Undersampled MRI reconstruction

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Abstract

Magnetic Resonance Imaging (MRI) examination times can vary from fifteen minutes to one hour, which is inconvenient for both the doctor and the patient. Additionally, human motion during the scan can significantly decrease the quality of the images. Undersampled MRI allows for fewer measurements in Fourier-space, thereby reducing the scan time by 4-8 times. However, in this approach, some information is lost according to the Nyquist-Shannon sampling theorem. The main hypothesis of this study is the possibility of using general information from the scan space through machine learning to mitigate this problem.

1 Introduction

In MRI machines, the spectrum of the object under study (so-called k-space, corresponding to the Fourier spectrum of the image) is read to obtain an image. Full k-space data is required for correct image reconstruction. Obtaining complete k-space takes a lot of time, to speed up MRI reconstruction is performed from incomplete k-space (also called undersampled MRI) using compressed sensing or deep learning methods. In the case of incomplete k-space, there is also the question of how much of the k-space should be measured and how much should be skipped (undersampled pattern optimization). Recent studies have shown that for accelerated MRI, k-space pattern optimization for specific data (specific modality, organs) improves reconstructed images compared to standard sampling patterns.

This project proposes to further investigate the issue of accelerated MRI reconstruction, namely the optimization of magnetic field gradient configuration. Medical MRI machines use a constant field gradient - in this case, the resulting k-space data corresponds to the Fourier spectrum of the image. This project will investigate the possibility of optimizing the magnetic field gradient to improve the quality of accelerated MRI reconstruction

2 Problem statement

1. $(\mathrm{M}, \mathrm{Y}) \in \mathcal{D}$ – Dataset
2. $\mathrm{M}, \mathrm{Y} \in \mathbb{R}^{k\times k}$, $\mathrm{Y} = \mathcal{F}(\mathrm{M})$ – MRI image and its Fourier transformation
3. $I : \mathbb{R}^{k\times k} \longrightarrow \mathbb{R}^{k\times k}$ – Filter function, which preserves other elements and zeroes other

The goal is to find function $B^* : \mathbb{R}^{k\times k} \longrightarrow \mathbb{R}^{k\times k}$ which minimizes the risk over the image distribution:

$$B^* = argmin_B R(B)$$

where

$$R(B) = \mathbb{E}_{\mathrm{Y},\mathrm{M}}[L(B(I(\mathrm{Y})), \mathrm{M})]$$