Varying Kernel Extent Gridding Reconstruction

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Introduction: Variable-density k-space trajectories have been used to increase resolution or reduce scan time by undersampling the high spatial frequency components [1]. For image reconstruction, regular gridding reconstruction with a constant kernel extent [2] can be used; however, such reconstruction does not consider the space-variant properties implicit in variable-density sampling. Here, we propose the use of a varying kernel extent gridding reconstruction method. This method leads to an image in which the undersampled spatial frequencies contribute to the FOV supported by the local sampling density (which we refer to as the acquisition FOV). While the resultant image exhibits space-variant resolution, the aliasing and noise energy are reduced.

Method: In a variable-density trajectory, the increasing inter-sample distance between k-space samples leads to aliasing artifacts due to the reduced acquisition-FOV supported by the high spatial frequencies. In our method, assuming a variable-density spiral trajectory as an example, k-space can be partitioned into several subsets (annuli). Starting with the innermost subset, a progressively smaller part of the FOV can be reconstructed from each subset. Figure 1 displays an example where the object is the superposition of 2 sinusoids. The main-lobe width of the convolution kernel can be varied to cover the local inter-sample gap for different annuli. This limits the spatial extent of reconstruction to the corresponding acquisition-FOV for each annulus. The error energy contribution can be decreased by a larger main-lobe width kernel [3]. Therefore, the aliasing artifacts and noise contribution of a certain annulus are reduced outside of the corresponding acquisition-FOV. Deapodization for each annulus is performed only within the acquisition-FOV.

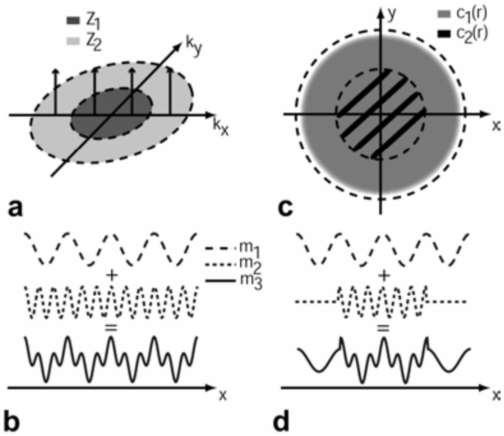

Figure 1. ***a:*** *The low and high spatial frequency impulses fall into different annuli Z_1 and Z_2.* ***b:*** *The central cross-section of the input, m_3, as a superposition of the low and high frequency components, m_1 and m_2.* ***c:*** *The corresponding spatial extents for reconstruction. m_2 is retained only in c_2, whereas m_1 within the extent of c_1.* ***d:*** *The superposition after reconstruction.*

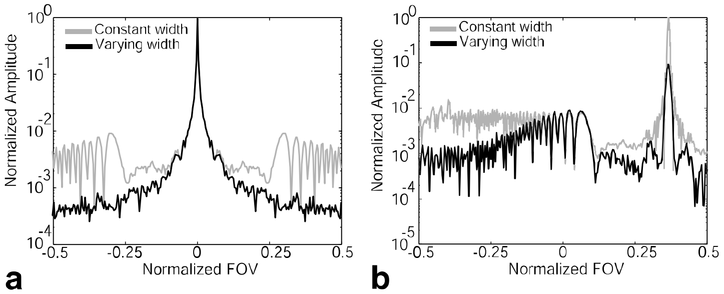

Figure 2. *The cross-sections of the point spread functions for regular gridding and varying kernel extent methods with an impulse at the center* ***(a)*** *and close to the edge* ***(b)*** *of the FOV.*

Results: Figure 2 shows the cross-sections of the impulse responses for regular gridding and varying kernel extent methods assuming a variable-density spiral trajectory with the sampling density linearly falling off to one-sixth at the edge of k-space. For this figure, FOV refers to the acquisition-FOV for the center of k-space. The aliasing energy towards the edge of the FOV is reduced with the proposed method without sacrificing the resolution at the center of the FOV. The aliasing energy reduction, the resolution change and the SNR efficiency as a function of the number of annuli have been analyzed as outlined in [3] and the results are shown in Fig. 3. The computational complexity is comparable to gridding. The choice of the number of annuli is a trade-off between image quality and processing time.

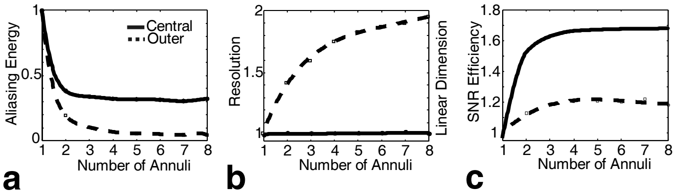

Figure 3. ***a:*** *The relative aliasing energy,* ***b:*** *the resolution in terms of linear dimension,* ***c:*** *the SNR efficiency versus the number of annuli for impulses at the center and the periphery of the FOV.*

The method was tested on a variable-density spiral acquisition on a 1.5 T GE Signa system with a 5-inch surface coil. As shown in the images of Fig. 4, the arrows point to the aliasing artifacts in the low SNR region (due to coil sensitivity) of the image. Both the partial density compensation method [4] (which reduces aliasing artifacts by adjusting the sampling density compensation) and the proposed method effectively reduce the artifacts; however, only the latter preserves the resolution at the center of the FOV. The effective center of the reconstruction FOV can be shifted to the centers of different ROIs in an image and the results can be patched afterwards. This allows one to adjust the trade-off between resolution and artifact suppression. Figure 4.d displays an example where the effective center of the reconstructed FOV was shifted to the high SNR region. The combined image has reduced artifacts in the low SNR region and high resolution in the shifted region.

Conclusion: The proposed reconstruction method can be used to reduce the aliasing artifacts in the outer parts of the FOV, while preserving resolution at the center.

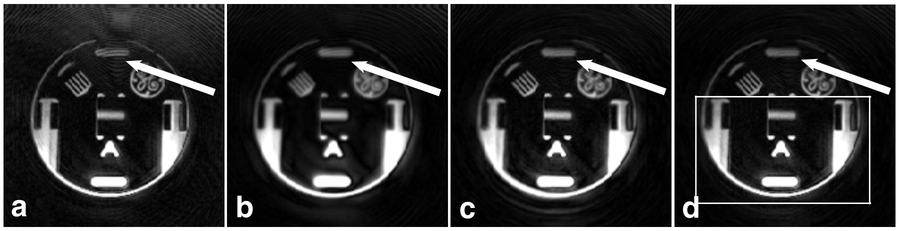

Figure 4. *A phantom acquisition with a variable-density trajectory: 17 interleaves, FOV linearly falling from 20 cm to 5 cm and 0.8 mm in-plane resolution. The reconstructed images for* ***a:*** *regular gridding,* ***b:*** *partial density compensation,* ***c:*** *varying kernel extent methods.* ***d:*** *Two separate ROIs are reconstructed with varying kernel extent method and combined. The center of the reconstruction FOV was shifted to the center of the ROI within the rectangle.*

References:
1. Tsai C, *et al.* MRM 43:452-58, 2000.
2. Jackson J, *et al.* TMI 10:473-78, 1991.
3. Pipe J. MRM 43:867-75, 2000.
4. Pipe J, *et al.* MRM 41:179-86, 1999.