Compressive Sensing and Low Contrast Detectability

J. D. Trzasko[1], A. Manduca[1], and M. A. Bernstein[1]
[1]Mayo Clinic, Rochester, MN, United States

Introduction: Compressive Sensing (CS) is a powerful data acquisition and reconstruction paradigm that has facilitated the substantial acceleration of several MRI applications with little compromise in image quality [1,2]. To date, the most successful applications of CS to MRI have focused on situations where the information of interest is represented by high-contrast features (e.g. contrast-enhanced MR angiography). However, in many MRI applications low-contrast features are of greater clinical interest. Given the fundamental link between sparsity-driven reconstruction methods and shrinkage or thresholding-based regression [3], there has been expressed concern that CS is not well-suited for the task of low-contrast object detection (LCOD). In this work, we investigate the potential of the CS paradigm for LCOD and compare its performance against the widely-used approach of zero-filling (ZF), with and without appropriate windowing.

Methods: The American College of Radiology (ACR) Quality Control (QC) phantom was imaged with our standard daily quality assurance protocol on a 3.0T GE MRI running 14.0 software: RF spin echo, TR=500ms, TE=20ms, bandwidth = $\pm$15.63 kHz, 256×256 matrix, 250 mm FOV, and 11 5-mm thick axial sections. The 5.1% contrast detectability plane (slice #11) was identified and the corresponding raw k-space data was then retrospectively undersampled along the phase-encoded direction such that only a symmetric band of low-frequency components was retained. Ten different sampling rates uniformly spaced between 10% and 100% were investigated. ZF reconstructions were performed both without and with apodization (matched bandwidth Fermi filter with 16 voxel transition window). CS reconstructions using the ℓ_1-norm prior and finite spatial differences as the sparsifying operator were performed using a modification of the quasi-Newton algorithm defined in [2]. Each reconstructed image was manually evaluated by three independent observers. Following ACR guidelines [4], the number of complete visually detectable spokes (out of 10) was assessed for each reconstructed image as a measure of LCOD performance.

Results: Fig. 1a shows a plot of the number (mean and SD across observers) of detectable spokes for both ZF reconstructions and for the CS result across the set of tested sampling rates. Above 60% sampling, all three methods offer uncompromised LCOD. Below 60% sampling, however, CS clearly offers superior LCOD over both ZF-based methods, with windowed ZF slightly outperforming non-windowed ZF. An example set of reconstruction results is shown in Figs. 1b-e.

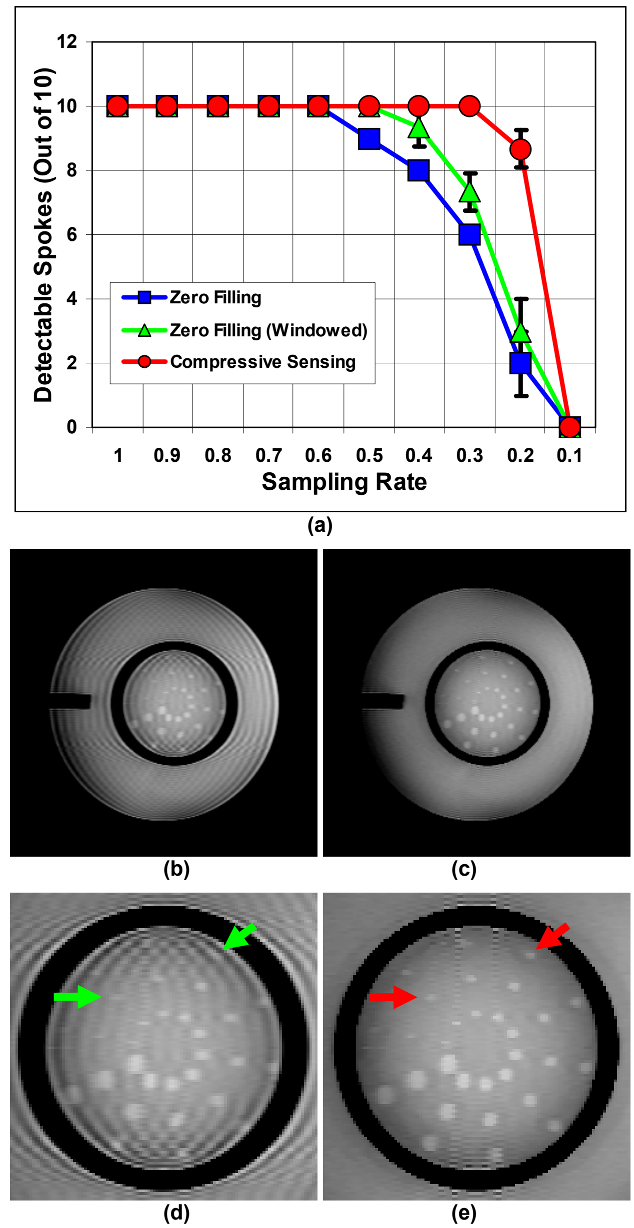

Figure 1. (a) LCOD results for evaluated image reconstructions at different sampling rates. (b) and (c) show the (windowed) ZF and CS reconstruction results at 30% sampling, and (d) and (e) are zooms of pertinent regions. Arrows highlight some of the low-contrast features of interest.

Discussion: This preliminary investigation suggests that, in addition to their proven capabilities in high-contrast applications, CS methods may also offer significant advantages over ZF methods for LCOD tasks. This is particularly important because many diagnostic tasks in clinical MRI are more closely related to LCOD than high-contrast detectablility. Also, LCOD can serve as a surrogate for signal-to-noise ratio in situations where the latter is difficult to interpret, such as highly undersampled acquisitions Future work may include the use of an automated scoring program (such as that described in [5]) to more systematically assess LCOD consistency when employing various undersampling strategies.

References: [1] Lustig et al.,MRM 58(6):1182-1195,2007; [2] Trzasko and Manduca, IEEE TMI 28(1),2009; [3] Donoho and Johnstone, Biometrika 81(3), 1994; [4] “Phantom Test Guidance for the ACR MRI Accreditation Program and Phantom Site Scanning Instruction Guide”, www.acr.org; [5] McGee et al., Proc. ISMRM 2007, p.3302.