Fast Correction of the Gradient Field Non-uniformity for Large FOV Continously Moving Table Techniques

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Introduction

Effective methods for the correction of gradient magnetic field distortions using *a priori* error fields and field mapping have been previously presented. Large field-of-view (LFOV) imaging using a continuously moving table[1,2] is a new imaging approach that acquires data in hybrid (x, k_y, k_z)-space; this makes it difficult to directly apply these traditional correction approaches in fast MR imaging applications, such as angiography. Some investigators have addressed this issue for constant table motion;[3,4] although, their approaches demonstrated improvement, they were limited by slow table motion, small spatial extent in z,[3] lengthy correction time[3], large hybrid-space overlap[4],and faint banding artifacts[4]. Here, we propose a real-time hybrid-space data-combining strategy that minimizes gradient geometric distortion. Results in phantoms and humans show rapidly produced 3D LFOV images with high spatial accuracy (≤1.5 mm error). In addition, the proposed method allows correction of data acquired with variable as well as constant table motion, $v(t)$.

Methods

Our approach to LFOV imaging allows interactive and variable table motion together with under-sampling the hybrid-space.[2,5,6] Both the acquisition patterns and the table motion have required the development of data combining strategies for overlapping hybrid-space data. Rather than simply replacing existing data with newly acquired data, we have proposed averaging the overlapping data by weighting the data collected near the magnet iso-centre more heavily. As the table moves, the k-space encoding pattern rapidly refreshes the data near the centre of hybrid-space, thereby providing less gradient-distorted samples even with relatively fast table motion. Figure 1 shows two typical readouts acquired at time-points, t_1, t_2, (corresponding to table positions, x_1, x_2) at a particular (k_y, k_z)-phase-encoding. The hybrid-space data is determined after applying weighting functions, $w_1(x)$ and $w_2(x)$ (with parameter a or b), to the overlapping portion (with a distance L) of the Fourier-transformed readouts, $S_1(x, k_y, k_z)$ and $S_2(x, k_y, k_z)$:

$$S_{corrected}(x,k_y,k_z) = w_1(x)S_1(x,k_y,k_z) + w_2(x)S_2(x,k_y,k_z)$$

$$w_2(x) = 1 - w_1(x)$$

$$w_1(x) = \begin{cases} 1, & 0 \le x < a \\ (x+a-L)/(2a-L), & a \le x < L-a \\ 0, & L-a \le x \le L \end{cases} \quad \text{or} \quad \frac{1}{1+\exp(-bx)}$$

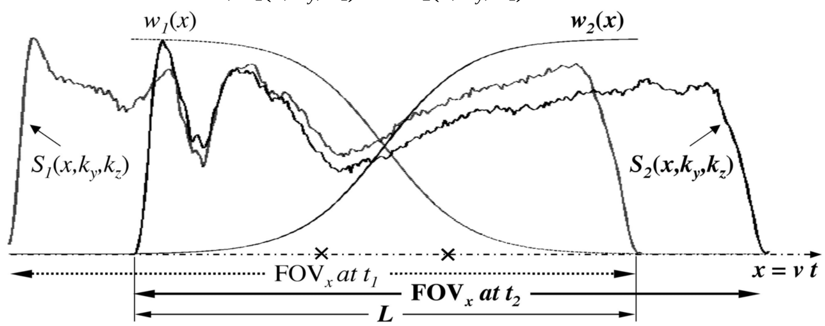

Figure 1. Two typical readout echoes acquired at two time-points, t_1, t_2, at the same phase-encode while the table was being moved. The overlapped data are averaged with data near the magnet iso-centre (×) *being more heavily weighted.*

Piecewise linear and sigmoidal weighting functions (shown in Figure 1 and described above) with stochastic and elliptic-centric acquisition patterns were used.[2,5] Two data sets each from four volunteers and two large phantoms were collected on a 3 T MR scanner (Signa; GE Med Systems, Waukesha, WI) using the body coil. The first data set was used as a reference and was obtained with a non-moving table 3D acquisition and then geometrically corrected with the conventional method. The second acquisition set (256×128-256×16) was acquired with the interactive moving table technique at slow (~1 cm s^{-1}) and fast (~2 cm s^{-1}) table motion rates. We collected only a portion (15% to 40%) of the hybrid-space in 60 s to 90s scan times. Data combining was done in real-time right after Fourier transformation in the k_x-direction. The LFOV images were reconstructed offline by simple Fourier transformation in the (k_y, k_z)-direction.

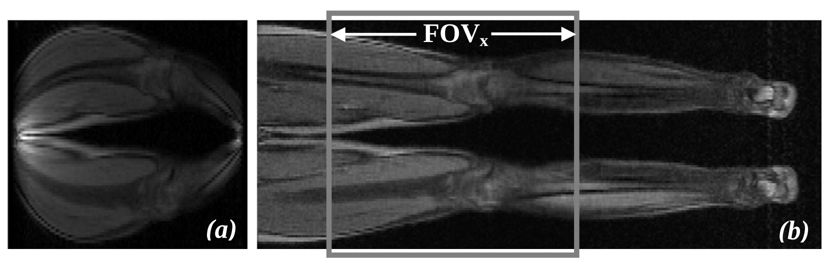

Figure 2. (a) Uncorrected FOV_x = 48 cm slice (b) a portion of the geometrically corrected LFOV slice with linear data combination. Spatial error < 0.9 mm.

Results

Figure 2 presents the results using linear data combination (with $a = L/3$) for slow table motion and FOV_x = 48 cm. Figures 2a and 2b show an geometrically-distorted slice and the LFOV slice after using the proposed correction, respectively. The spatial distortion was greatly reduced throughout the LFOV volume. Similar results were obtained in all subjects with a maximum error of 1.1 mm for slow table motion and up to 1.5 mm for fast table motion.

Discussion

We have proposed and successfully evaluated a real-time data combining strategy for minimizing gradient geometric distortions. This approach allows fast correction of LFOV data acquired with interactive table motion by exploiting the inherent hybrid-space data overlap. Due to fast and repeated acquisition of data near the centre of the hybrid-space, our method produces LFOV images with little gradient non-linearity-induced spatial distortion. In general, the speed of the table affects the functionality of the correction algorithm on the quality of the image.

References

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