# 3D cones trajectory with anisotropic field-of-view

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**Introduction:** Three dimensional cones [1,2,3] is the most time and SNR efficient k-space sampling trajectory for 3D imaging. Gurney et al. [4] recently provided a highly efficient algorithm for readout gradient design when the imaging field of view (FOV) and spatial resolution is isotropic. In this work, we extend Gurney's design to anisotopic FOVs. We utilize the method of Larson et al [5] to determine the appropriate cone angles, and propose a new method for optimizing the sampling density along each cone. The resulting FOV is shaped like a flattened cylinder (hockey-puck) and spatial resolution remains isotropic. We demonstrate 3D carotid imaging with a 73.2% reduction in scan-time compared to isotropic FOV cones with comparable image quality.

**Methods:** Design of time-optimal anisotropic cones involves two essential steps: 1) finding the minimum number of 3D conical surfaces along with the inter-cone spacing and 2) determining the minimum sampling requirement along each conical surface. In this abstract we focus on the second step (detailed in Figure 1c) of optimizing the intra-cone sampling. Since the FOV is symmetric about the z-axis, we can determine these requirements by projecting the cones onto any $\mathbf{k_z}$ - $\mathbf{k_{xy}}$ plane where they can be viewed as radial spokes. Figure 1 illustrates the optimal sampling requirement for 3D cones with isotropic (Figure 1a) and anisotropic FOV coverage (Figure 1b,c). The spacing between adjacent conical surfaces can be optimized for anisotropic FOV coverage by varying the conical angles using the method developed by Larson et al [5]. The next step is to reduce the radial sampling density along each cone by applying a geometrical constraint in $\mathbf{k_z}$ - $\mathbf{k_{xy}}$ plane which ensures that every rectangle with dimensions 1/FOVz an 1/FOVxy (red boxes in Figure 1) in this plane contains at least one sample point. The dimensions of this rectangle are related to the degree of FOV anisotropy. The cones in $\mathbf{k_z}$ - $\mathbf{k_{xy}}$ plane are still oversampled near the k-space origin. The near origin sample spacing can be increased by shifting the samples on adjacent cones appropriately in a hexagonal fashion. Experiments were performed on a Signa Excite 3T scanner (GE Healthcare), first in a resolution phantom using a birdcage head coil (results not shown), and then in human volunteers using a 4-channel carotid array coil (Pathway MRI). The carotid imaging sequence consisted of 3 modules: DSG+DIR preparation, fat saturation and 3D-cones imaging. Imaging parameters used were [FOV-15x15x3.75cm$^3$], [Resolution-1x1x1mm$^3$].

**Results and Discussion:** Plot containing the scan time reduction as a function of the anisotropy is shown in Figure 2. The non-uniformly sampled data was reconstructed iteratively using the conjugate algorithm (CG). Quadratic penalty is used for conditioning the non-Cartesian system matrix. NUFFT [6] is used for interpolating the non-uniformly acquired k-space data. Figure 3 compares images reconstructed from anisotropic and isotropic FOV coverage. The image reconstructed using proposed trajectory is comparable to isotropic counterparts with minimal artifacts.

**Conclusion:** We describe a method for generating 3D cones trajectories for anisotropic fields of view. Relative to isotropic-FOV cones, a 4 fold reduction in the Z-FOV will result in 73.2% reduction in scan time without any perceptual loss in reconstructed image quality except for SNR loss.

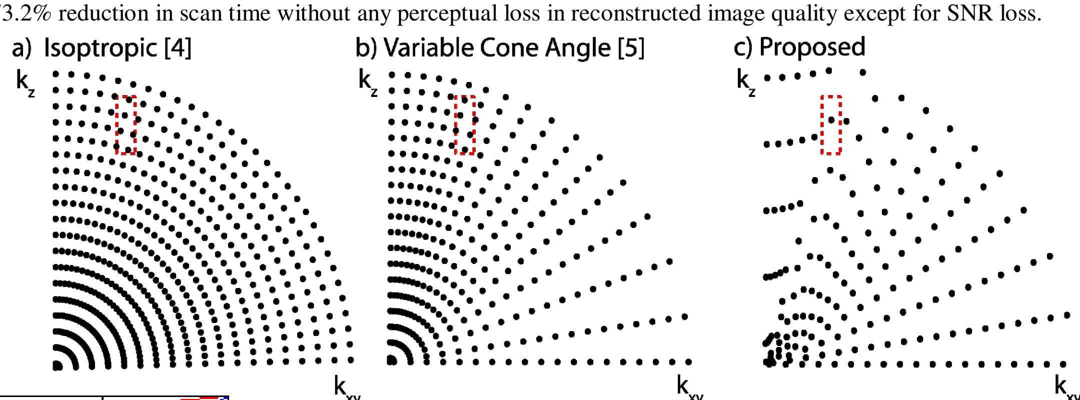


Figure 1) $\mathbf{k_z}$ - $\mathbf{k_{xy}}$ plane view showing k-space sampling density for 3 cone trajectories: a) The isotropic FOV design places samples uniformly on a polar grid. b) The angular spacing between cones is varied to obtain a hockey-puck FOV shape. c) The proposed method further reduces the sample density along each cone by applying a weaker no empty rectangle (dashed red) constraint.

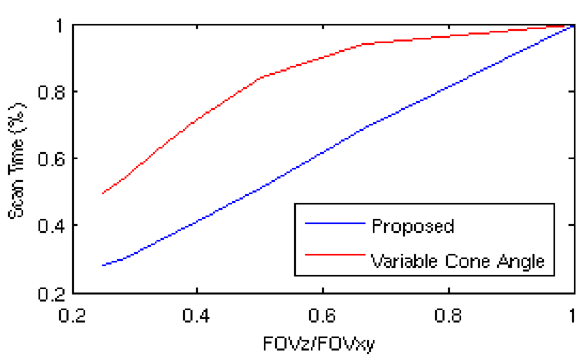


Figure 2: Scan time reduction as a function of FOV anisotropicity. As FOVz decreases in comparison with FOVxy the proposed method offers significant reduction in scan time.

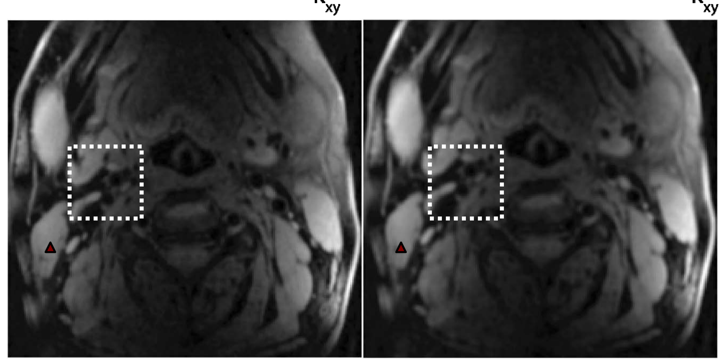

Figure 3: Comparison of images reconstructed using the proposed anisotropic trajectory with its isotropic counter-part. The dashed box indicates the bifurcation of the left carotid artery and SNR was measured on the sternocleidomastoid muscle (triangle). Using the proposed method number of readouts is reduced by approximately 73% and the measured SNR dropped as expected by a factor of 2.

**References:**

1)Stehning et al. MRM 2004; 52 : 197:203. 2)Barger et al. MRM 2002; 48 : 297:305.
3)Rahmer et al. ISMRM 2004; 12 : 2345. 4)Gurney et al. MRM 2006; 55 : 575:582.
5)Larson et al. TMI 2008; 27 : 47:57. 6)Fessler et al. TSP 2005; 53 : 3393-402.