Group Sparse Compressed Sensing and Fourier Synthesis in MRI with high acceleration or non-Cartesian applications

Compressed sensing (CS) based signal recovery from undersampled acquisitions is based on the general assumption that the underlying signal is sparse in some transform domain [1,2]. Over the last years CS has been of great interest to accelerate the acquisition of Magnetic Resonance Imaging (MRI)[3]. These methods exploit the sparsity and compressibility of MRI in the spatial, temporal or spatiotemporal domains. However, in MR images might be some additional information that could be incorporated as a prior information into the CS reconstruction to achieve higher acceleration factors. We propose two group-sparse based approaches to incorporate prior knowledge in CS MRI reconstruction: a) exploiting the spatial structure or b) exploiting the intensity distribution of the signal in the sparse representation. In our talk, we will focus on these two methods titled as 'k-t group sparse' (k-t GS) and 'k-t group sparse using intensity based clustering' (k-t GSI) and we will demonstrate their application on 2D cardiac and 3D hyperpolarized lung MR data.

In order to use the group sparse CS formulation, the association of elements to different groups must be known in advance. In MRI, a low resolution separate or interleaved training data can give a rough estimate of the underlying sparse signal from which the groups can be learned. In this talk, we will propose two methods based on group sparse formulation namely k-t group sparse (k-t GS)[4] and k-t group sparse using intensity based clustering (k-t GSI)[5]. Each of these two methods uses a different group assignment procedure. K-t GS uses spatial structure based group assignment, whereas k-t GSI uses intensity order based group assignment.

In spatial structure based group assignment, the groups are assigned based on spatial connectivity of the support elements. First, the support of the signal is learned by thresholding the signal from training data and those support elements that lie in consecutive locations are assigned to a unique group. Every element that is not the part of signal support is assigned as an individual group.

In intensity based group assignment, the groups are assigned based on their intensities of the signal elements using a K-means clustering algorithm. The intensity based group assignment procedure is more generalized than the spatial structure based group assignment as the support elements do not need to be lying together spatially.

We will demonstrate the use of k-t GS and k-t GSI methods in cardiac and respiratory MR applications. The results will be compared against standard CS reconstructions. The tuning of performance parameters for these methods will also be discussed.

Outlook:

In future, we will be expecting more and more constrained CS formulations for better reconstruction. One problem is to identify different constraints, each of which provides a unique information about the underlying sparse signal. This will ensure that addition of constraints will always be advantageous and will tend to improve the CS reconstruction. However, the bottle neck for the signal recovery will be still the degree of undersampling and the SNR, where the prior information learned from the undersampled data is not precise enough to improve the CS reconstruction. Due to generalized formulation of k-t group sparse methods, additional constraints or different norm minimizations (such as nuclear norm minimization) can be added together with the mixed l_1-l_2 norm formulation in Eq 2.

Time permitting, we will also describe speculative applications of Fourier Synthesis, inspired from astronomical imaging, to non Cartesian MRI.

1. Donoho DL. Compressed sensing. IEEE Transactions on Information Theory 2006;52(4):1289-1306.

2. Candes EJ, Romberg J, Tao T. Robust uncertainty principles: Exact signal reconstruction from highly incomplete frequency information. IEEE Transactions on Information Theory 2006;52(2):489-509.
3. Lustig M, Donoho D, Pauly JM. Sparse MRI: The application of compressed sensing for rapid MR imaging. Magn Res Med 2007;58(6):1182-1195.

4. Usman M, Prieto C, Schaeffter T, Batchelor PG. k-t group sparse: a method for accelerating dynamic MRI, in press, Magn Res Med; 2011
5. Prieto C, Usman M, Batchelor PG, Schaeffter T. k-t group sparse using intensity based clustering, ISMRM 2011, Montreal, Canada.