A Block Reordering Technique in a Compressed Sensing Framework

Srikant Kamesh Iyer[1,2], Tolga Tasdizen[1,2], Ganesh Adluru[3], and Edward DiBella[3,4]

[1]*Electrical and Computer Engineering, University of Utah, salt lake city, Utah, United States,* [2]*Scientific Computing and Imaging Institute (SCI), University Of Utah, salt lake city, Utah, United States,* [3]*UCAIR, Department of Radiology, University of Utah, salt lake city, Utah, United States,* [4]*Department of Bioengineering, University of Utah, salt lake city, Utah, United States*

Introduction: Dynamic contrast enhanced MRI (DCE-MRI) is a technique used to study and track contrast kinetics in an area of interest in the body over time. It is desirable to have high spatial and temporal resolution in DCE MRI. Recent advances in the field of compressed sensing (CS) have shown that high quality images can be reconstructed from few samples collected in k-space. Total variation (TV) [1, 2] is a popular constraint that is often used in CS reconstructions to remove streaking artifacts and noise from images when reconstructing images from undersampled data. Also it has been shown that additional information such as the order of signal intensities of pixels when use to modify the TV constraint [3] improves the reconstructions further. One limitation of applying ordering information to one large block consisting of all the time frames is that if there is large motion in one part of the data, the incorrect ordering information that is extracted from the data can affect all the time frames in the reconstructed image. Applying the reordering information over smaller groups or blocks helps localize this effect and may improve the robustness to motion. We propose to extend [3] by applying the constraint to smaller groups of data to make the method more robust to motion. Here we use a TCR [1] reconstruction of the undersampled data as the reference image to get the sorting order for each pixel location. The new method showed improvement in robustness to motion and also improved contrast. Comparisons were made with TCR and TCR with reordering [3]. Our method is different from [4] where small blocks were used as a way to relax the reordering. That is, it was required that between blocks the ordering matched that obtained from reference data, but variations within blocks were allowed, and block sizes of 1,4 and 8 pixels were used. Here the blocks are larger and only within-block ordering is employed. We use a TV variation in time constraint within each block.

Methods: The series of acquired undersampled images were reconstructed by minimizing the cost function given by $\min_m C = \|Em - d\|_2^2 + \lambda \|\nabla_t m_{BR}\|_1$. Here *d* is the acquired k-space data, *E* represents the physical imaging process and m is the reconstructed image. m_{BR} represents the reordering relation between pixels along the time axis applied blockwise. This is similar to the method in [3], but in [3] the reordering was applied to a single large block consisting of all time frames. It was shown in [3] that reordering information acts as a powerful prior and can help improve the quality of the reconstructed images when compared to TCR reconstructions, especially in the presence of motion when TCR can cause some smoothing of the image. The method was applied to radial data simulated from a fully sampled Cartesian dataset obtained from a Siemens Trio 3T scanner with a phased array cardiac coil. A saturation recovery turbo flash sequence with TR/TE~(2.5/1.4) msec, with a 12 degree flip angle, 8 mm slice thickness and 70 time frames was used. There was motion present in the first 16 and last 30 frames. This information can be inferred from the IFT of the undersampled data or from the TCR reconstructions. Hence the dataset was split into 3 groups of size 16 frames, 24 frames and 30 frames respectively. A "standard" TCR [1] reconstruction was used as the reference data to determine the sorting order information for each of these 3 blocks. The temporal TV constraint was performed on each of these 3 blocks independent of the other and no TV was performed between these blocks. The data from 4 coils were reconstructed independently and combined using square-root-of-sum-of-squares.

Results: We found that that smaller block size help improve the robustness of the reconstruction to motion in the data. Also the reconstructions match the fully sampled data more faithfully. Features in the right ventricle (arrows in Fig. 1) are better visualized in the new blockwise method when compared to TCR and TCR with reordering applied to a single large block of data. Comparisons with TCR and TCR with single block reordering are shown in Fig1. The difference images shows that smaller blocks help localize the effect of motion. Though not shown here, when the perfect reordering was given to the two reconstruction schemes by using the fully sampled image as the reference data, the reconstructed images matched the fully sampled image very well.

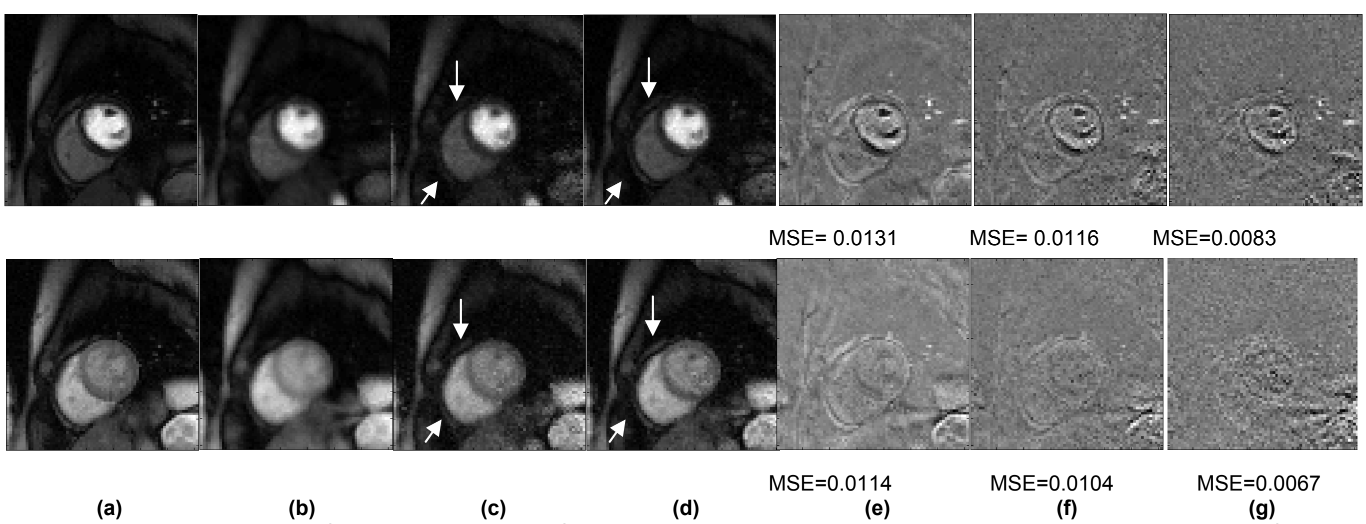

Fig1.**(a)**Fully sampled data, **(b)** TCR reconstruction, **(c)** TCR with reordering applied as one large block, **(d)** Blockwise reordered TCR with 3 blocks, **(e)**image difference **(a)**-**(b)**, **(f)** image difference **(a)**-**(c)**, **(g)** image difference **(a)**-**(d)**. The mean squared errors (MSE) are shown below the figure.

References: [1]Adluru et al. Magn Reson Med 2007;57:1027. [2]Kamesh Iyer et al. Proc ISBI 2010. [3]Adluru et al. Int J Biomed Imaging 2008;2008:341684. [4]Ramirez et al. Medical Imaging, IEEE Transactions on 2011;30:1566.