Variable Field-of-View Three-Dimensional Projection-Reconstruction Imaging

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Introduction

Three-dimensional projection reconstruction (PR) has recently become popular for angiography applications using VIPR [1], and also ultra-short TE imaging [2]. It is robust to motion and flow, supports short TEs and TRs, and can provide isotropic resolution. We have developed a method for designing variable field-of-view (FOV) shapes for 3D PR using projection sampling anisotropy in two dimensions.

Theory and Methods

The projection spacing of a set of cones defines a FOV circularly symmetric about z, FOV_θ (Fig. 1a), while the projection spacing along the cones limits the FOV only in x and y, FOV_φ (Fig. 1b), which can seen by extending 2D PR sampling results [3]. Our algorithm separately designs the polar and azimuthal sampling (Θ, Φ), so the desired FOV must be decomposed into FOV_θ and FOV_φ such that FOV = min(FOV_θ, FOV_φ). The polar sampling angles, $\Theta[n]$, are designed using FOV_θ and the 2D radial anisotropic FOV algorithm [3], where Θ is limited to $\pi/4$ for radial diameter acquisitions and $\pi/2$ for radial spokes. The azimuthal sampling angles on cone n, $\Phi[m_n]$, are then also designed using the 2D algorithm, with FOV_φ scaled by $\sin(\Theta[n])$ to compensate for the cone circumference.

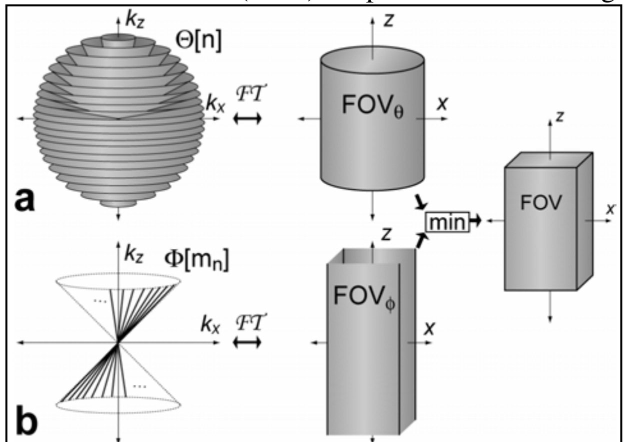

Figure 1: The (a) polar and (b) azimuthal sample spacing is used to vary the FOV in all dimensions.

This design can be improved upon by forming a spiral path on a sampling sphere, as is done for isotropic sampling [4]. First, $\Theta[n]$ is interpolated to a new set of polar angles, $\Theta_S[k]$, where there are $N_{\varphi,\mathrm{est}} \sin\left(\frac{\Theta[n]+\Theta[n+1]}{2}\right)$ samples between $\Theta_S = \Theta[n]$ and $\Theta_S = \Theta[n+1]$, and $N_{\varphi,\mathrm{est}}$ is the number of projections required for FOV_φ at the equator. The azimuthal angles, $\Phi_S[k]$, are then calculated as in the 2D algorithm, with FOV_φ scaled by $\sin(\Theta_S[k])$. Figure 2 shows an isotropically sampled spiral [4] and an anisotropic spiral designed with our method. The polar and azimuthal sample spacing is used for density compensation.

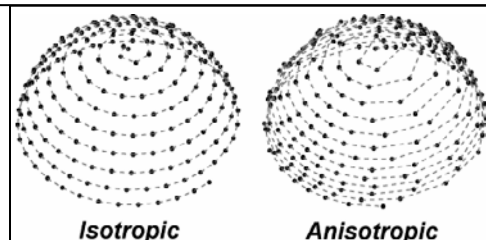

Figure 2: 3D sampling patterns

Results

Figure 3 shows point spread functions (PSFs) demonstrating the variable FOV shapes. The in vivo results in Fig. 4 show that aliasing in reduced and thin slabs can be imaged with 3D PR using this method. A larger spherical FOV is not possible in a single breath-hold.

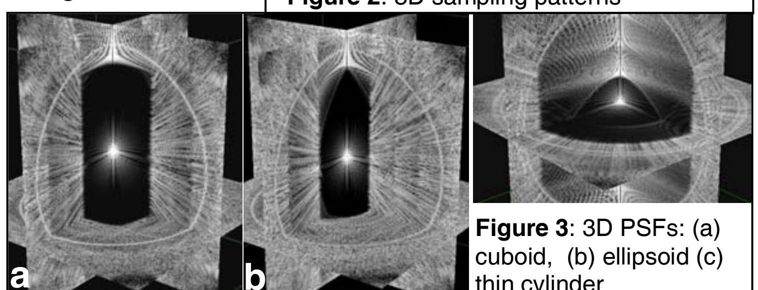

Figure 3: 3D PSFs: (a) cuboid, (b) ellipsoid (c) thin cylinder

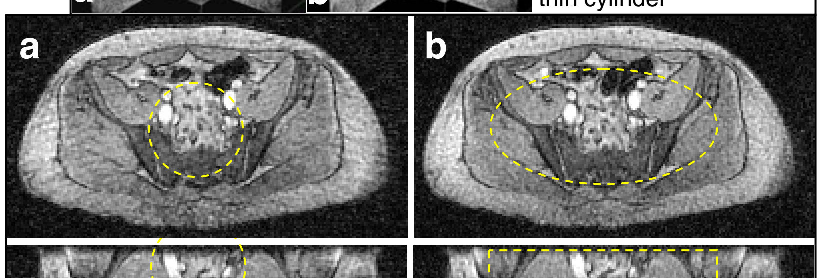

Figure 4: Breath-hold SPGR 3D PR (25 s) with 2 mm resolution and a 3 cm slab – axial slice (top) and coronal slice (bottom). (a) Spherical FOV using 2519 projections showing streaking artifacts. (b) Cylinder ellipse FOV using 2529 projections, where the slight undersampling does not produce artifacts. The dashed lines indicate the designed FOV.

Discussion

Variable FOVs allow for unique and new applications for 3D PR. They efficiently sample k-space to match the imaged region. The projection to FOV area ratio is similar across FOV shapes.

References: [1] Barger AV, et al. MRM 48: 297-305 (2002).
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[3] Larson PEZ, et al. Proc. 14th ISMRM, p. 340 (2006).
[4] Wong STS, et al. MRM 32: 778-784 (1994).