Variable Spatial Resolution Reconstruction from Data Acquired with Non-Constant Sampling Density in Phase-Encoding Direction

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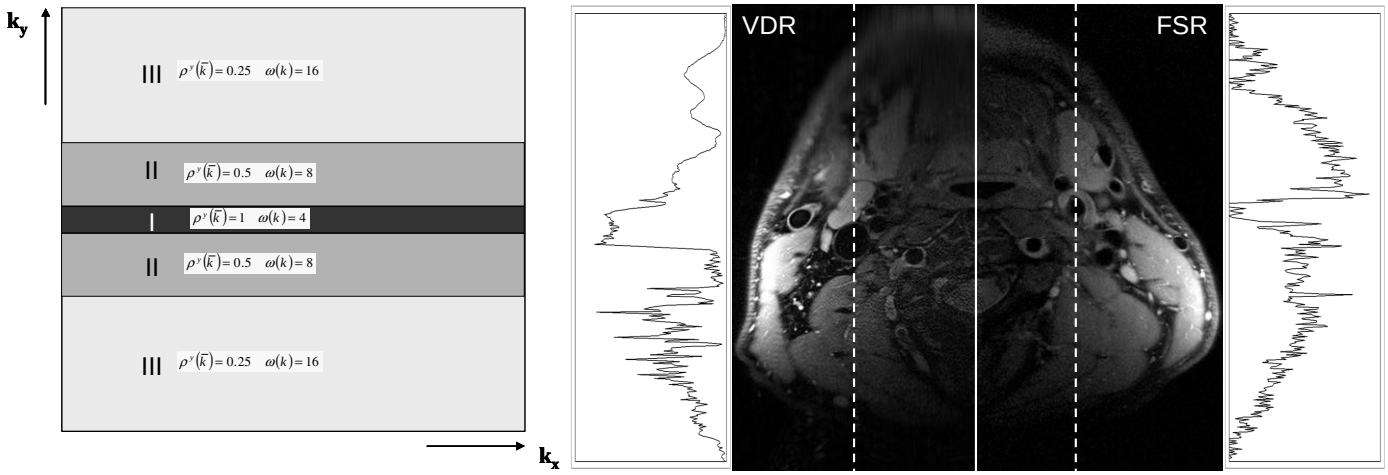
Introduction

An attractive technique for increasing imaging speed in MRI is the acquisition of k-space data with reduced sampling density for higher frequency portions of k-space. Due to the under-sampling of the high-frequency components, this approach is prone to cause high-frequency aliasing artefacts. Cukur et al. [1] suggested a varying kernel extent gridding reconstruction technique for reconstruction of variable density spiral data for reduction of aliasing artefacts under the expense of local compromises in spatial resolution. The concept is applied to the reconstruction of data acquired with non-constant sampling density along phase-encoding direction.

Methods

Cartesian k-space data with gradually decreasing sampling density along phase-encoding direction was acquired and resampled onto a dense Cartesian grid by convolution interpolation (gridding). Instead of using a constant gridding kernel width $w(\bar{k})$ during gridding, the kernel width is chosen inversely proportional to the local sampling density. Assuming a finite number *i* of different sampling densities, the k-space data after gridding $\tilde{S}(\bar{k})$ results as $\tilde{S}(\bar{k}) = \sum_i \left(S(\bar{k}) O_s(\bar{k}, i) \mathrm{X}_i(\bar{k})\right) * C(\bar{k}, \Delta k_i)$, with $\mathrm{X}_i(\bar{k}) = \begin{cases} 1 & \Delta k = \Delta k_i \\ 0 & else \end{cases}$, O_s being the sampling function, *C* the sampling density dependent gridding kernel, and *S* the sampled input k-space data. Fourier-transformation of $\tilde{S}(\bar{k})$ yields $\tilde{M}_{mf}(\bar{r}) = \sum_i \left(M(\bar{r}) * PSF_s(\bar{r}, \Delta k_i) * \chi_i(\bar{r})\right) c_i(\bar{r}) = \sum_i \left(M_i^f(\bar{r}) * PSF_s(\bar{r}, \Delta k_i)\right) c_i(\bar{r})$, with $\chi_i = FT^{-1}(\mathrm{X}_i)$, $M(\bar{r}) = FT^{-1}(S(k))$, and $M_i^f(\bar{r})$ being the band-pass filtered representation of $M(\bar{r})$ derived from all frequency data sampled with sampling density Δk_i. The image function $\tilde{M}_{mf}(\bar{r})$ results as the superposition of various spectrally filtered versions of $M(\bar{r})$ convolved with the sampling PSF_s and weighted by the Fourier transform of the convolution kernel. The increasing width of the interpolation kernel with decreasing sampling density causes a rapid decay of high frequent component in the image with increasing distance to the image centre, which is used for suppression of high-frequency aliasing artefacts.

Results



a) b)

Figure 1: Reconstructions b) obtained by the variable density reconstruction technique from 33% of k-space data (VDR) acquired with sampling densities as indicated in a), and obtained by conventional reconstruction from fully-sampled k-space data (FSR).

Figure 1 shows images of the carotid artery (b) obtained from fully sampled k-space data (FSR) in direct comparison with the suggested approach (VDR), in which the image was reconstructed from only 33% of k-space data acquired with gradually decreasing sampling density along phase-encoding direction. In the VDR image, aliasing artefacts could be almost completely suppressed and the concomitant gradually decreasing spatial resolution along phase-encoding direction is obvious in the image and in the intensity profile.

Discussion

The variable resolution reconstruction technique enables an almost artifact free image reconstruction from data acquired along a Cartesian trajectory in about 30% of the conventional acquisition time by gradually decreasing the sampling density in phase-encoding direction. The concomitant gradually decreasing image resolution limits the usability of the technique to applications in which the region-of-interest (ROI) is confined in a slab aligned orthogonal to the phase-encoding direction, or high spatial resolution is only required in a limited ROI.

[1] Cukur T., et al. Varying kernel extent gridding reconstruction. ISMRM 2007, p 1912