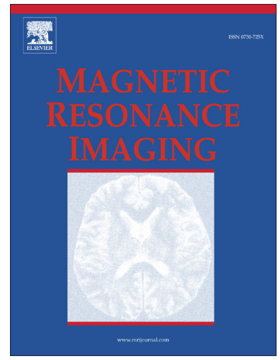

An autoencoder based formulation for compressed sensing reconstruction

Angshul Majumdar

PII: S0730-725X(18)30196-6
DOI: doi:10.1016/j.mri.2018.06.003
Reference: MRI 8976

To appear in: *Magnetic Resonance Imaging*

Received date: 2 August 2017
Revised date: 4 June 2018
Accepted date: 4 June 2018

Please cite this article as: Angshul Majumdar , An autoencoder based formulation for compressed sensing reconstruction. Mri (2017), doi:10.1016/j.mri.2018.06.003

An Autoencoder Based Formulation for Compressed Sensing Reconstruction

Angshul Majumdar
Indraprastha Institute of Information Technology, Delhi, India
angshul@iiitd.ac.in

***Abstract*—This work proposes a new formulation for image reconstruction based on the autoencoder framework. The work follows the adaptive approach used in prior dictionary and transform learning based reconstruction techniques. Existing autoencoder based reconstructions are non-adaptive; they are trained on a separate training set and applied on another. In this work, the autoencoder is learnt from the patches of the image it is reconstructing. Experimental studies on MRI reconstruction shows that the proposed method outperforms state-of-the-art methods in dictionary learning, transform learning and (non adaptive) autoencoder based approaches.**

I. INTRODUCTION

The problem of reconstructing images from lower dimensional projections have received considerable interest in the last decade. The problem is most prevalent in magnetic resonance imaging (MRI) and X-Ray computed tomography (CT). In MRI the problem arises owing to the slow data acquisition time; in order to accelerate scans, the K-space is randomly under-sampled and there is a need to recover the underlying image. The mathematical problem turns out to be an under-determined linear inverse problem. In general such problems have infinitely many solutions; but since the images are known to be sparse in certain domains (e.g. wavelet, DCT, etc.), compressed sensing (CS) based techniques can be leveraged to solve these. CS exploits the transform domain sparsity of the images in order to recover them from lower dimensional projections.

CS employs fixed sparsifying bases like DCT, wavelet, finite difference etc. It has been seen that better reconstruction results can be obtained, when the sparsity basis is learnt from the image (adaptively) during reconstruction. Dictionary learning and transform learning based reconstruction techniques fall under this category.

Dictionary learning (DL) enjoys popularity both in image / signal processing research as well as in machine learning / computer vision. Transform learning (TL) is relatively new; there are only a handful of papers on application of this technique on signal processing problems (such as reconstruction and denoising). Its application in machine learning is nascent. Both DL and TL are employed in signal and image processing for solving inverse problems (reconstruction, denoising etc.).

This work proposes an autoencoder based formulation for image reconstruction. Autoencoders are hardly known to the signal processing community. It is popular in deep learning research; used as basic building block for deep neural network.

Autoencoders have been used in the past to solve inverse problems like denoising and reconstruction. But the success has only been partial. They yield results at par with CS based methods but cannot compare with DL or TL. This is mainly because, a deep learning based approach was adopted to solve the inverse problem. The autoencoder was trained on a generic dataset and assumed that it will generalize to the unseen image. Such a heuristic approach works for natural images where huge volumes of training data are available openly. But not for medical images (or any other scientific imaging modality per se), where training samples are always few – the learnt autoencoder does not generalize.

In this work we propose an autoencoder based formulation where it will be learnt from the image (to be reconstructed) in an adaptive fashion. This is in line with modern adaptive (DL and TL based) reconstruction paradigm. Results on MRI reconstruction shows that our proposed method yields by far the best reconstruction results from highly under-sampled data.

II. BACKGROUND

A. Sparsity Based Reconstruction Techniques

To accelerate data acquisition in MRI, the K-space is under-sampled. The data acquisition can be expressed as a linear problem,

$$y_{m\times 1} = A_{m\times n}x_{n\times 1},\ m < n \qquad (1)$$

where x is the image to be reconstructed, A the restricted Fourier operator and y the acquired K-space data.

In general (1) is an under-determined linear inverse problem that has infinitely many solutions. However, medical images are known to be sparse in some transforms like wavelet, DCT, finite difference etc. Compressed sensing (CS) exploits the transform domain sparsity in order to uniquely recover a solution to (1).

Incorporating transform domain sparsity in (1) leads to,

$$y = AS^T\alpha \qquad (2)$$