MRI Image Reconstruction from undersampled K-Space data

EE698K: Project Proposal
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1 Introduction

1.1 Magnetic Resonance Imaging (MRI)

MRI is a medical imaging technique that uses strong magnetic fields and radio waves to generate cross-sectional images of the human body. MRI is based on the science of nuclear magnetic resonance. Hydrogen atomic nuclei can absorb and emit radio frequency energy when placed in an external magnetic field. MRI exploit this property of hydrogen nuclei to map the location of water and fat in the human body as it has abundance of these molecules. Pulses of radio waves are used to excite the hydrogen nuclei of a particular region, localized using magnetic field gradients, and the emitted radio wave is sensed to generate an image of the affected region. Different contrasts are generated between tissues based on the relaxation properties of the hydrogen atoms therein. Unlike traditional cameras, the data obtained from the MRI sensors is in a different space called K-Space, which is basically the Fourier Transform of the actual image. The image is then reconstructed from the K-Space data to get a good quality image of the inside of human body.

1.2 Compressed Sensing (CS)

Compressed sensing aims to reconstruct images from fewer measurements than what were traditionally thought to be necessary [3]. MRI data acquisition is a very slow process which may result in suboptimum output because the patient has to stay still during that time which is difficult and also a big inconvenience. Applying compressed sensing to MRI offers significant scan time reductions, with benefits for patients and health care economics. Various reconstruction techniques are used to get good quality results from the undersampled MRI data. Our project is based on understanding some of those techniques and implementing it on a real life dataset.

2 Previous Work

- D.L. Donoho introduced the Compressed Sensing in [1], and showed that CS allows natural images of m pixels to be faithfully represented by non-adaptive non-pixel samples of the order $O(m^{1/4}\log^{5/2}(m))$.
- Sparse MRI [2] exploited the sparse nature of MRI data and applied the CS on K Space data and gave techniques for reconstruction of the MR image.
- Ravishankar Et al. [4] successfully demonstrated the use of Dictionary Learning for reconstruction from highly undersampled K-Space data.
- In the paper [5] the authors proposed a novel framework for MR image reconstruction which is significantly faster than previous approaches involving synthesis dictionaries, while also providing comparable or better reconstruction quality.

3 Problem Statement

From a highly undersampled K-Space data of an MRI scan, our aim is to obtain a high quality image using appropriate transforms that will be learnt using different techniques.

4 Dataset

We are going to use the following opensource dataset: "**MR Datasets for Compressed Sensing**". The dataset is built as a result of colaboration between Prof. Michael Lustig at UC Berkeley and Dr. Shreyas Vasanawala at Stanford's Lucille Packard Children's Hospital. The dataset consists of following kinds of K-Space samples:

1. UnderSampled images: 28 abdomen scans, 21 knee scans.

2. Fully Sampled (at nyquist rate): 20 knee scans.

Since we have both kinds of data we can work on reconstruction techniques on undersampled scans, and can also utilize fully sampled scans in case if we want to change the under-sampling technique.

5 Tentative Approach

Following is an outline of the approach we are planning to take:

- First we'll set up the platform, and perform simple Inverse FFT on fully-sampled K-Space images to obtain grayscale images.

- Undersampled scans are sparse in K Space. So we'll try image reconstruction by solving the sparse representation problem of minimizing the Total Variance (TV) [2].

- Then we'll implement Dictionary Learning on K-space images (obtained via Compressed Sensing), as in [4].

- Then we'll implement the approach used in [5] that simultaneously adapts a transform and reconstructs the image from the undersampled k-space measurements.

- Rest of the work will be spent on comparing the results and introducing our own modifications to hopefully reduce the reconstruction error and/or execution time further.

If time permits, we could try to implement some other reconstruction methods also and compare their results with the already implemented methods.

References

[1] David L. Donoho. Compressed sensing. *IEEE Transactions on information theory*, 52.4:1289–1306, 2006.

[2] David Donoho Lustig, Michael and John M. Pauly. Sparse mri: The application of compressed sensing for rapid mr imaging. *Magnetic resonance in medicine*, 58.6:1182–1195, 2007.

[3] Donoho D. L. Santos J. M. Pauly J. M. Lustig, M. Compressed sensing mri. *IEEE signal processing magazine*, 25.2:72–82, 2008.

[4] Saiprasad Ravishankar and Yoram Bresler. Mr image reconstruction from highly undersampled k-space data by dictionary learning. *IEEE transactions on medical imaging*, 30.5:1028–1041, 2011.

[5] Saiprasad Ravishankar and Yoram Bresler. Sparsifying transform learning for compressed sensing mri. *Biomedical Imaging (ISBI), 2013 IEEE 10th International Symposium on. IEEE*, 2013.