Efficient Radial Tagging: Undersampled Radial Acquisition with Polar Fourier Transform Reconstruction

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Purpose: Polar (circular and radial) tagging, which has been recently developed, provides advantages such as more intuitive description of cardiac deformation as well as direct use of k-space information for post-processing steps. In radial tagging, the information required for strain imaging is spread in a donut shaped region in k-space (Figure 1). This k-space feature can be exploited to make the acquisition and reconstruction of tagged images more efficient if acquired through polar trajectories. With Cartesian reading scheme, the real-time acquisition is hindered by the number of phase encoding steps required for artifact-free imaging and typically takes around 15 seconds. Although non-Cartesian trajectories benefit from shorter scan times, they are not widely used in clinical settings due to reconstruction difficulties. In this study, we present an efficient and robust acquisition/reconstruction coherent approach for radial tagging based on undersampled radial k-space reading. The performance of the approach is quantified on phantom as well as human tagged images acquired with various numbers of radial data lines.

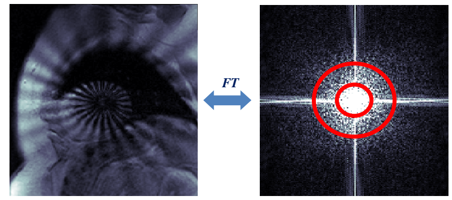
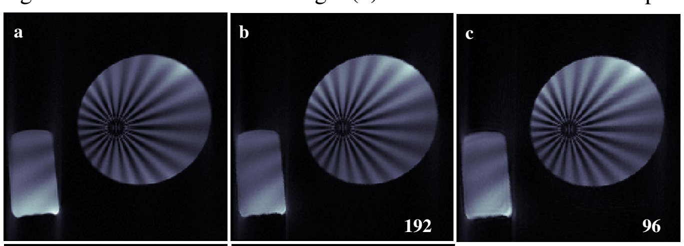


Figure 1. Radial tagging pattern and its corresponding k-space. Radial tagging spreads the energy of taglines in a wide donut-shaped region.

Method: MR images with radial tag pattern were acquired from phantom as well as a healthy volunteer through a 2D segmented radial k-space sampling scheme on a 1.5T Siemens TIM Avanto scanner. The number of acquired radial views for the phantom data was 192 and for the volunteer were chosen as 88, 64 and 40 spokes. Each set consists of 19 phases in a cardiac cycle, which took 12 seconds of breath-holding for acquisition of 88 to about 5 seconds for acquisition of 40 radial views. Images were first reconstructed by scanner default method as a reference. They were then reconstructed by applying the Polar Fourier Transform (PFT) method[1]; a Hankel-based transform for reconstruction of non-uniform distributed data on polar grids. To examine the effect of reducing the number of spokes and subsequently the scan time on the quality of taglines in the final images, we subsampled the raw data with number of spokes varied from 96 to 24. To expedite the reconstruction algorithm, the Bessel functions required for the Hankel Transform step were pre-calculated and saved as a look-up matrix.

Results: The reconstructed images from phantom data are depicted in Fig. 2. Fig. 2(a) was reconstructed on the MR scanner using the available algorithms for radial datasets. Fig. 2(b) was reconstructed with adapted PFT method on the original data (192 radial spokes) in order to verify the accuracy and precision of the reconstruction algorithm. Reconstructed images from reduced number of spokes are shown in Fig. 2(c-e). The overall shape and quality of taglines have been retained while streaking artifacts become visible in highly subsampled data. The Correlation coefficient and Relative RMS Error for each reconstructed image are depicted in terms of the number of projections in Fig. 3. Fig. 4(a-c) is illustrated the in-vivo images of 6th cardiac phase with 88, 64 and 40 radial views respectively and (d) is the same reconstructed image by the scanner from 40 spokes. With implementation of the algorithm on a 2.2GHz Dual Core CPU using Matlab, reconstruction of the phantom data with 192 projections took 2.5 seconds while for 24 radial views, it took 0.25 seconds. The average reconstruction times for each phase of myocardium images with 88, 64 and 40 views were 0.65, 0.42, and 0.28 seconds respectively.



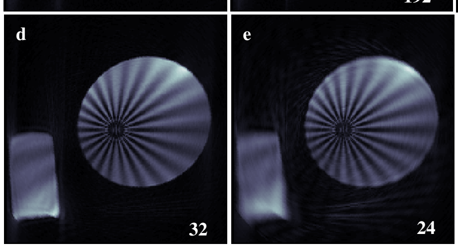


Figure 2. Phantom images reconstructed by (a) MR scanner, (b-e) PFT method from various radial spokes.

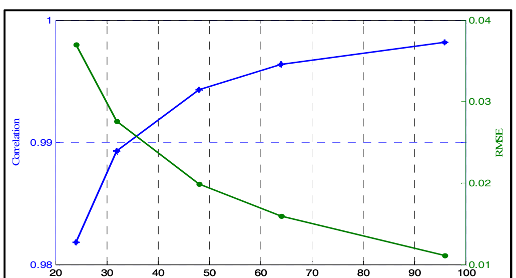


Figure 3. The Correlation coefficient and Relative RMS Error of reconstructed images

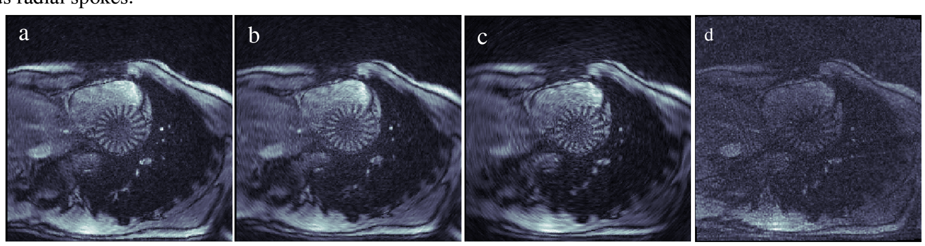


Figure 4. PFT reconstruction of 6th cardiac phase from (a) 88, (b) 64, and (c) 40 acquired radial views, and (d) reconstructed image by MR scanner from 40 spokes.

Conclusions: Experiment results showed high robustness of PFT method against the reduced number of radial data lines unlike the commonly used algorithms for non-Cartesian acquisitions which suffer from significant artifacts in such cases and thus constrain iterative reconstruction algorithms[2]. This property can be exploited towards real-time imaging which is necessary in some cardiac assessments such as stress test. In addition, the method is adequately fast for in-line reconstruction. With regard to the current limitations of highly subsampled polar trajectories, the establishment of PFT will be promising for efficient and fast strain imaging in a real-time manner.

References: 1. Guo H, and Song AW, *ISMRM*, 2004. **2.** Block, KT, et. al., *Mag. Reson. Med.* 57.6: 1086-1098, 2007.