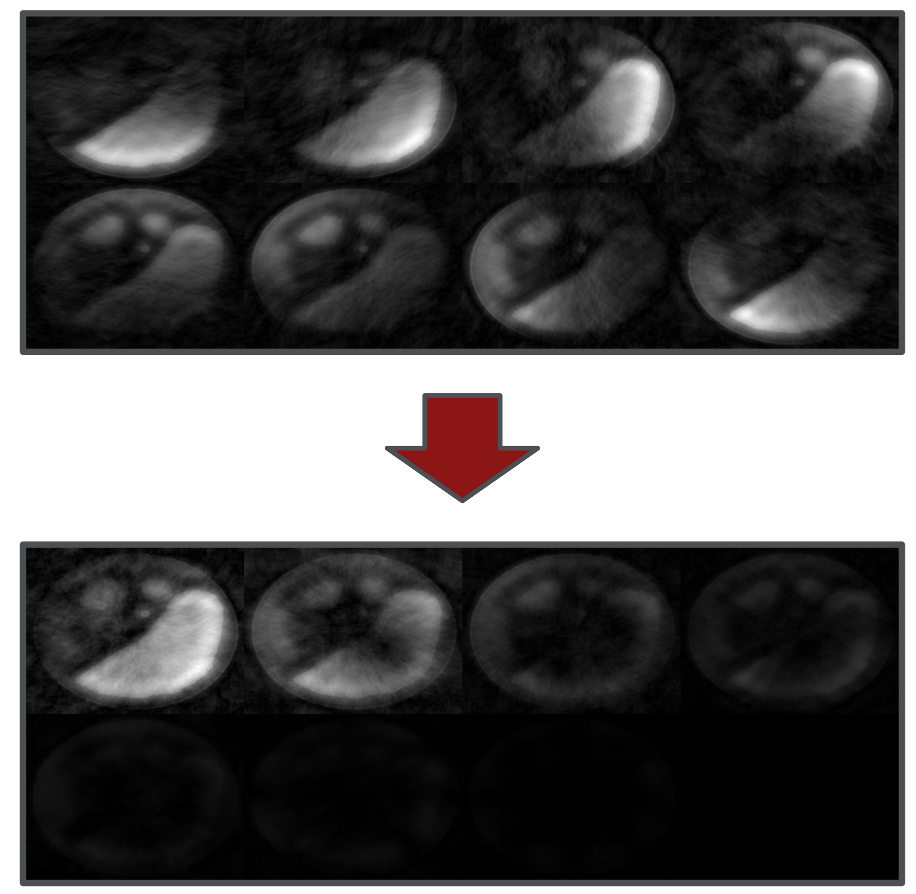
Methodology: Denoising and Data Consistency

Undersampling Strategies

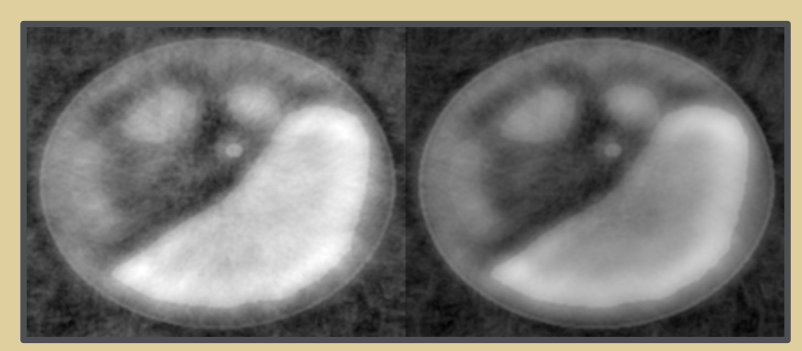


Parallel Imaging: Coil Compression

Data is acquired on multiple receiver coils, each of which captures a fraction of the volume. The problem size is reduced and denoising is achieved by compressing to an eigenspace representation.

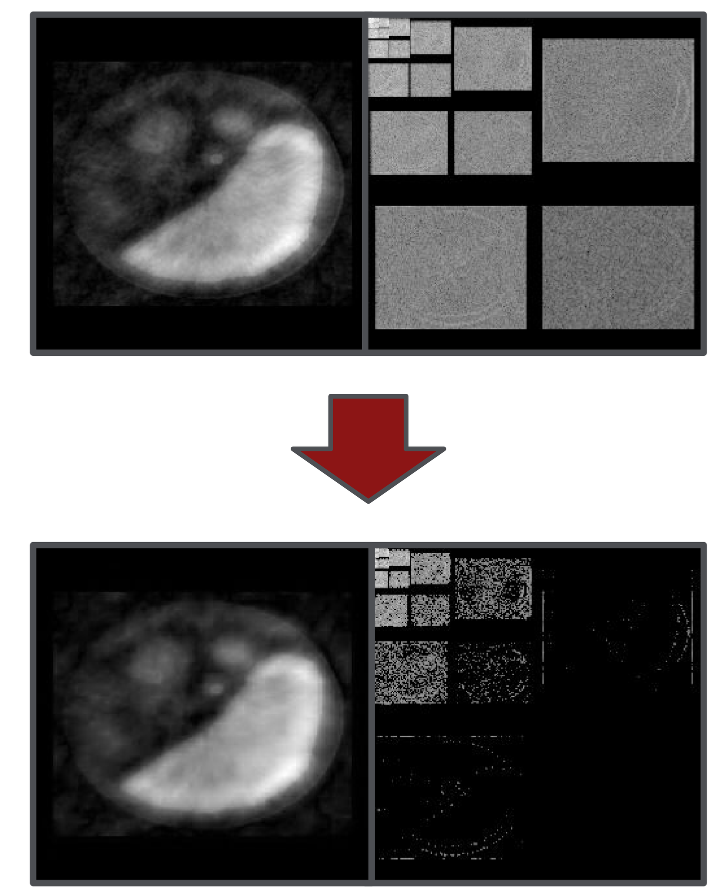


The image energy is compressed into a fraction of the original number of channels, while signal noise remains spread across the channels.

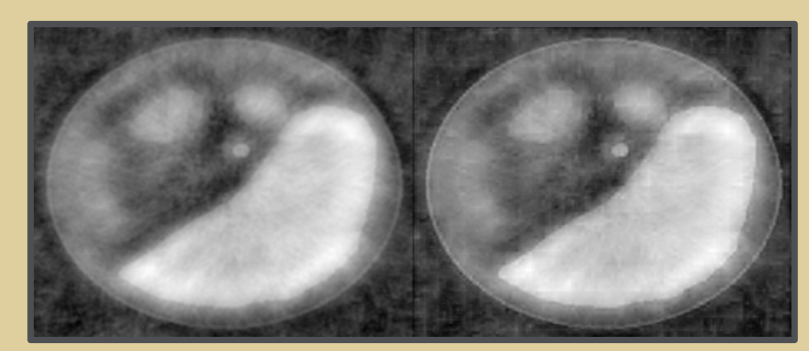


Spatial CS: Wavelet POCS Type Algorithm

Magnetic resonance images have an exploitable sparsity in the wavelet domain. Thresholding small wavelet coefficients results in denoising.

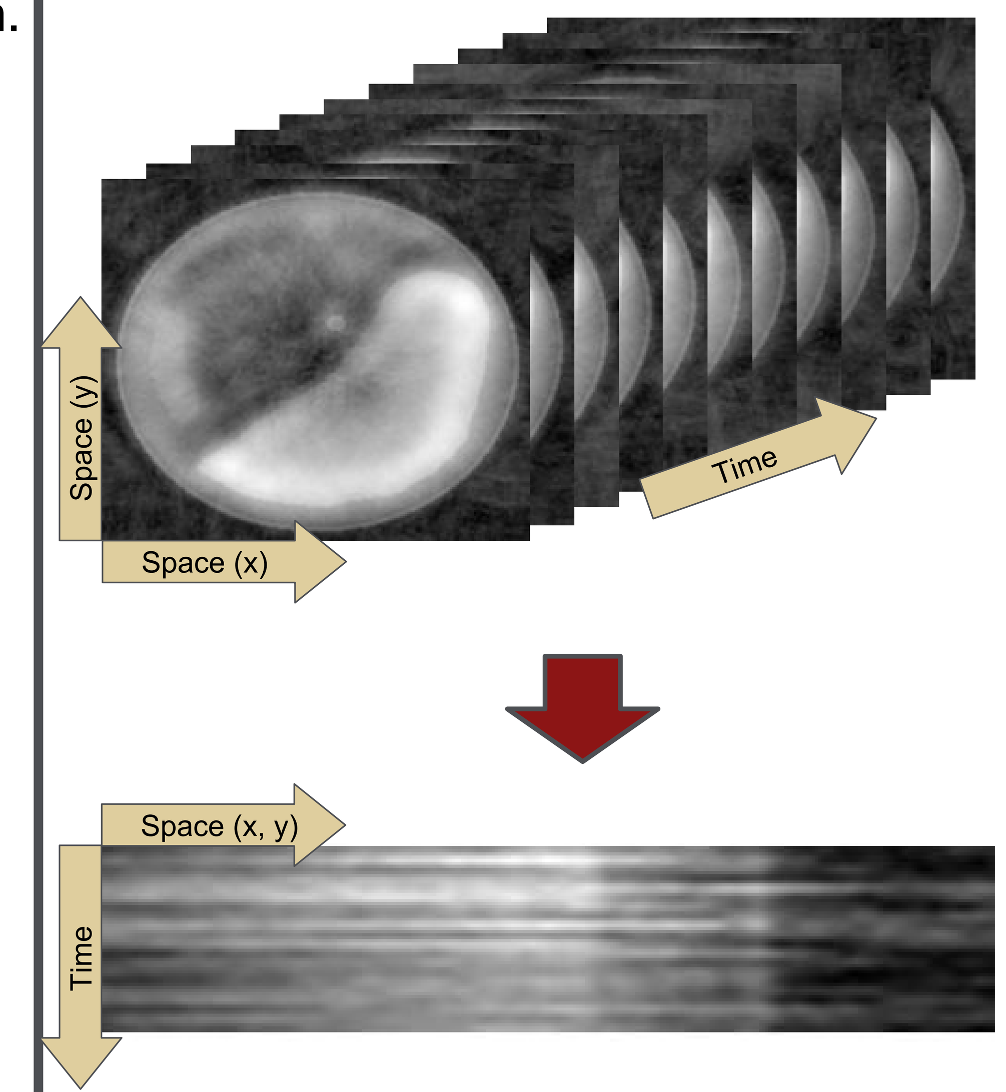


After thresholding, the known sampled data is restored. The process is repeated iteratively until sufficient convergence.



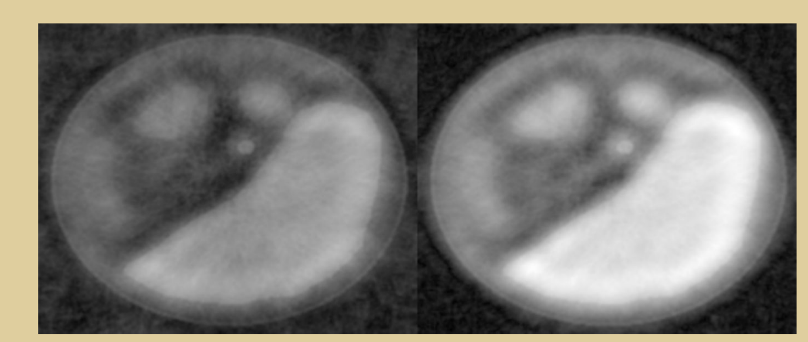
Temporal CS: SPIRiT + Temporal Sparsity

Casorati Matrix



Temporal POCS Type Algorithms

- Low-Rank Approximations
- FFT Thresholding
- Wavelet Coefficient Thresholding



References

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[2] M.Lustig, D.Donoho, and J.M.Pauly, "Sparse MRI:The application of compressed sensing for rapid MR imaging," *Magnetic Resonance in Medicine*, vol. 58, pp. 1182–1195, 2007.

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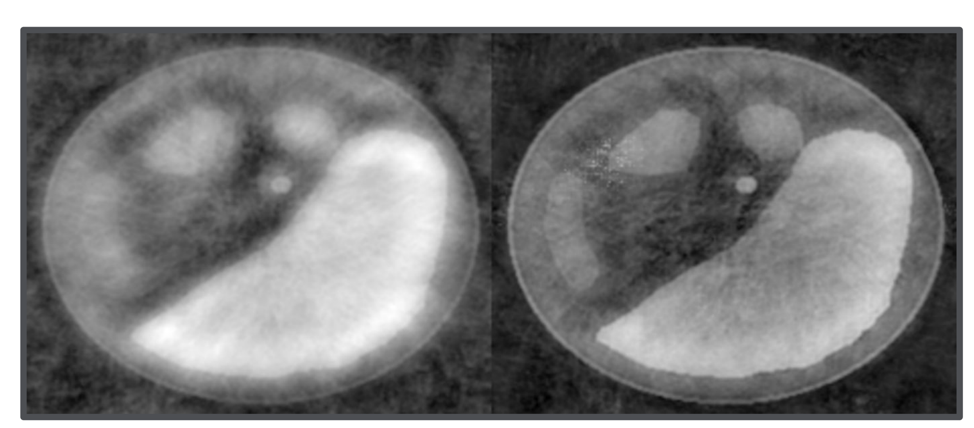
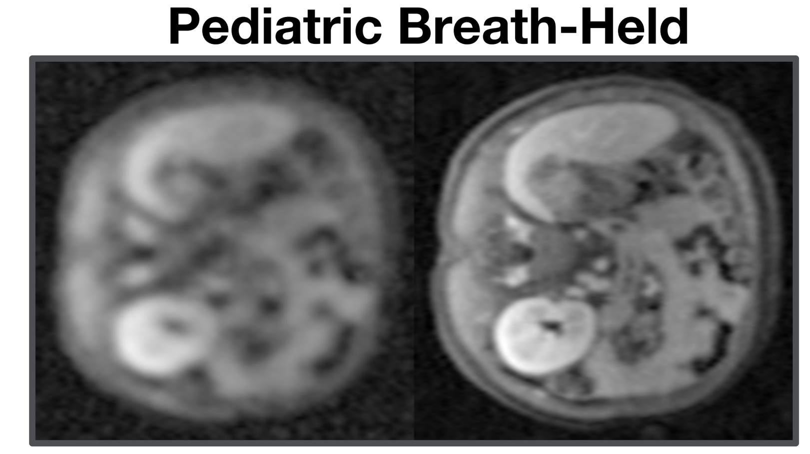
Qualitative Results

16x Undersampled DCE Phantom



18x Undersampled DCE Pediatric Breath-Held



18x Undersampled DCE Pediatric Breath-Held