Adaptive-Kernel Reconstruction of Variable-Density Trajectories

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Introduction

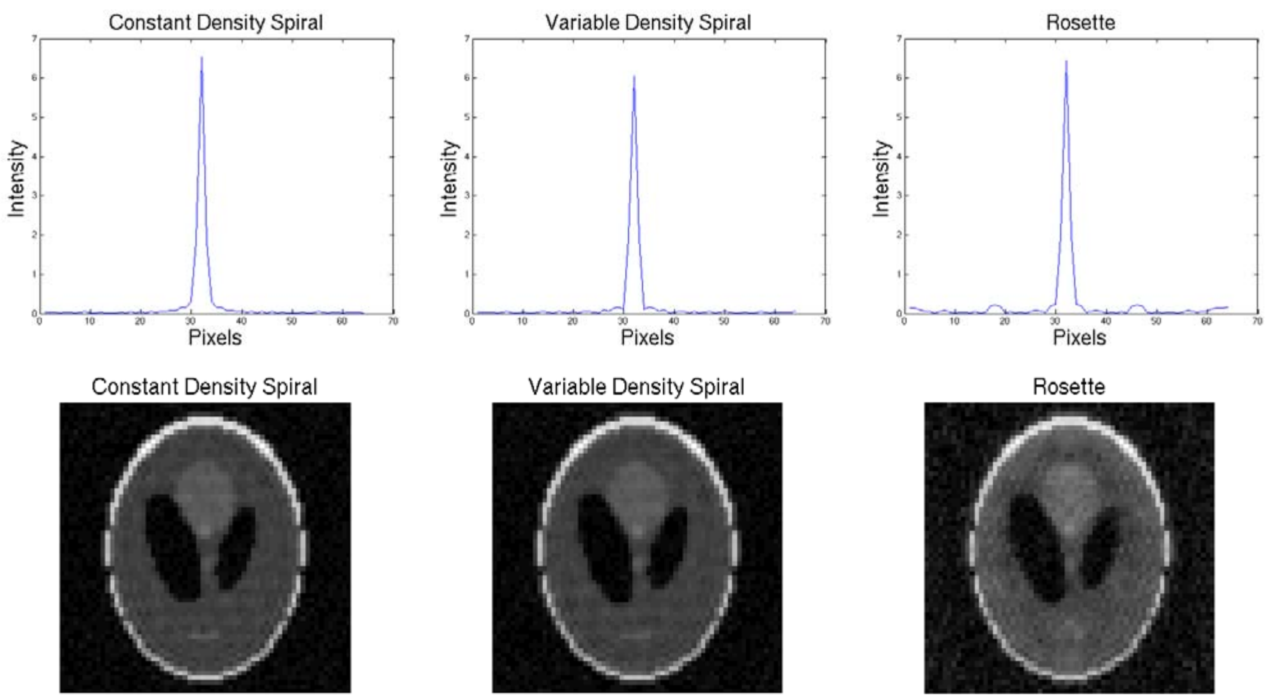
Fast, single-shot imaging methods are essential for cardiac imaging, fMRI, DTI, etc. Non-Cartesian sampling methods can offer faster acquisitions by fully sampling the center of *k*-space, where image energy is concentrated, while undersampling at high frequencies. For example, variable-density spiral acquisitions[1] have been shown to offer significant speed improvements, but they suffer from high-frequency artifacts that reduce image quality. To reduce such artifacts, we examined the reconstruction of both non-uniform spiral and rosette trajectories with adaptive kernels to characterize artifacts and spatial resolution. The kernel size is adjusted throughout k-space based on the azimuthal and radial distance between a given signal point and its nearest neighbors in k-space. This adaptive reconstruction scheme greatly reduces undersampling artifacts, permitting an arbitrary trade-off between speed and sampling density.

Methods

A Shepp-Logan head phantom image was sampled using both variable-density spiral and rosette single-shot trajectories based on a 20-cm FOV and 64×64 baseline matrix. For the variable density spiral, sampling time and angular frequencies were established to fully sample near the origin of *k*-space[2], and an undersampling factor of 4 was used for $k > 0.5k_{max}$ resulting in a 20ms acquisition time, as compared to 50 ms for the equivalent fully sampled spiral. For the rosette, 20 cycles through $k = 0$ per rotation was used for an 18ms acquisition time; this corresponds roughly to an azimuthal undersampling factor of 10:1. For the simulated acquisitions, a maximum gradient strength of 40mT/m was assumed with a peak slew rate of 200T/m/s. Gridding kernel size was based on the azimuthal and radial distances between a given signal point and nearest neighbors. These distances were used to define a circular-sector kernel bounded azimuthally and radially (i.e. kernel bounds were lines of constant angle and radius). A 2D (azimuthal, radial) sinc gridding function was used to fill the *k*-space matrix prior to 2DFT and magnitude reconstruction.

Results

The left images show the PSF and Shepp-Logan images for the uniform spiral, with the variable density spiral in the center and the rosette result on the right. The PSF for the 50ms uniform spiral and 20ms variable density spiral are essentially similar. The rosette example (18ms acquisition) demonstrates a narrower PSF with more artifacts as evident in the phantom image.



Discussion

Use of non-uniform trajectories reduces the image acquisition time and can do so without introduction of significant artifacts over the uniform trajectory due to moderate undersampling of high-spatial frequency *k*-space. Spatial resolution is not appreciably compromised in the case of a 20ms single-shot acquisition variable density spiral as compared to the uniform density version. The low-density rosette trajectory also produces an acceptable PSF when used as a single-shot acquisition of less than 20 ms duration, despite a remarkably sparse 10:1 azimuthal undersampling.

[1]Tsai, C.M., Nishimura, D., Magn Reson Med 43:452-458, 1998. [2]Kim, D.H., Adalsteinsson, E., Spielman, D.M., Magn Reson Med 50:214-219, 2003.