

Arbitrary Fields of View in Radial Imaging

P. E. Larson¹, P. T. Gurney¹, D. G. Nishimura¹

¹Electrical Engineering, Stanford University, Stanford, CA, United States

Introduction

Radial imaging, or projection reconstruction (PR), acquires data on radial spokes, enabling short TEs as well as being robust to motion, making it suitable for short-T₂ and dynamic imaging applications. It requires longer scan times than Cartesian trajectories for the same imaging volume because of oversampling in the center of k-space. The scan time can be decreased by reducing the number of spokes acquired, as is done in angular undersampled PR [1]. This assumes motion is restricted to a central circular region of support and streaking artifacts outside of this area are tolerated.

We present a method to reduce radial imaging scan times with non-circular field of views (FOVs) by non-uniform angular sampling. Unlike previous methods [1-3], our method allows for arbitrarily shaped FOVs. This method can be applied to 2D and 3D PR, as well as cones [4] and TWIRL trajectories [5].

Theory/Methods

The FOV in radial imaging is determined by the sample spacing at the end of the spokes, where $FOV = 1/(k_{\max} \Delta\Theta)$. The observation that the FOV at an angle φ is defined by the sample spacing perpendicular to φ allows us to define the FOV angularly as $FOV(\varphi) = 1/(k_{\max} \Delta\Theta(\varphi + \pi/2))$. Using this we can recursively calculate a set of angles $\Theta[n]$ for a given $FOV(\varphi)$, with the constraint that $FOV(\varphi) = FOV(\varphi + \pi)$, as:

$\Theta[n+1] = \Theta[n] + 1/(k_{\max} FOV(\Theta[n]))$. The set of angles must obey the symmetry relation $\Theta[n] = \Theta[n - N/2] + \pi$, where N is the total number of spokes, so are scaled appropriately. The extent, k_{\max} , corresponding to the spatial resolution, is unchanged.

Results

Figure 1 shows three angular sampling patterns and their point spread functions (PSFs) that define the FOV. A standard uniform angular sampling pattern with 126 spokes and the resulting circular FOV is shown in Fig. 1a. Figure 1b shows the sampling pattern of an elliptical FOV where the minor axis is half that of the circular FOV, reducing the number of spokes to 98. The rectangular FOV in Fig. 1c shows the flexibility of this algorithm to produce arbitrary FOV shapes. 110 spokes were required for the sides lengths to be the same as the axes of the ellipse in Fig. 1b.

Figure 2 shows lower leg images acquired with an ultra-short echo time sequence with TE = 500 μ s, TR = 100 ms, flip = 30°, 512 samples per spoke, 1 mm resolution, and a transmit/receive extremity coil on a GE 1.5T scanner. Using elliptical and rectangular FOVs (Fig. 2b,c) allowed for a 50% reduction in scan time without inducing any aliasing artifacts. Uniform angular undersampling by the same amount, resulting in a circular FOV, leads to bad streaking artifacts, as shown in Fig. 2d.

Discussion

This method is also very useful for undersampled PR. In dynamic applications, the region of support for motion can be arbitrary, allowing an increased frame rate. This technique can be extended to 3D PR and 3D cones acquisitions by rotating the 2D sampling pattern. Rotating an ellipse will produce a spheroid FOV, while rotating a rectangle will produce a cylindrical FOV. This will further reduce the scan time, and 3D acquisitions are more likely to take advantage of an anisotropic FOV. We also have extended this algorithm to include anisotropic resolutions, resulting in an additional parameter of k-space extents.

References:

- [1] Scheffler K, et al. MRM 40:474-80 (1998).
 [2] Scheffler K. JCAT 23: 162-6 (1999).
 [3] King K. MRM 39: 448-56 (1998).

- [4] Irarrazabal P, et al. MRM 33: 656-62 (1995).
 [5] Jackson JI, et al. MRM 25: 128-9 (1992).

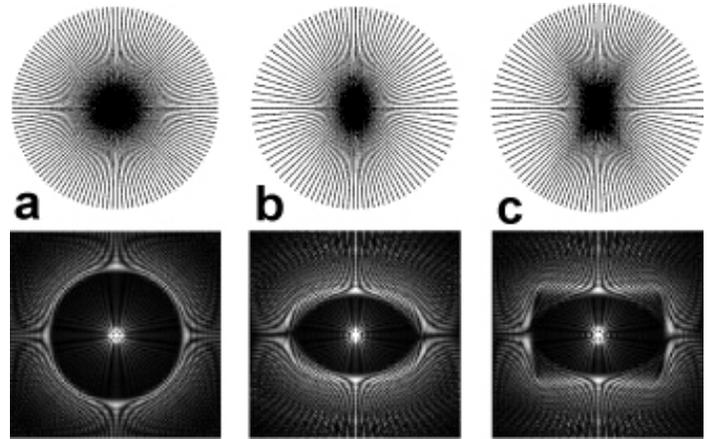


Figure 1: Angular sampling patterns (top row) with the corresponding PSFs (bottom row): (a) circular FOV (126 spokes), (b) elliptical FOV (98 spokes) and (c) rectangular FOV (110 spokes). The PSFs are windowed to show aliasing.

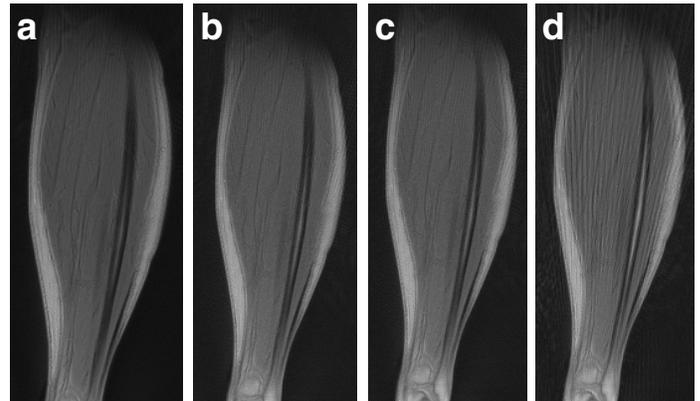


Figure 2: Lower leg images: (a) 25 x 25 cm circular FOV requiring 786 spokes, (b) 7.5x25 cm elliptical FOV with 394 spokes, (c) 6.5x24 cm rectangular FOV with 390 spokes, (d) 12.5x12.5 cm circular FOV with 392 spokes. The non-circular FOV images (b,c) show no aliasing artifacts or loss of resolution but were acquired in half the time. The circular FOV acquired in half the time (d) results in aliasing artifacts.