Motion Correction of MRI from Orthogonal k -Space Phase Difference

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Abstract. Correction of artifacts in MRI from in-plane 2-D rigid body translational motion is possible using only the raw data of two standard 2DFT images acquired of the same object with phase encode direction swapped. Previous techniques simply use multiple or orthogonal images to reduce artifacts through interference or geometric averaging. The orthogonal k -space phase difference (ORKPHAD) provides an overdetermined system of linear equations which can be solved directly to find the phase errors caused by the motion, and thus correct for arbitrary translations in both image.

1 Introduction

It is well known that rigid body translations of an object in MRI will create image artifacts along the phase encode (PE) direction in standard 2DFT imaging (1). Methods have been proposed to take advantage of the directionality of the artifacts to improve image quality by combining images with dissimilar artifact patterns. Two such methods are ghost interference techniques (2) and the orthogonal correlation algorithm (ORCA) (3). Neither technique attempts to deduce the motion record or to correct the k -space phase errors caused by the motion. Acquiring two images with swapped PE direction, as in ORCA, makes it possible to determine and correct for the motion directly using the orthogonal k -space phase difference (ORKPHAD).

2 Theory

If one assumes 2-D in-plane translational interview motion, $4N$ unknown motions may corrupt the two $N \times N$ images. The phase difference at each point in k -space yields N^2 equations involving only $4N$ unknowns. Equation 1 shows how the motion relates to the phase difference at the (n_1, n_2) position in the k -space phase difference array. The vector $\mathbf{k}$ holds the frequency coefficients across one row or column of k -space. The vectors $\mathbf{P}_A$ and $\mathbf{F}_A$ are the motions in pixels for the first image in the phase and frequency encode directions respectively. Similarly, $\mathbf{P}_B$ and $\mathbf{F}_B$ are the motions for the second image. After the phase difference is properly unwrapped, the motion records can be found by a weighted least squares inversion of the system of equations.

$$\Phi_A - \Phi_B = \frac{2\pi}{N} (\mathbf{k}[n_1] \mathbf{P}_A[n_1] + \mathbf{k}[n_2] \mathbf{F}_A[n_1] - \mathbf{k}[n_2] \mathbf{P}_B[n_2] - \mathbf{k}[n_1] \mathbf{F}_B[n_2]) \quad [1]$$

3 Methods

Separate volumes of 2-D spin echo images of a volunteer's moving wrist were acquired with orthogonal phase encode directions. The corrupted images were then corrected with the ORKPHAD technique.

4 Results

ORKPHAD successfully improved both corruptions. The results in Fig. 1 show results for slice 6 of the 12 slice volume. All slices showed similar improvement.

Fig. 1. ORKPHAD results for slice 6: static (a,b), corrupted (c,d), and corrected (e,f).

References

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