Approach and Execution

Introduction

Magnetic Resonance Imaging (MRI) is a widely used medical imaging technique which uses nuclear magnetic resonance to acquire images in Fourier domain. The major challenge to MRI currently is the long scan times required to produce high resolution or large FOV MR images. This is limited due to the physical and physiological constraints.

To speed up the process Compressed Sensing can be applied to MRI as it allows for the under-sampling of the k-space to faithfully reconstruct images. As outlined in section it does this through satisfying three requirements: sparsity, incoherent under sampling and non-linear reconstruction methods. Wavelet, TV and L1 minimization.

Currently, the conventional method (Sparse MRI) does not use prior information from a previous image to speed-up acquisition or improve image reconstruction. However, in many types of MRI scans this information is available and may potentially be used. Such applications include the following:

1. Dynamic MRI, Diffusion MRI- Multiple images are acquired at a single imaging session. This allow for exploitation of similarity along the temporal(time domain)
2. Multi-contrast MRI- Scanning of region with different contrasts (T1 and T2 weighted images). Structural similarities exist between the images which are able to enchance image reconstruction.

Referenced based compressed sensing has be explored a lot over the past few years in various applications of MRI. Current methods which use a reference based approach are listed in the table below.

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| --- | --- | --- |
| **Author** | **Description** | **Imaging application tested** |
| Liang and Lauterbur (Ref. 44) | Exploiting temporal similarity in dynamic MRI using generalized scheme imaging | Dynamic MRI (dynamic T1-weighted and diffusion MRI) |
| Hanson et al. (Ref. 11) | Exploiting two high resolution reference images to improve dynamic imaging in a generalized scheme | Dynamic MRI (DCE MRI) |
| Hess et al. (Ref. 12) | Exploiting reference image for generation of basis functions, used to improve dynamic MRI | Dynamic MRI (MR angiography) |
| Tsao et al. (Ref. 32) | Incorporating reference image and prior on changed regions for improved reconstruction | Longitudinal MRI |
| Tsao et al. (Ref. 45) | Exploiting spatiotemporal correlations for dynamic MRI (training-based approach) | Dynamic MRI (cardiac imaging) |
| Lustig et al. (Ref. 16) | Random sampling in *k*-*t* space, reconstruction based on wavelet-Fourier sparsity | Dynamic MRI (cardiac imaging) |
| Haldar et al. (Ref. 46) | Using anatomical priors to improve SNR via penalized ML | Single-contrast MRI |
| Lang and Ji (Ref. 17) | Exploiting similarity to a reference image in a CS framework | Dynamic MRI (brain DCE) |
| Gamper et al. (Ref. 18) | Exploiting sparsity in the *x*-*f* space for dynamic MRI | Dynamic MRI (cardiac imaging) |
| Jung et al. (Ref. 19) | Exploiting sparsity of residuals in dynamic MRI | Dynamic MRI (cardiac imaging) |
| Yun et al. (Ref. 13) | Exploiting a reference image for basis functions generation used to improve dynamic MRI | Dynamic MRI (brain fMRI) |
| Samsonov et al. (Ref. 33) | Exploiting sparsity of gradient of difference between baseline and follow-up scans | Longitudinal MRI |
| Chen et al. (Ref. 20) | Exploring the exploitation of a reference frame in x-t and x-f domains in dynamic MRI | Dynamic MRI (cardiac imaging) |
| Wu et al. (Ref. 24) | Using noisy reconstruction as a reference for sorting in parallel imaging | Single-contrast MRI |
| Peng et al. (Ref. 25) | Exploiting reference image for sparsifying transform generation | Single-contrast MRI |
| Bilgic et al. (Ref. 28) | Exploit similarity of spatial derivatives in multicontrast MRI | Multicontrast MRI |
| Du and Lam (Ref. **26**) and Lam *et al.* (Ref. **27**) | Exploiting similarity to a reference image in a CS-based hybrid reconstruction and registration scheme | Single-contrast MRI |
| Nguyen and Glover (Ref. 14) | Exploiting a reference image for generation of basis functions used for generalized series reconstruction of dynamic MRI | Dynamic MRI (brain fMRI) |
| Haldar et al. (Ref. 15) | Using structural MRI for SNR improvement of DWI in an ML scheme | Diffusion MRI |
| Qu *et al.* (Refs. **29** and **30**) | Exploiting similarity of image patches within and between multicontrast MRI in CS framework | Multicontrast MRI |
| Huang et al. (Ref. 31) | Joint TV and group wavelet based reconstruction for multicontrast MRI | Multicontrast MRI |
| Chiew et al. (Ref. 21) | Low-rank based reconstruction | Dynamic MRI (brain fMRI) |
| Li et al. (Ref. 34) | Using nonreference-based reconstruction as a prior for reference-based reconstruction | Longitudinal MRI |
| Adluru et al. (Ref. 22) | Exploiting TV-based reconstruction for improved low-rank based reconstruction | Dynamic MRI (cardiac imaging) |
| Otazo et al. (Ref. 23) | Low-rank based reconstruction | Dynamic MRI (cardiac imaging, MR angiography) |
|  | Exploiting reference image in an adaptive-weighted CS scheme | Single- and Multi-Contrast MRI, Longitudinal MRI |

From closer inspection of the existing methods, the reference based methods are applications specific and assume substantial similarity in image or other domain.

Similar to previous methods, this thesis aims to introduce a novel method to use previous information from a previous similar reference image to enhance the image reconstruction. The similarity is assumed to be in the image domain. The proposed method will use the CS framework proposed in [1] and include weighting factors for both the L1 and TV components. In this new algorithm the image will be reconstructed first using algorithm in [1] and then a reference image will processed and its edges will be determined. Using this edge information, the reconstructed image will be image registered with the edges. The weighting factors of the L1 and TV weightings on edge components will then be optimized to account prior information. Using the new weighting factors, the image will then be reconstructed again. To demonstrate the performance of the proposed method, various typical images, multi-contrast images will be used at reduction factors up to 10. Using structural similarity (SSIM) and peak signal-to-noise ratio (PSNR) as image quality metrics, the proposed method was compared with the conventional method.

Methodology.

As mentioned in section 1.1.1. Currently the conventional method of compressed sensing in MRI does not use prior information or a reference image in its algorithm. In many instances such dynamic MRI, angiography and (t1 and t2 images) these

**Methodology**

CS MRI

Equation. And changes to MRI

Similarities in typical MRI applications

Weightings in general

Image Registration Algorithm (Flow Chart)

Full Flow chart of MRI process

**Experimental Method**

Weizman, L., Eldar, Y. C. and Ben Bashat, D. (2016), Reference-based MRI. Med. Phys., 43: 5357–5369. doi:10.1118/1.4962032