Efficient DTI Artifact Correction via Spatial and Temporal Encoding

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Introduction

Diffusion tensor imaging (DTI) commonly relies on echo-planar imaging (EPI) sequences to acquire data. EPI is particularly vulnerable to Nyquist ghosts and geometric distortions due to field inhomogeneities. In this work, through the addition of a single additional b0 scan, we present a method to remove Nyquist ghosts and correct off-resonance distortions in DTI acquisitions with no need for additional reference data. Previously, both spatial encoding [1] and temporal encoding [2] have been employed to suppress Nyquist ghosts and correct for geometric distortions. Our contribution here is a fusion of these two techniques, to efficiently acquire, reconstruct, and correct artifacts in diffusion weighted EPI images. We show that high-quality DTI images with efficient correction for both Nyquist ghost artifact and geometric distortion can be reconstructed with only one additional b=0 scan. To evaluate the proposed scheme, results via phantom study and in-vivo human brain data are shown.

Theory

Nyquist ghosts and distortion not only degrade DTI image quality, but also result in inaccurate DTI quantitative measurements. Many approaches have been proposed to correct them. For high efficiency imaging, we introduce the combination of parallel imaging (pMRI) and PLACE to correct the artifacts in DTI, shown in Fig. 1. As in PLACE, we introduce an additional b=0 scan which is shifted in k-space by 1 k-space line (1Δk). Interleaving the odd and even lines from these two scans will produce two images nearly free of Nyquist ghosts. The coherent addition of these two images after phase alignment will further suppress the ghosts and enable estimation of high-quality self-referenced pMRI coefficients [3].

The acquired data for all b values are then separated into two sets—one for positive read-outs and the other for negative read-outs. Each set is then reconstructed using the pMRI coefficients computed from the b0 data. A magnetic field inhomogeneity map is then computed from the deghosted b0 images, which differ by a single echo-spacing [2]. Finally the deghosted images use the displacement map directly to correct for geometric distortion.

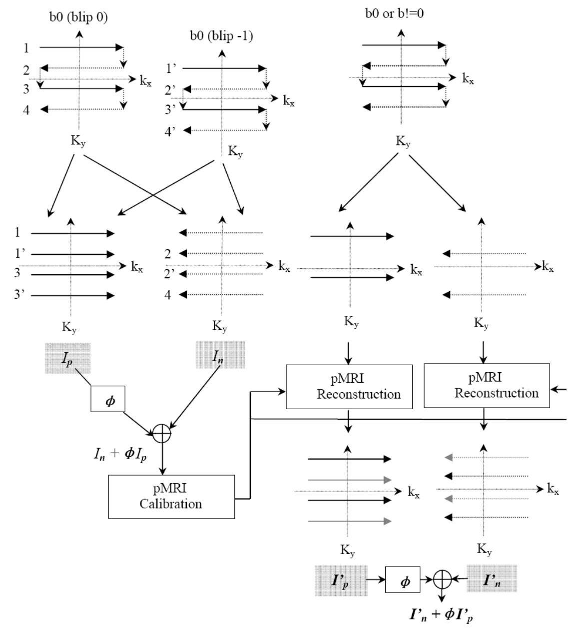

Fig.1. Data flow diagram for N/2 ghost removal using pMRI

Methods

A doped water phantom and healthy volunteer brain DTI acquisitions after informed consent were acquired on a GE Signa EXCITE 3.0T scanner equipped with the standard 8 channel head array coil (GE Medical Systems, Milwaukee, WI, USA). Standard DTI scans were acquired with only 1 additional shifted b0 data set. Acquisition parameters were: single-shot spin echo planar imaging (SE-EPI) sequence, TR/TE 6000/90ms, phantom b value = 600s/mm^2, brain b value = 1000s/mm^2 , diffusion-sensitive gradient directions = 6, image size = 128×128, FOV = 240 mm×240 mm, receiver bandwidth = 250 kHz , number of excitations (NEX) = 1.

Results

Fig. 2 illustrates b0 and DTI images obtained from a uniform phantom with an oblique black blade and a healthy volunteer's brain. Fig. 2a is the original magnitude image with N/2 ghosting and geometric distortion. In Fig. 2b, N/2 ghosting was suppressed by pMRI reconstruction. Fig. 2c shows images with both N/2 ghost artifacts and geometric distortion corrected. It is clear from the figure that both artifacts have been successfully corrected. Tractography before and after distortion correction are show in Fig. 2d and Fig. 2e.

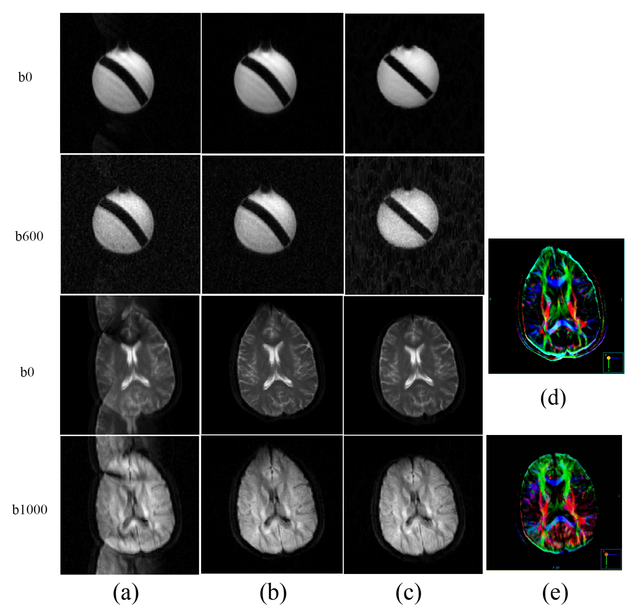

Fig.2. DTI images of a water phantom and human brain result: (a) Ghosted and distorted, (b) ghosting removed, (c) distortion corrected, (d) and (e) are color-coded tractography before and after distortion correction.

Discussion

By adding an extra shifted b0 acquisition to the standard DTI sequence, we were able to fuse spatial and temporal encoding to correct for both Nyquist ghosts and geometric distortion artifacts in a self-referenced way. Through the elimination of reference pre-scans, self-referenced DTI can now be performed in applications such as real-time imaging.

References

[1] Kellman & Mc Veigh, NMRB, 2009;19:352-361. [2] QS Xiang, et al. MRM 2007;57:731-741. [3] Hoge W.S., et al. Proc. ISMRM 2009, p2720.