DTI with prospective motion correction and reacquisition in a clinical subject population

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Introduction

Voluntary or involuntary subject motion is a major source of image artifacts in MRI. In diffusion-weighted imaging (DWI), slow bulk subject motion causes misalignment of multiple volumes from different averages or diffusion gradient directions which in turn results in image blurring and edge artifacts. Fast bulk subject motion causes signal dropout artifacts. These artifacts result in erroneous values in derived images like apparent diffusion coefficient (ADC) and fractional anisotropy (FA) when left uncorrected.

A new method based on Prospective Acquisition Correction (PACE) [1] with online reacquisition is proposed to correct for these slow and fast bulk motion artifacts in a fully automatic fashion (DW-PACE) [2]. The effectiveness of the new method is tested here in tumor subjects.

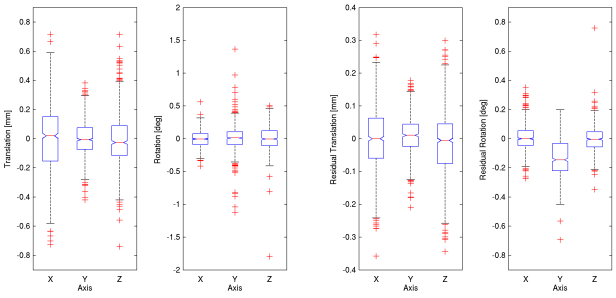

***Figure 1**: Translation and rotation values determined by DW-PACE (left) and residual translation and rotation value determined by AFNI (right). Note different y-axis scales.*

Methods

DW-PACE employs a modified version of PACE that uses separate reference volumes for each b-value used in the scan protocol. The reference volumes are continuously updated as the average of all prior measurements for a given b-value. The images to reacquire are determined in a two-step process based on the magnitude and phase data such that each image is assigned a score. The images with the highest scores are automatically reacquired at the end of the scan, up to a specified limit. Image reconstruction is performed on the scanner on the original acquisition data as well as on a second set of data where the affected images have been replaced by the reacquired ones.

All experiments were performed on a 3 T TimTrio (Siemens, Erlangen, Germany) using a 32-channel head coil. The proposed method was used to image 15 post-surgery tumor subjects. Acquisition parameters were as follows: TR 7.9 s, TE 82 ms, FoV 237 mm, 64 slices, 1.85 mm slice thickness, no gap, matrix size 128×128 (image pixel size 1.85 mm × 1.85 mm), bandwidth 1396 Hz/px, 6/8 phase partial Fourier, acceleration factor 2 using generalized auto-calibrating partially parallel acquisitions (GRAPPA) [3], 7 non diffusion-weighted volumes, 42 diffusion gradient directions, b-value 700 s/mm^2, 6.2% reacquisitions (maximum of 194 additional images), scan time 6:54 min:s without reacquisition. No triggering was used for any of these acquisitions. The subjects were instructed to hold still during the acquisition, as in all other MRI scans. Residual motion was determined using AFNI [4] based on the data without reacquisition.

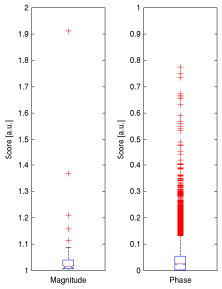

***Figure 2**: Distribution of scores derived from magnitude and phase data.*

Results and Conclusion

The distributions of registration values determined by DW-PACE as well as the residual registration values are shown in Figure 1. Maximum absolute translations per TR determined by DW-PACE were 0.72 mm, 0.42 mm, and 0.74 mm for x, y, and z-axis, respectively. Maximum absolute rotations per TR determined by DW-PACE were 0.56°, 1.36°, and 1.79° for x, y, and z-axis, respectively. Maximum absolute residual translations determined by AFNI were 0.36 mm, 0.21 mm, and 0.34 mm for x, y, and z-axis, respectively. Maximum absolute residual rotations determined by AFNI were 0.35°, 0.69°, and 0.76° for x, y, and z-axis, respectively. Figure 2 shows the distribution of scores as derived from the magnitude and phase data. There were only 61 scores derived from the magnitude data compared to 32195 scores from the phase data indicating that there were few incidences of fast bulk motion. The remaining images were not scored because there were either not enough pixels above the 5% background threshold in the magnitude data or the estimated slope of the phase in the phase data was not above the phase slope threshold of 0.3.

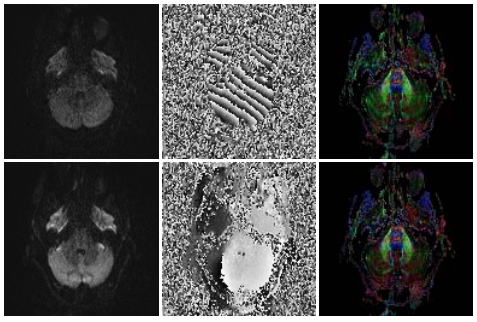

***Figure 3**: Effect of fast bulk motion on magnitude (left column), phase (middle column), and color-coded FA images (right column) before (top row) and after reacquisition (bottom row).*

Figure 3 shows an example of a fast bulk motion artifact: magnitude data shows signal attenuation, phase data shows rapid 2π phase transitions, and color-coded FA image shows erroneous greenish tint. Reacquired images are free of these artifacts. Reacquisition has also proven useful in data sets affected by spike related artifacts as shown in Figure 4. The reacquired images do not show the artifacts.

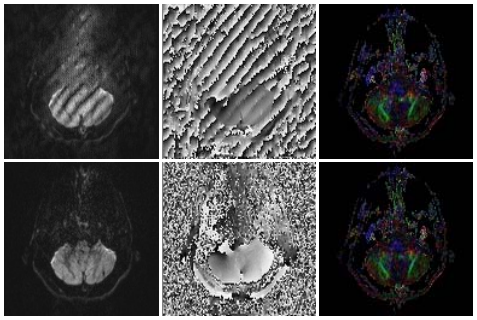

***Figure 4**: Effect of spike artifact on magnitude (left column), phase (middle column), and color-coded FA images (right column) before (top row) and after reacquisition (bottom row).*

DW-PACE worked well in all subjects. The co-registration values determined by DW-PACE were small i.e. subjects held still during most of the scan duration. Residual co-registration values were small indicating a good performance of DW-PACE.

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