# A swifter SWIFT using compressive sensing

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**Introduction:** Sweep imaging with Fourier transformation (SWIFT) is a novel MR imaging technique which allows for fast, short $T_2$ sensitive MR imaging with reduced motion artifacts and reduced signal dynamic range (1). Compressed sensing has been demonstrated as a viable technique to accelerate MR acquisition (2) and we demonstrate its utility to speed up SWIFT acquisitions. The SWIFT MR volume data is sparse in the total variation transform domain and the artifacts would be incoherent in this domain, thus satisfying the important requirements for compressed sensing based iterative reconstruction (2). The nonlinear conjugate gradient algorithm has been shown to be effective in reconstructing MRI data acquired through compressed sensing (2). Also, it is important to use a 3 dimensional total variation transform to exploit the sparsity in all the 3 dimensions and hence is used in the reconstruction.

**Methods:** 3D SWIFT data for a resolution phantom was acquired along 16,000 unique projections, with np=128; FOV=40 cm and TR= 4 ms, BW=31 kHz, total acquisition time 74 sec. The projections were acquired in blocks of 500. Each block was defined, using a sorted halton ordering scheme, to encompass a random but uniformly distributed sampled set of projections encompassing the object. The acquired k-space was gridded to Cartesian k-space as in (3) and Fourier transformed with density compensation to obtain the full k-space reconstruction of a matrix size of 138 x 138 x 138. The compressed sensing reconstruction was performed using 6 out of the 32 spheres hence providing an acceleration of 5.33 in time. The zero filled k-space was gridded as in the prior case and Fourier transformed with density compensation (zfwdc) to the same matrix size as before. This served as the initial estimate of the volume which was iteratively reconstructed using a custom implementation of a nonlinear conjugate gradient algorithm incorporating a 3D total variation norm and a data consistency L2 norm as shown in the equation below.

$$\epsilon(m) = \| F_u m - y \|_2 + \lambda_{TV}\, TV(m) \qquad \{1\}$$

where m is the desired MRI volume, $F_u$ is the Fourier transform operator, $\|.\|_2$ is the L2 norm operator, TV is the 3D total variation operator, $\lambda_{TV}$ is the regularization parameter for the TV term, and $\epsilon$ is the value of the cost function. For solving {1}, a total of 8 iterations were used. All implementations were performed using MATLAB, (Mathworks, Inc., MA.)

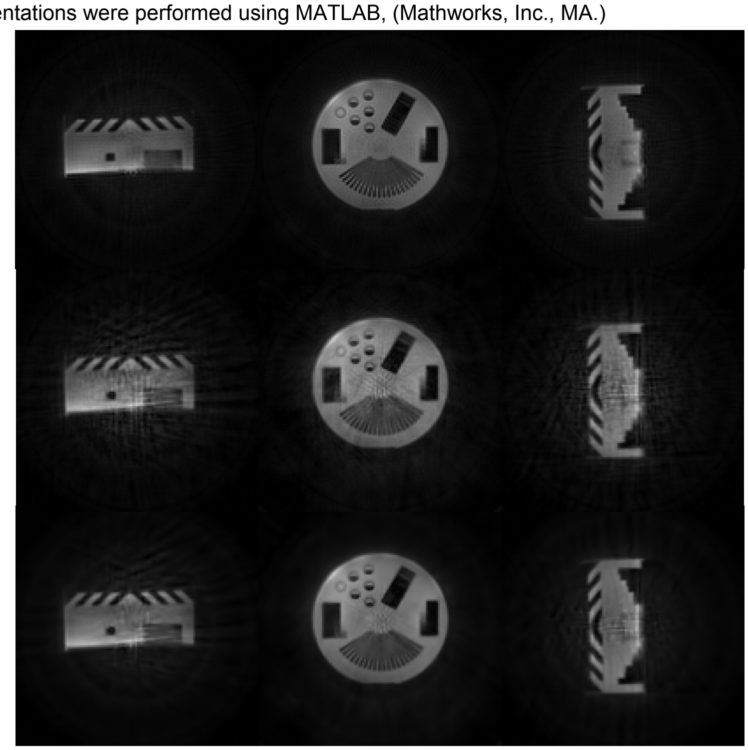


*Figure 1: Top panel shows the original (full k-space reconstruction) images of the 3 orientations of a particular slice while the center panel shows the corresponding zfwdc images and the bottom panel depicts the corresponding compressed sensing based reconstruction.*

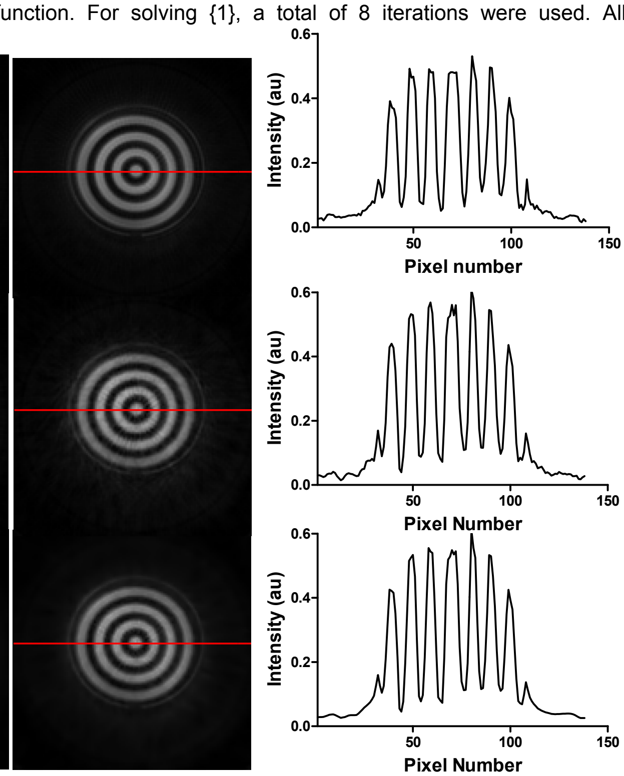


*Figure 2: The full k-space reconstruction of a slice with symmetric feature and its corresponding line intensity plot is shown in the top panel with the corresponding zfwdc (center panel) and compressed sensing reconstruction(bottom panel) at 5.33X shown below.*

**Results:** The top panel in figure 1 shows the full k-space reconstruction of the 3 orientations of a given slice while the corresponding zfwdc and compressed sensing reconstruction is shown in the center and bottom panels respectively. It can be observed that the compressive sensing based reconstruction successfully reproduces the fine detail in the image panel while also reducing the incoherent noise seen in the zfwdc images. Figure 2 shows a slice consisting of a symmetric feature for the full k-space reconstruction in the top panel with the corresponding zfwdc and compressed sensing reconstruction shown below. Intensities of a line through the center of the slice (depicted by the red line) are plotted on the right. Similar intensity profile as the full k-space reconstruction is seen with the compressed sensing based reconstruction with reduction in artifacts. The normalized RMSE value for the reconstructed volume, computed on a region of interest determined by the radial field of view containing the object, was calculated to be 0.0108.

**Conclusion and future work:** The application of compressed sensing to accelerate SWIFT MR imaging has been demonstrated on a phantom with more than 5 fold acceleration with reduction in artifacts and noise while maintaining low reconstruction error. Further improvements in reconstruction are being investigated with the use of wavelets for compression. A potential application of a swifter SWIFT would be the dynamic imaging of $T_2$ exchange based contrast agents (4) within acceptable acquisition times.

**Reference:** 1. Idiyatullin D, et. al. J Magn Reson 2006;181(2):342-349. 2. Lustig M,et.al. Magn Reson Med 2007;58(6):1182-1195. 3. Jackson JI, et. al. IEEE T Med Imaging 1991;10(3):473-478. 4. Terreno, Magn Reson Med 2002; 47(4) 639-648

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