Variable-density MRI k-space scanning: Acquisition and reconstruction for dynamic imaging

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Magnetic resonance imaging (MRI) has become a major noninvasive imaging modality over the past 25 years, providing excellent flexible soft-tissue contrast. Conventional MRI is relatively slow compared to other imaging modalities because data are obtained in the spatial frequency domain of images, termed k-space. Very little information can be obtained simultaneously and thus MR utilization in imaging dynamic processes and body regions with physiological motion has been limited. Recently fast imaging techniques have been developed to accelerate the acquisition, including utilizing multiple receivers to partially encode spatial positions and exploiting variable density k-space sampling. In this thesis, variable density k-space sampling techniques and reconstruction methods for dynamic imaging are presented.

Variable-density k-space sampling strategies allow accelerated scanning through undersampling higher spatial frequencies and oversampling lower ones, thus have favorable properties for generating dynamic images. To take advantage of the great computation speed afforded by the fast Fourier transform (FFT), image reconstruction of variable-density sampling methods have been implemented using interpolation or "gridding" algorithms, which require a sampling density compensation for the preference of the acquisition trajectory. An existing method of density compensation for static imaging is expanded to create a series of temporal filters that generate dynamic imaging capabilities with arbitrary sampling trajectories. The method first demonstrated complex flow patterns in the chest and abdomen and separated arterial and venous structures in these regions after a MR contrast injection.

Variable density k-space strategies using multiple echoes are used to dramatically increase the capabilities of MR for fast functional cardiac imaging and coronary imaging within a breath-hold. Here the density compensation methods developed earlier for vascular imaging are used to depict the myocardium, cardiac chambers and coronary arteries throughout the cardiac cycle without a contrast injection. Methods to utilize multiple-echo trajectories with robust image quality are shown in each cardiac application. The ability to visualize both the coronary lumen and the epicardial fat bed in which the coronaries lie are demonstrated for the first time.