SPIRAL-PR: A NEW POLAR K-SPACE TRAJECTORY FOR FLEXIBLE VARIABLE-DENSITY SAMPLING

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INTRODUCTION

Polar k-space trajectories acquire data in a coordinate system described by a radial (*r*) and azimuthal (θ) variable. The most common polar trajectories are spiral and projection-reconstruction (PR). An attractive feature of polar trajectories is that they can generate high-quality images from undersampled data [1]. This is accomplished by employing a variable-density sampling strategy which undersamples the outer regions of k-space, whilst maintaining a sufficient density in the inner region (Fig. 1). Since only the low-intensity outer k-space data experiences aliasing, the intensity of the resulting artifact in the reconstructed image is also low [2,3]. In a fixed data acquisition time, varying the undersampling pattern provides a means for trading off improved spatial resolution against increased artifact.

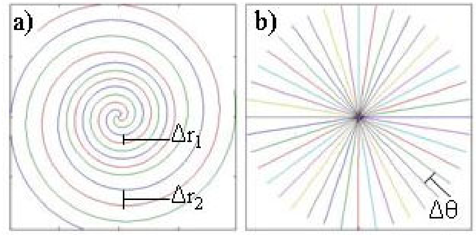

Figure 0: (a) Variable-density spiral trajectory. Radial density in the inner region (Δr_1) is higher than the outer region (Δr_2). (b) PR trajectory. Azimuthal density is determined by the spacing ($\Delta\theta$) between projections. The density can be altered by varying the number of projections.

One drawback with existing polar trajectories is that their ability to vary the density, and thus alter the parameters of the resolution-artifact tradeoff, is limited. Spiral density can be varied in the radial direction, while PR density can be varied in the azimuthal direction only (Fig. 1). Additionally, the PR sampling density always varies at a fixed rate proportional to 1/*r*. In this abstract, we introduce a new polar k-space trajectory, spiral-PR, that has a much more flexible variable-density capability. It allows one to vary the sampling density independently and arbitrarily in both radial and azimuthal directions.

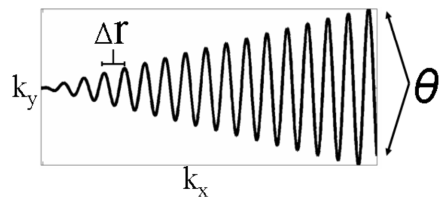

Figure 2: Single spiral-pr sector.

THEORY

Spiral-PR is a hybrid trajectory which employs PR sampling on one axis, and spiral on the other. A single "sector" of the trajectory is illustrated in Fig. 2. The remaining sectors are obtained by rotation (Fig. 3a). The radial density is determined by the distance between the cycles (Δr), and the azimuthal density is related to the amplitude of the sinusoid (θ) and the spacing between adjacent sectors. Since these parameters can be varied independently over time, so too can the radial and azimuthal densities. As an example, Fig. 3b illustrates an undersampled spiral-pr trajectory with the radial and azimuthal undersampling beginning at different points along the trajectory, and varying at different rates of change. This flexibility in varying the density allows for a large degree of freedom in altering, and thus optimizing, the resolution-artifact tradeoff.

METHODS AND RESULTS

Phantom and *in vivo* images were acquired using the fully- and undersampled spiral-pr trajectories in Figs. 3a,b. In the same data acquisition time, the undersampled trajectory provides a theoretical resolution of 1.3mm, vs. 2.3mm for the fully-sampled case. In the phantom images (Figs. 3c,d), the improved resolution provided by the undersampled trajectory is obvious. Note, however, that the undersampled image *does* possess artifact in the form of streaking (due to azimuthal undersampling [3]) and high-frequency artifact (due to radial undersampling [1]). This artifact is of low-intensity, however, and does not significantly interfere with structures in the image. A similar improvement in resolution with minimal artifact can be observed in *in vivo* images of the heart (Figs. 3e,f).

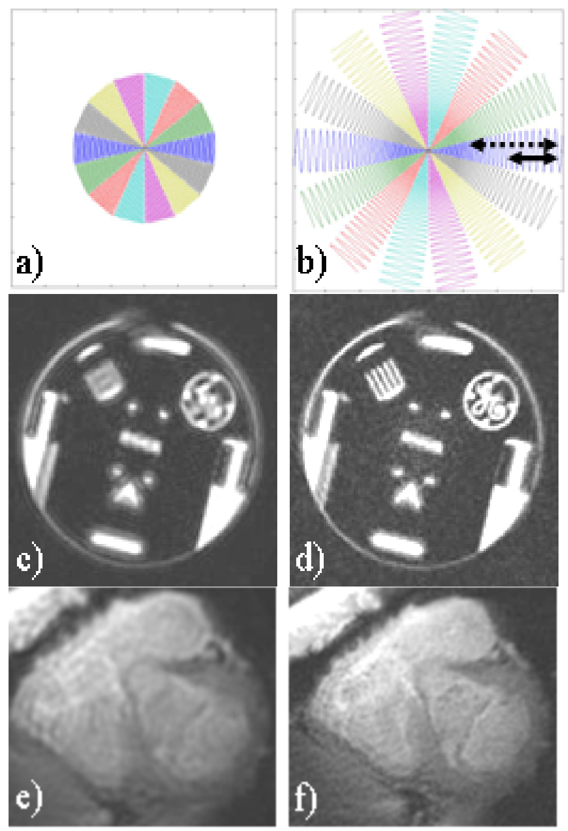

Figure 3: (a) Fully- and (b) under-sampled 14 sector spiral-pr trajectories. The dashed and solid lines in (b) indicate the regions of radial and azimuthal undersampling respectively. (c), (d) Phantom and (e), (f) in vivo cardiac images generated from the spiral-PR trajectories in (a), (b).

CONCLUSIONS

The spiral-PR trajectory has been shown to provide a large amount of flexibility in its ability to vary the sampling density. In the future, this flexibility may allow one to better optimize the resolution-artifact tradeoff inherent in undersampled acquisitions.

[1] C. Tsai *et al.*, *MRM*, 2000, 43, p. 452-458.
[2] J.H. Lee *et al.*, *MRM*, 2003, 50, p. 1276-1285.
[3] K. Scheffler *et al.*, *MRM*, 1998, 40, p. 474-480.

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