# Reconstruction of Line tagged Cardiac images by Compressed Sensing algorithm using Contourlet transform from appropriate k-space sampling

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**Introduction :** RF tagging pulses are used to spatially label an image with a specified physical or physiological properties such as myocardial motion, fluid flow, magnetic field inhomogeneity, $B_1$-field nonuniformity, etc. RF tagging in cardiac imaging can be used to analyze the heart wall motion. Here, there is always a push towards higher spatial and/or temporal resolution to enable more accurate quantification [1].

In this abstract, work on combining line tagged cardiac imaging with the compressed sensing (CS) algorithm [2] is presented. CS algorithm can effectively reduce the scan time by random undersampling of k-space and by using a reconstruction based on an appropriate sparsifying transform. Since line tagged cardiac images are characterized with contours, we take advantage of this property in applying the CS algorithm. We show that an adequate sparsifying transform, namely the contourlet transform, is well suited to compactly represent the contours. In addition, we exploit the distinct k-space feature of tagged images.

**Theory and Methods :** Line tagged images has two properties. First, the image has many contours since they are line tagged. Second, the tagged k-space data shows sinusoidal line pattern due to the tag modulation (Fig. 3(a), (b)) [3]. Due to these properties, we can apply CS by semi-randomly sampling k-space and use a sparsifying transform that can be more effective in representing the contours than the commonly used wavelet transform. The contourlet transform [4] has been previously shown to efficiently represent smooth contours compared to wavelets.

To show the advantage of using the contourlet for line tagged images, images were reconstructed using only the most significant coefficients (2.5% of the total pixel numbers) for the wavelet and contourlet transform. The image used was characterized with contours similar to tagged cardiac images (Fig. 1(a)). The root mean square error (RMSE) criteria was used for quantitative comparison. Also, randomly undersampled k-space data (20% sampling) was acquired and reconstructed by applying the CS algorithm to each transforms. Finally, we compared reconstructed images from the CS algorithms using contourlet transform with different variable density random sampling patterns (40% sampling).

In vivo line tagged cardiac data were collected using 3T Siemens Tim Trio MRI scanners (TR = 25.85ms, TE = 2.54ms, FOV = 360 x 290 mm, Flip angle = $10^o$, Voxel size = 2.0 x 1.6 x 7.0 $mm^3$, single breath-hold time = 32sec, temporal resolution = 29 ms). Simulations and data reconstruction were performed using MATLAB R2007b.

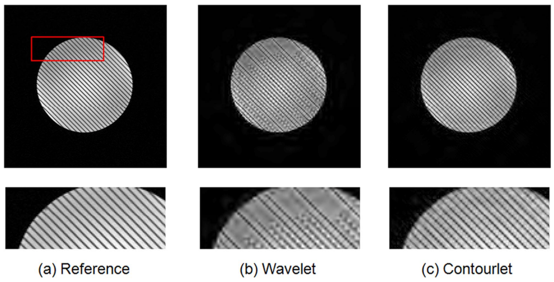


*Figure 1: Water phantom images reconstructed using 2.5% most significant coefficients (RMSE (b) 7.54%, (c) 4.09%)*

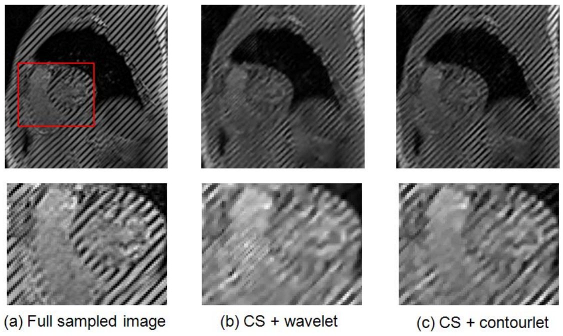


*Figure 2: Reconstructed images using 20% sampled k-space data (RMSE (b) 8.69%, (c) 7.44%)*

**Results and Discussion :** In Fig. 1, water phantom images were reconstructed from the same number of the most significant coefficients (2.5% of the total pixel numbers). Images using contourlet transform (RMSE: 4.09%) shows better representation of the tagged lines than wavelet transform (RMSE: 7.54%) especially at the enlarged regions. In Fig. 2, using undersampled random k-space data (20% k-space sampling), reconstructed images using the contourlet transform (RMSE: 7.44%) resulted in better resolved images than wavelet transform (RMSE: 8.69%). From these two experiments, it can be seen that line tagged images can be effectively represented by a sparsifying transform and that the contourlet can be more efficient compared to the wavelets due to its usage of directional filterbanks.

Fig. 3 shows schematic representation of the general k-space data, line tagged k-space data (tagging angle: $90^o$) and different semi-random k-space sampling patterns used. Fig. 3(c) shows a variable density random undersampling pattern that is only fully sampled at the region of the non-tagged peak (sampling pattern 1). Fig. 3(d) shows k-space sampling pattern that is fully sampled at the region of the non-tagged and tagging peaks yet maintaining randomness in other regions of k-space (sampling pattern 2). These patterns sampled the same number of data points (40% sampling). Fig. 4 shows reconstructed images from each k-space sampling pattern (represented in Fig. 3.) by CS algorithm using contourlet transform. As expected, reconstructed image from sampling pattern 2 (RMSE: 4.66%) shows better reconstruction performance than sampling pattern 1 (RMSE: 7.77%).

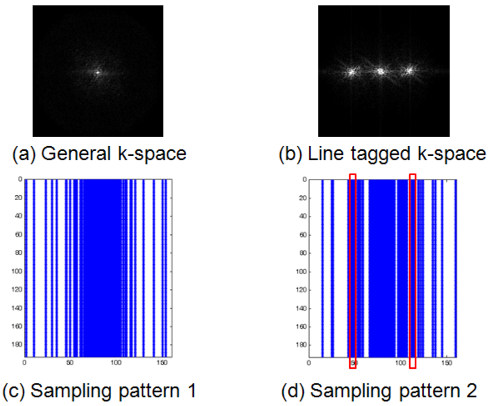


*Figure 3: Schematic representation of k-space ((a), (b)) and k-space sampling pattern (40% sampling) ((c), (d))*

**Conclusion :** Line tagged images have many contours. An effective means of compressing these images is with the contourlet transform which uses directional filter banks. We have shown that using this transform under the CS algorithm, we can improve reconstruction performances compared to other approaches. In addition, line tagged k-space has additional 'tagging peaks', therefore a semi-random k-space undersampling pattern can further improve the reconstruction performance. These features can be exploited for higher spatial or temporal resolution in breath-hold line tagged cardiac imaging.

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**References :** [1] V M. Pai, et al., Curr Cardiol Rep, 8(1), 53-58, 2006. [2] M. Lustig, et al., MRM, 58, 1182-1195, 2007. [3] J P. A. Kuijer, et al., JMRI, 24, 1432-1438, 2006. [4] M. N. Do, et al., IEEE Trans. Image Proc, 14, 2091-2106, 2005.

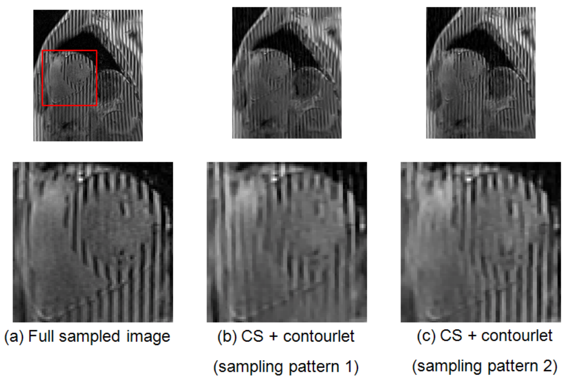


*Figure 4: Reconstructed images from each sampling pattern in Fig. 3. (RMSE (b) 7.77%, (c) 4.66%)*