Compressed Sensing in Dynamic Enhanced Lung Imaging: A comparison with k-t BLAST

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Introduction: The foundation of compressed sensing (CS) [1] followed by the assessment of its possibilities in MRI have gradually evolved into an innovative fast imaging technique capable of recovering highly undersampled MR datasets for various applications including dynamic cardiac imaging, as such images often demonstrate intrinsic sparsity accompanied with incoherent/noise-like aliasing artifacts generated by randomized sampling patterns in the corresponding spatio-temporal Fourier transform domain (Fig.1)[2]. Dynamic contrast-enhanced (CE) lung imaging, with high resemblance with dynamic cardiac imaging for having high intensity variation constrained in compact image space together with corresponding sparsity in x-f space, may serve as a potential candidate for the CS techniques. This work is to assess the possibility of applying CS in such application by comparing simulated results with their counterparts in k-t BLAST [3]. While k-t BLAST was shown to be a well-performing alternative for dynamic CE lung imaging [4], our results show that CS may also be an encouraging candidate as it slightly outperforms k-t BLAST and demonstrate relative stability in most time frames of the trial.

Method: Dynamic CE MR images were obtained using an inversion-recovery-prepared, segmented EPI technique with TI/TR/TE/ETL =180/6.5/1.2/4, matrix 256 x256, and slice thickness =10~12 mm with two coronal slices acquired. Our trials included 7% extra fully-sampled low frequency ky-lines in addition to constrained random sampling pattern [5]. These fully sampled low frequency data not only benefit the reconstruction of randomly undersampled images by serving as self-referenced estimations which improve CS reconstructions, but more importantly provide possibilities of enhancing the image qualities without sacrificing much of the acceleration factor. OMP[7] was chosen as the reconstruction algorithm for its relative effectiveness upon solving low/midsized CS problems.

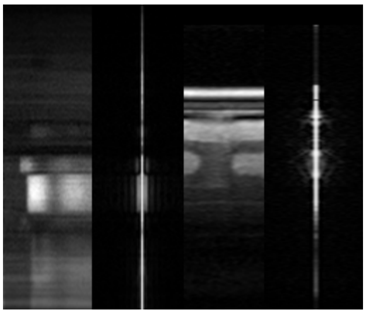

Figure 1: intensity variation of image space and corresponding x-f space(lung x-t, lung x-f,cardiac x-t, cardiac x-f).

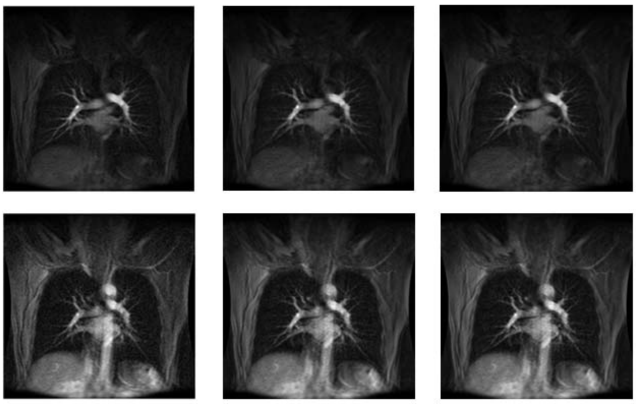

Figure 2: Selected images from slice 1(top: phase 15; bottom: phase 31) comparing original(left), k-t BLAST accelerated(mid),

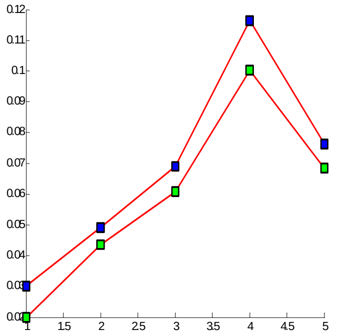

Figure 3: RMS error of k-t BLAST (blue) v.s CS from acceleration 1 -5

Results: Figure 2 depicts the image reconstructed. Error of k-t BLAST v.s CS framework ranging from acceleration factor 1 to 5 is shown in figure 3, in which CS framework slightly outperforms k-t BLAST in terms of RMS error. While both methods experience sudden error increment at 4-fold acceleration, its CS counterpart remains relatively mild in error variation. Further phase by phase RMS error analysis (see Figure 4) shows that while k-t BLAST demonstrates higher accuracy in the few phases before contrast enhancements, CS framework in general reveals slightly improved reconstruction and remains relatively stable in terms of accuracy throughout the whole trial.

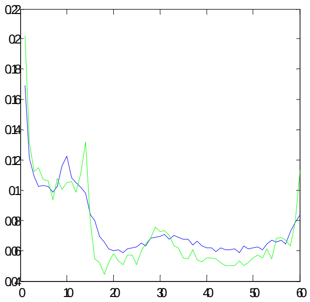

Figure 4: Phase-by-phase RMS error of k-t BLAST(blue) v.s CS(green). Note k-t BLAST excels in enhancement phases and CS outperforms in general

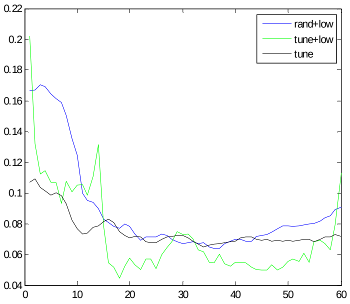

Figure 5: Sampling pattern v.s phase-to-phase RMS error (green: constrained random+low-freq; blue: random+low-freq; black; constrained random only

Discussion: This work assesses the adoption of CS in contrast-enhanced dynamic lung imaging and demonstrates enhanced results comparing with its counterpart in k-t BLAST. Though lung imaging resembles cardiac imaging in terms of inherent spatio-temporal sparsity and relative compact high-intensity spatial regions, the branching morphology of pulmonary artery followed by subsequent diminutive yet wide scattering variation adds further difficulty to CS application. Though their differences in fluctuation tendency of reconstruction accuracies is consistent with the report in [5] stating k-t BLAST's relative superior performance at static timeframes in contrast with CS's relative successes in other phases, the capability of CS upon targeting irregular scattered image variation such as that of pulmonary capillaries remain to be further verified. As for sampling pattern, while classification of different random sampling patterns and their effectiveness is beyond the scope of this work, our other preliminary results indicate that constrained-random sampling incorporated with fully sampled low frequency data, is likely to be a better choice in lung dynamic imaging upon reducing RMS error.

Acknowledgements

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References:

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