Comparison of highly accelerated TV and low rank methods for breast DCE data

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Introduction: Dynamic Contrast-Enhanced (DCE) magnetic resonance imaging (MRI) of breast tumors provides a promising method for the evaluation of vessel permeability in the tumor area. By analyzing the time curve of uptake and washout, DCE-MRI can also be used to help determine if the tumor is benign or malignant. High spatial resolution is desirable to identify tumor location, and high temporal resolution can improve the accuracy of quantitative analysis of the uptake and washout curves [1]. However, high spatial resolution typically comes at the expense of high temporal resolution, and vice versa. For this reason, a variety of highly accelerated image acquisition schemes are under exploration to enable the acquisition of images with both high spatial and temporal resolutions for DCE-MRI. Recently, a number of constrained reconstruction algorithms using Total Variation (TV) [2] and Low Rank (LR) [3] have been proposed to mitigate the tradeoff between spatial and temporal resolution. In this work, we compare two of these acceleration methods on DCE breast MRI.

Methods: Bilateral imaging with fully sampled k-space data was acquired on two subjects, both with confirmed breast lesions, using a 3D spoiled gradient echo sequence. Imaging was performed on a Siemens 3 Tesla scanner equipped with a seven channel dedicated breast coil. A 0.1mL/kg dose of Omniscan was injected at 4mL/sec after a 20mL saline flush at 2mL/sec. Scan parameters for the first subject were TR = 2.35ms and TE = 0.99ms, while those for the second subject were TR = 3.16ms and TE = 1.24ms. Both scans employed a flip angle of 10 degrees and an acquisition matrix kx, ky, kz, t = 256 x 83 x 64 x 43. A 3/4 partial Fourier acquisition was used in both the ky and kz directions. Temporal resolution was 12 seconds for the first scan and 15 seconds for the second [4]. To compare the two different reconstruction methods, the data from each coil was undersampled offline with a pseudo-random undersampling mask with an acceleration rate R of 13, as shown in Figure 1. The undersampling pattern for each time frame was chosen differently to obtain the incoherent aliasing required by compressed sensing techniques [5]. The reconstructed images were then compared both qualitatively and quantitatively to the images reconstructed from the fully-sampled dataset. The total error energy and signal-to-error ratio (SER) were used as quantitative measures of reconstruction performance.

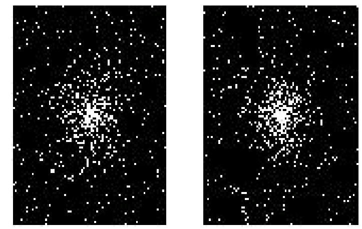

Figure 1: Two time frame sampling masks using variable density with acceleration rate R =13.

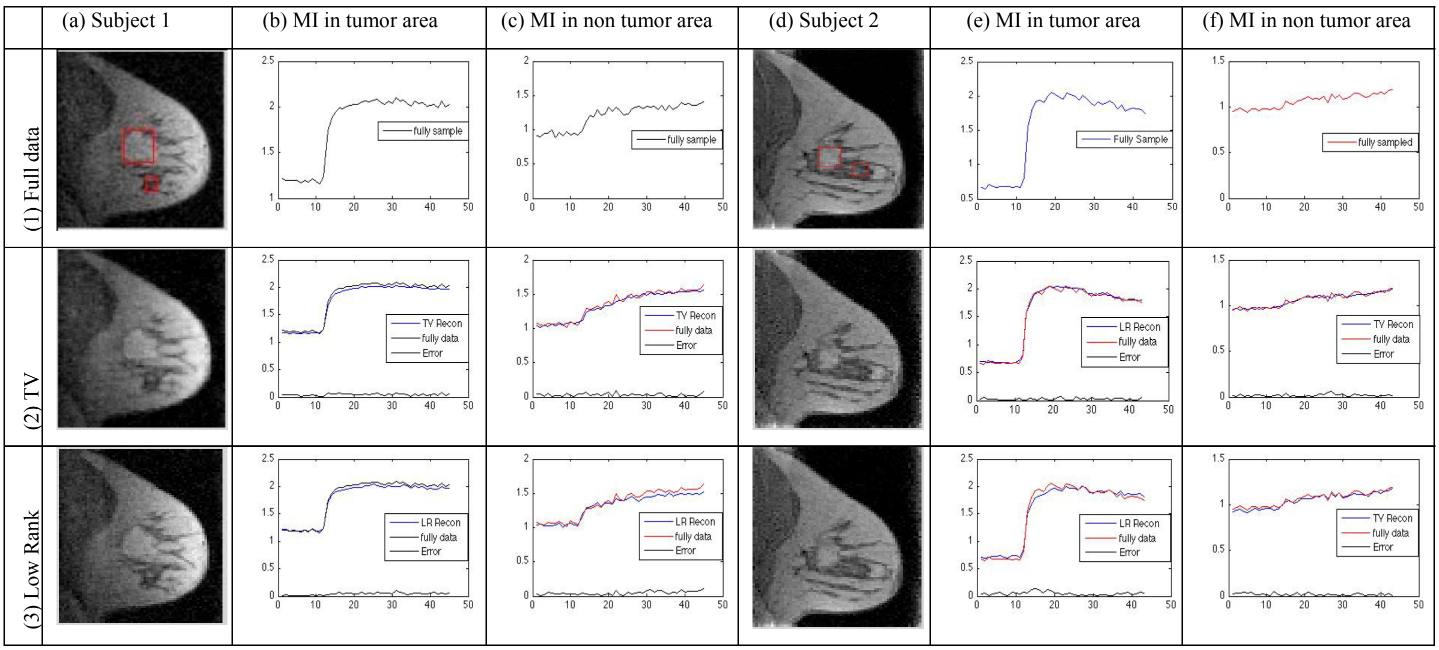

Figure 2: Comparison of fully-sampled reconstruction, TV (R = 13), and LR (R = 13). Column (a) shows reconstructed images from a single coil (first subject), while column (d) shows images reconstructed from all seven-coil channels (second subject). Row 1 shows the fully-sampled reconstruction, while rows 2 and 3 show the R = 13 reconstructions for TV (row 2) and LR (row 3). Columns (b), (c), (e), and (f) show time curves of the mean signal intensity (MI) as a function of frame number in the ROIs indicated by the red boxes.

Results: Both TV and Low rank show impressively good results even at the acceleration rate R = 13, although LR shows slightly better performance than TV (Table 1). As can be seen in Figure 2, the LR images appear slightly more blurred than the TV images. However, LR appears to better match the ROI intensity curves in most cases (Figures 2c(3) and 2f(3)). TV also blurs the images slightly, while smoothing out some of the detail in the ROI intensity curves (Figures 2c(2) and 2f(2)).

Discussion: This work demonstrates that high acceleration rates are potentially feasible in DCE-MRI using both the TV and LR constrained reconstruction algorithms. Future work will seek to validate these results in actual accelerated patient scans. We will also explore the combination of different constraints to further improve image reconstruction quality.

	TV	LR
Subject 1 SER (dB)	18.44	21.51
Subject 1 Total Error	$2.47x10^4$	$1.77x10^4$
Subject 2 SER (dB)	16.27	17.24
Subject 2 Total Error	$4.48x10^4$	$4.07x10^4$

Table 1: Comparison of the quantitative results from TV and LR.

References: [1] Barrett et al., JMRI, 2007; 26:235–249.[2] G. Adluru et al, JMRI 2009; 29:466–473. [3]Sajan et al., IEEE Transaction on Med. Imaging, May 2011, Vol.30, No. 5. [4] Ganesh et al JMRI 2010 32:1217-1227. [5]Lustig M et al. MRM 2007; 8:1182-95