A Comparison of Iterative and Non-Iterative Approaches For Sampling Density Compensation in PROPELLER Imaging.

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Introduction: In the PROPELLER sampling scheme [1], data is collected along a blade, which is rotated to fill in the Fourier space of the object. For fast image reconstruction, the k-space data is interpolated onto a Cartesian grid and then Fourier transformed to image space. Interpolation on the Cartesian grid is performed with: $M = \{[(M_s \cdot W)\otimes C]\cdot \text{III}\}\otimes^{-1} C$, where M is the data sampled on the Cartesian grid, M_s is the data on the PROPELLER grid, W is the weighting function that compensates for the non-uniform sampling density, III is the Cartesian grid, and C is the convolution function for the interpolation. Both non-iterative [2] and iterative [3] approaches have been proposed for the estimation of W. In this study, the two methods were compared under different sampling conditions. When sufficiently sampling k-space with a PROPELLER sampling grid the two approaches produced similar results. In contrast, iterative estimation of W produced superior results than the non-iterative method in case of k-space under-sampling.

Methods: PROPELLER acquisitions were simulated by calculating analytically the Fourier transform of the Shepp-Logan phantom along a PROPELLER sampling grid. Two sampling patterns were simulated. Sampling pattern S_1 had 12 blades, 16 lines, and 128 points, and S_2 had 12 blades, 8 lines, and 128 points. No noise was added to the data. The field of view (FOV) in image space was considered to be 1 (arbitrary units). Therefore, the spacing between samples on the Cartesian grid in k-space was 1 in spatial frequency units. The image was reconstructed on a 128x128 Cartesian grid. The convolution function C was obtained iteratively by constraining the Kaiser-Bessel function (w=5,beta=16,order=8) within ±FOV in physical space, and ±2/FOV in k-space [3]. The weighting function for the non-iterative approach was given by $W=S/(S\otimes C)$, where S is the PROPELLER grid [2]. For the iterative method the weighting function was given by $W_{i+1}=W_i/(W_i \otimes C)$, where W_1 is the weighting function from the non-iterative approach [3]. For S_1, 33 iterations were needed in order for $(W\otimes C)\cdot S_1$ to converge about unity with error (±0.01). For S_2, 5 iterations were necessary for $(W\otimes C)\cdot S_2$ to converge about unity with error (±0.1).

Results & Discussion: Figure 1 shows the original image and the reconstructed images for sampling grids S_1 and S_2, using both the iterative and non-iterative methods for calculating the weighting function W. Profiles of the original and reconstructed images are shown in figure 2 for both sampling grids. The images reconstructed using the iterative and non-iterative approaches where very similar to each other and to the original object when sufficiently sampling k-space (grid S_1). In contrast, when under-sampling k-space (grid S_2), both reconstructed images contained significant image artifacts. However, the image obtained using the iterative approach for estimating W appeared to be more similar to the original image than that obtained with the non-iterative method.

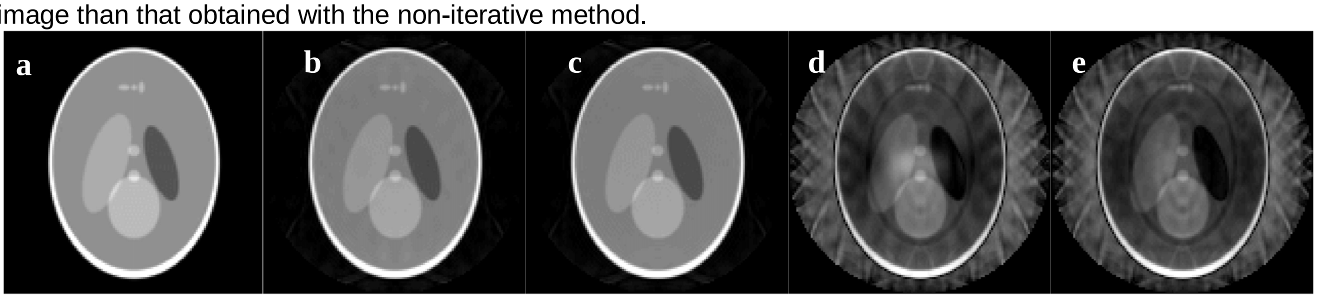

Figure 1: Original image (a). Reconstructed image for S_1 using the non-iterative (b), and the iterative (c) method. Reconstructed image for S_2 using the non-iterative (d), and the iterative (e) method.

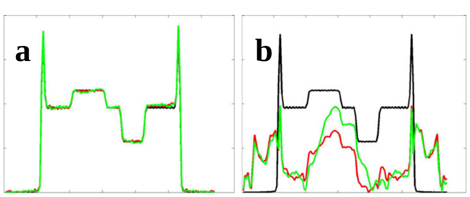

Figure 2: Image profiles along the x-axis. Image (a) was obtained using grid S_1, and (b) using grid S_2. The green line corresponds to the non-iterative method, the red line corresponds to the iterative method and the black line shows the profile of the original image.

References: 1) Pipe JG, Farthing VG, Forbes KP. Magn Reson Med 47:42(2002). **2)** Jackson JI, Nishimura DG, Macovski A. Selection of a convolution function for Fourier inversion using gridding. IEEE Trans Med Imaging 10:473(1991). **3)** Pipe JG, Menon P. Sampling density compensation in MR I: Rationale and iterative numerical solution. Magn Reson Med 41:179(1999).