Five-Dimensional Echo-Planar Correlated Spectroscopic Imaging in Human Calf and Breast using Group Sparsity and Total Variation-based Compressed Sensing Reconstruction

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Introduction

Echo-planar spectroscopic imaging (EPSI) accelerates the acquisition of MR Spectroscopy (MRS) using simultaneous encoding of one spatial and spectral dimension per repetition time (TR), however it is limited by the spectral overlap which is inherent in one-dimensional (1D) MRS techniques[1]. Five-dimensional echo-planar-based correlated spectroscopic imaging (5D EP-COSI) acquires undersampled data in two spatial dimensions (y-z) and one indirect spectral dimension (F_1) to allow improved spectral dispersion for each voxel within a 3D volume[2]. Compressed sensing (CS) techniques are applied to reconstruct the undersampled data[3]. This study compares the application of two CS techniques – Group Sparsity[4] (GS) and Total Variation[5] (TV) – to reconstruct the 5D EP-COSI data in the human calf muscle and breast, and in a corn oil phantom.

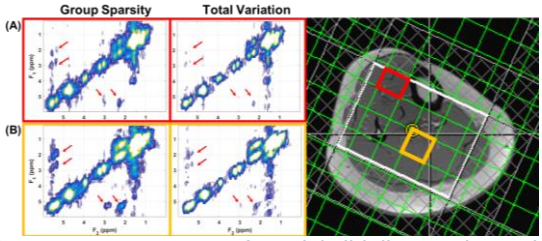

Figure 1: COSY spectra from (A) tibialis anterior and (B) soleus muscle, reconstructed with GS and TV.

Methods

Human subjects were recruited with IRB approval to record 5D EP-COSI data in the calf and breast. The data was 8× undersampled in the k_y-k_z-t_1 space, and the acquisition parameters were as follows: TR = 1.5 s, TE = 35 ms, voxel size = 1.5 × 1.5 × 1.5 cm^3, matrix size = 16 × 16 × 8, spectral width SW_2 = 1190 Hz, SW_1 = 1250 Hz, 512 t_2 points, 64 t_1 increments, and scan time 25.6 minutes. Fully-sampled corn oil phantom data (2 spatial + 2 spectral) was retrospectively undersampled at reduction factors (RF) of 2 and 4 and normalized root mean square error (nRMSE) values were calculated to assess reconstruction accuracy between the two methods. Both CS approaches are based on the Split-Bregman formulation with regularization parameters for each algorithm adapted according to the noise level in the data.

Results

Qualitatively, Figures 1 and 2 demonstrate that GS-based CS reconstruction recovers cross peaks in both breast and calf data better than TV. Table 1 shows that in terms of nRMSE, GS more accurately reconstructs COSY spectral from all voxels compared to TV.

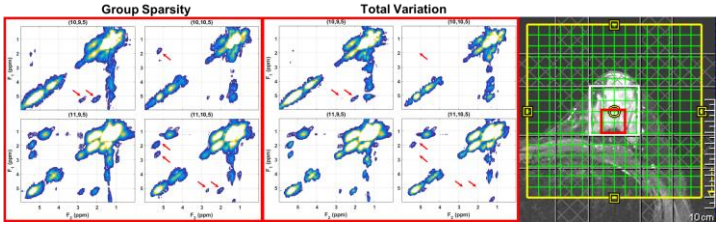

Figure 2: 2 × 2 voxel region in a central slice extracted from the breast data. GS (left) and TV (right) reconstructed COSY spectra.

Discussion & Conclusion

GS is a more suitable regularization approach than TV for CS reconstruction of prospectively undersampled 5D EP-COSI data. These techniques are further being evaluated in additional cases to compare the reliability of the GS and TV approaches in breast cancer and diabetic calf muscle.

GS				TV			
RF = 2		RF = 4		RF = 2		RF = 4	
7.06E-03	6.74E-03	1.31E-02	1.18E-02	2.22E-02	1.99E-02	3.67E-02	3.47E-02
7.07E-03	5.42E-03	1.29E-02	9.90E-03	2.07E-02	1.80E-02	3.14E-02	2.89E-02
6.62E-03	5.27E-03	1.21E-02	9.74E-03	2.46E-02	1.80E-02	3.91E-02	3.04E-02
6.50E-03	6.37E-03	1.13E-02	1.15E-02	2.73E-02	2.55E-02	3.16E-02	3.10E-02

Table 1: nRMSE values for GS and TV reconstructions of corn oil phantom data, for all voxels within a 4×2 region.

References

[1] Posse et al., JMRI, 2013; 37:1301-25 [2] Wilson et al., MRM, 2015; 74(5):1199-208 [3] Burns et al., Algorithms, 2014; 7(3):276-94 [4] Goldstein et al., SIAM J. Imag. Sci., 2009; 2(2): 323-43.

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