# On non-Cartesian reconstruction by prior-data-driven k-t PCA

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**Introduction**

The k-t PCA method was proposed to reconstruct dynamic MRI by prior-information constraints [1]. Previous research has concentrated on reconstruction from lattice k-t space sampling, for which the training data are obtained from low-resolution images reconstructed using the central k-space. Training data acquired from non-Cartesian imaging methods such as radial imaging, however, may be prone to errors from streaking artifacts. We proposed a prior-data-driven k-t PCA method [2] where no extra acquisition of the training data is required. The reconstruction mainly relies on x-f principal components (PCs) extracted from pre-existing images acquired at similar anatomical position instead of central k-space from the imaged subject, which entails prior information free from streaking artifacts. This property makes prior-data-driven k-t PCA uniquely suitable for arbitrary k-space sampling strategies. Here we demonstrate its feasibility with numerical simulation of radial k-space sampling scheme from cine cardiac imaging, and the results show that the proposed method enables the acceleration provided by prior-data-driven k-t PCA to be combined with the advantages of arbitrary sampling strategies.

**Theory**

We extend the reconstruction problem of Cartesian trajectory to that of general sampling patterns. The problem is solved by: $\mathbf{w}_{x,f} = (\mathbf{E}^{H}\mathbf{\Psi}^{-1}\mathbf{E})^{+}\mathbf{E}^{H}\mathbf{\Psi}^{-1}\mathbf{d}_{k,t}$ , where $\mathbf{w}_{x}$ is the weighting of the PCs of each reconstructed x-f profile in Cartesian grid, $\mathbf{d}_{k,t}$ is the raw data in k-t space, and $\mathbf{\Psi}^{-1}$ is the noise covariance matrix in x-f space. The encoding matrix $\mathbf{E}$ includes the following operations: projection of x-f profiles onto each PCs which are extracted from a set of pre-existing homogeneous data ( $\mathbf{P}$ ), Fourier transform from x-f space to k-t space ( $\mathrm{FT}_{x,f\rightarrow k,t}$ ), and sampling with a non-Cartesian trajectory ( $\Xi_{k,t}$ ): $\mathbf{E} = [\Xi_{k,t} \quad \mathrm{FT}_{x,f\rightarrow k,t} \quad \mathbf{P}]$ .

**Materials and Methods**

Simulation was performed to investigate the feasibility of the proposed method, using a set of fully Cartesian-sampled cine cardiac images with 30 cardiac phases acquired by Short-axis 2D TrueFISP with ECG gating which was performed on a Philips Achieva 3T scanner with matrix size 256x256, 35° flip angle, and 10mm slice thickness. Radon transform was used to generate the full-sampled raw data on the radial trajectory, such that the simulated data were with 360 projections and 180 samples on each projection. This data set was used to generate the under-sampled data for reconstruction by selecting a subset of projections. Fig. 1 depicts the sampling scheme. Ten PCs were extracted from five other cine cardiac imaging data pre-acquired from different experiments, and 28040 x-f profiles were selected for principal component analysis (PCA). Prior-data-driven reconstructions from different acceleration factors were discussed in terms of relative root mean square (RMS) error and intensity variation along the time domain.

**Results and Discussion**

The reconstructed images are shown in Fig. 2. Reconstruction by our proposed method reduced the streaking artifact considerably, even from substantially down-sampling k-space data. The myocardial contraction was depicted accurately, although the results revealed slightly temporal blurring during systolic and diastolic phases (red arrows). Overall images quality was good, but slight residual artifacts were discernible (green arrow). Moreover, relative RMS error plotted in Fig. 3 shows that the reconstruction error increased only slowly as the accelerating ratio increased (3.5% in myocardium at 10-fold acceleration), which implies that it is possible to achieve even higher accelerating ratio.

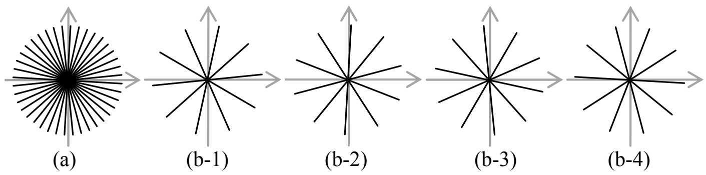


**Fig. 1:** The sampling scheme of 4-fold acceleration: (a) is the fully-sampled k-space for reference, and (b-1) to (b-4) are under-sampled k-space for different frames. (b-1) denotes the frames of number 4n (n is an integer), and the frame contains projections {1, 5, 9, 13…}. (b-2) denotes the frames of number 4n+1, and the frame contains projections {2, 6, 10, 14…}. Frames of number 4n+2 and 4n+3 follow this operation as shown in (b-3) and (b-4).

**Conclusion**

We showed that by using prior-data-driven k-t PCA, it is feasible to robustly reconstruct under-sampled dynamic images of arbitrary trajectory. The key issue lies in the fact that the selection of x-f-domain PCs from pre-existing data as basis for image reconstruction is independent of k-space sampling. The experimental results indicate that the proposed method reduces streaking artifact while maintaining temporal resolution from highly under-sampled k-space data. The study can theoretically be extended to reconstructions of spiral and other non-Cartesian trajectory, which is the subject of continual future work.

**References**

[1] H Pedersen et al., Magn Reson Med, 2009; 62:706-716
[2] ML Chu et al., submitted to ISMRM 2012.

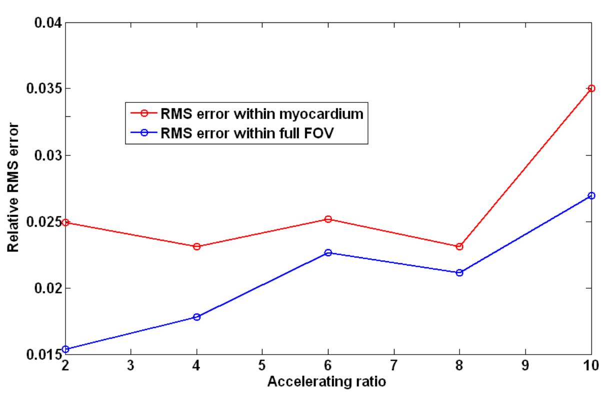


**Fig. 3:** Relative RMS error form acceleration of 2 to 10 within full FOV (bottom) and within myocardium (upper).

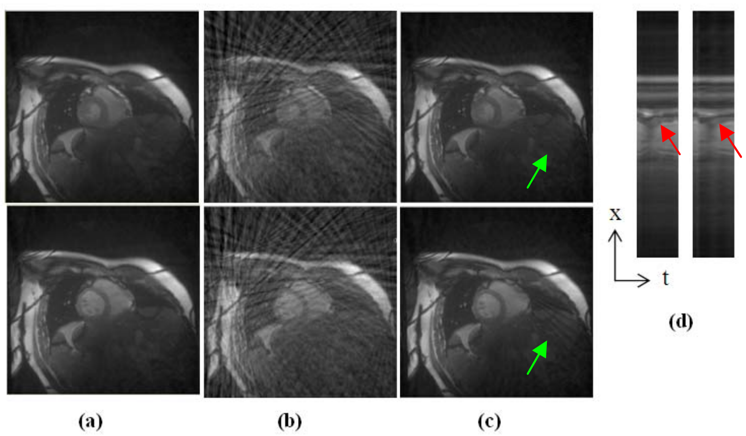


**Fig. 2:** The non-accelerated reference (a), 6- fold accelerated images reconstructed by traditional regridding method (b) and our proposed method. The first row is images of a specific systolic phase and the second row is images of a specific diastolic phase. (d) is the x-t space of non-accelerated reference (left) and reconstructed images by our proposed method (right).