Static Magnetic Field Inhomogeneity Correction of Radial MRI Using an Alternating Gradient Readout Acquisition

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Introduction: Static magnetic field (B0) inhomogeneities are one of the major causes of artifacts in MRI. Although numerous correction methods have been implemented for acquisitions acquired in Cartesian k-space, relatively little investigation has been conducted for radial MRI. B0 inhomogeneities can cause signal displacements in image space along the frequency encode direction. In this work, a previously described reverse gradient method [1] is applied to correct radial MRI data without prior knowledge of the B0 inhomogeneities.

Materials and Methods: Radial MRI data of a phantom, comprising of 256 projections equally spaced over 180°, were acquired on a 3T Achieva scanner (Philips Healthcare, Best, The Netherlands). The data were acquired with alternating frequency encode directions, which allows one to approximate the data with reversed readout gradient by comparing a given projection with the average of its closest pair of neighbors. The two data sets (the original k-space and its reversed readout approximation) were both 1D Fourier transformed into the spatial domain (sinogram space). The displacement was detected by Runge-Kutta-Fehlberg 5th order integration with adaptive step size. The numerical method solved the position pairing from the original k-space data and from its reversed readout gradient approximation. For each projection pair (original and reversed), the integration method was applied to estimate the true location and intensity for each spatial domain projection sample [1]. The frequency encoding direction in radial MRI is the same as that for one single spatial projection according to the Fourier Projection-Slice Theorem, so the field inhomogeneity correction of this approach essentially operates in sinogram space. After applying the correction to each projection and obtaining a corrected sinogram, the final image was reconstructed using NUFFT [2]. The numerical integration needed boundary conditions, which were implemented by thresholding to exclude the background region in each projection. Estimation of the final corrected projection samples required spline interpolation [3] to resample the non-uniformly spaced signal locations yielded by the integration. The method proposed in [1] did not account for complex numbers, so phase was estimated by averaging the real and imaginary parts for the original data and its reversed readout approximation.

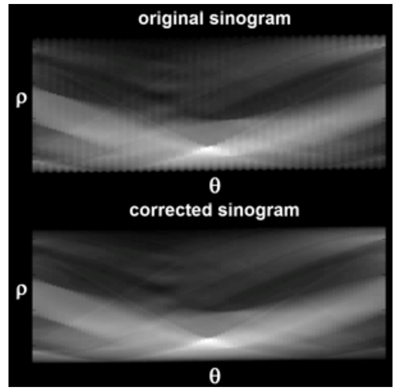

Figure 1. Original sinogram (top) com-pared to corrected sinogram (bottom).

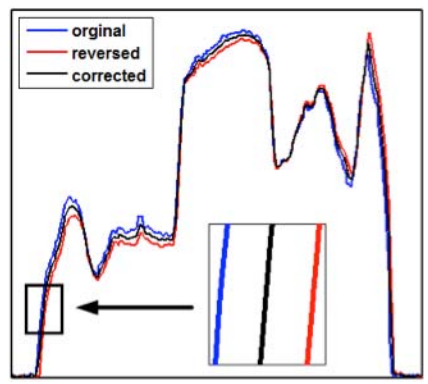

Figure 2. Runge-Kutta-Fehlberg 5th order correcting corrupted projections (blue and red) to the corrected value (black).

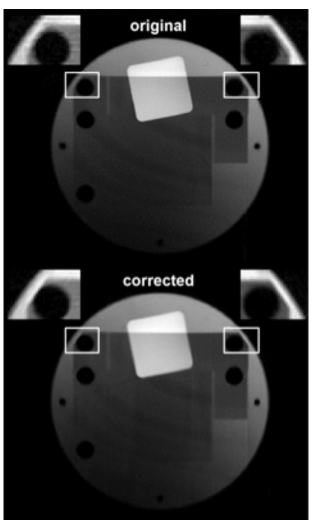

Figure 3. Comparison of recon-struction without (top) and with (bottom) correction.

Results: The corrected sinogram is smoother than the original as shown in Figure 1 where the zigzag of the pattern in original sinogram (top) is no longer seen in the corrected one (bottom). The result of the integration is illustrated in Figure 2. The “original” blue curve indicates one single projection in the original sinogram degraded by field inhomogeneity; the “reversed” red curve represents the same project-ion experiencing a reversed readout gradient; the “corrected” black curve is the estimated trajectory of the unbiased projection with field inhomogeneity removed. A zoom-in window clearly shows the displacement, for blue and red curves from the black curve. The reversed readout gradient causes the blue curve and the red curve to locate on different sides of the black curve [1]. Figure 3 compares reconstruction results. Improvement is noticeable around the holes highlighted with white rectangles.

Conclusion: Static magnetic field inhomogeneity correction for radial MRI data is feasible when the reversed readout gradient approximation is available. The radial MRI sinogram can be used as an intermediate space to estimate the true signal, and the method does not require any prior knowledge of the field inhomogeneities.

References: 1. Fitzpatrick JM et al. IEEE Trans On Med Imag (1992) 11(3):319-329. 2. Fessler JA et al. IEEE Trans on Sig Proc (2003) 51(2): 560-574. 3. Schoenberg IJ. Quart Appl Math (1946) 4:45-99.