Diffusion imaging with prospective motion correction and reacquisition

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Introduction

MR diffusion data is often affected by subject motion. This leads to mis-registration of the volumes from different diffusion gradient directions and signal dropout artifacts in individual images. Without correction, these errors cause blurring and edge artifacts as well as erroneous values of the derived images e.g. fractional anisotropy (FA). While motion without signal dropout artifacts can be corrected retrospectively, data affected by signal dropouts is typically lost and therefore leads to reduced SNR or biased results. We propose a method that includes prospective motion correction as well as reacquisition of image data affected by motion.

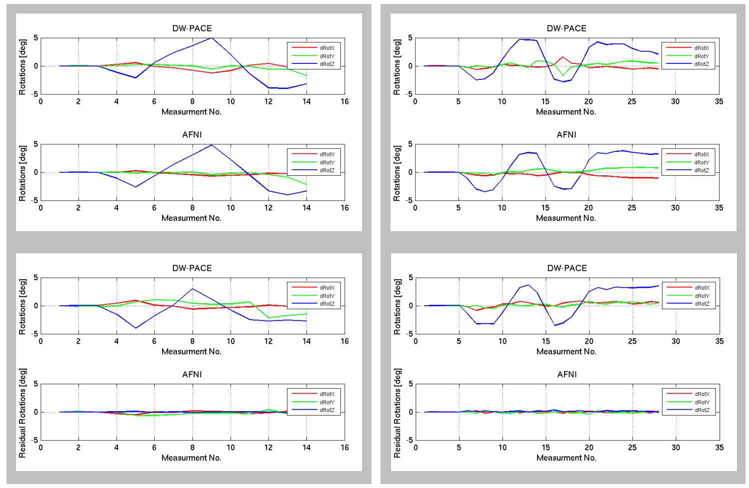

***Figure 1**: DW-PACE and AFNI rotational motion from experiments 1 (left) & 2 (right) and c (top) & d (bottom). With DW-PACE enabled (d) only residual motion is shown.*

Methods

A modified DTI sequence was implemented that includes motion correction and reacquisitions at the end of the normal scan. Prospective motion correction was based on PACE [1] but modified to use separate reference volumes for each b-value used in the scan protocol (DW-PACE). DW-PACE ensures that the diffusion gradients are applied in the proper frame relative to the subject in the presence of subject motion. The number of reacquisitions can be controlled freely as a percentage of the normal scan time. Signal dropout artifacts are determined in a two-step process: first, changes in the magnitude data for each slice from volume to volume are detected and result in a score with range 1.0 to 2.0; second, the phase data of any slice that is considered not affected in the magnitude data is used to calculate a second score with range 0.0 to 1.0. All scores are immediately fed back from the image reconstruction to the scanner control. At the end of the normal scan the selected percentage of images with the highest scores are reacquired. Image reconstruction is then performed on the original acquisition data as well as on a second set of data where the affected images have been replaced by the reacquired ones.

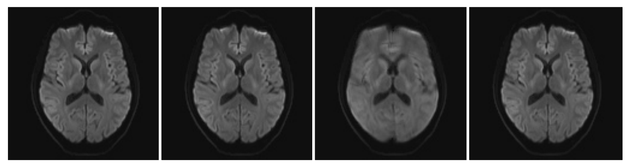

***Figure 2**: Trace-weighted images from experiments 1a-d. Note blurring in experiment c with subject motion and without motion correction.*

All experiments were performed on a 3 T TimTrio (Siemens, Erlangen, Germany) using a 32-channel head coil. Two sets of experiments were performed. To test the effect of subject motion without causing signal dropout, scans included a delay of 1 s per TR during which the subject was instructed to move the head about the z-axis. For the second set of experiments the subject was instructed to move the head during the acquisition to cause mis-registration as well as signal dropout artifacts. In each set, four different scenarios were tested: a) no motion & no correction, b) no motion & correction, c) motion & no correction, and d) motion & correction, where "correction" implies DW-PACE and reacquisition. The following acquisition parameters were used for the first set: TR 4 s, TR delay 1 s, TE 89 ms, FoV 220 mm, 23 slices, 5 mm slice thickness, 1 mm gap, matrix size 128, acceleration factor 2 using GRAPPA [2], 2 non diffusion-weighted volumes, 12 diffusion gradient directions, b-value 1000 s/mm^2; for the second set: TR 5.4 s, no TR delay, TE 79 ms, FoV 200 mm, 49 slices, 2.5 mm slice thickness, no gap, matrix size 80, acceleration factor 2 using GRAPPA, 4 non diffusion-weighted volumes, 24 diffusion gradient directions, b-value 700 s/mm^2, reacquisitions 10% i.e. a maximum of 137 images. To ensure the same slice prescription relative to the head position at the start of each scan, auto-align [3,4] scans were performed. Motion correction values as determined with PACE were compared to retrospective motion correction using AFNI [5].

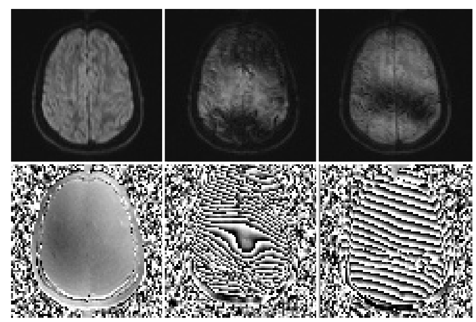

***Figure 3**: Examples of magnitude (top) and phase (bottom) images without (left) and with (middle & right) detected subject motion.*

Results and Conclusion

Both experiments showed that motion correction works reliably. Motion correction values estimated by DW-PACE are comparable to those found during post-processing using AFNI. Remaining detected motion after PACE motion correction is small (Fig. 1). In experiments with subject motion and without prospective motion correction, blurring is visible in the calculated diffusion maps (Fig. 2).
Motion detection worked well to identify images affected by subject motion (Fig. 3). Without reacquisition, artifacts are clearly visible in the diffusion maps. After replacing affected images by the reacquired images the resulting diffusion maps were comparable to these calculated from the scans without motion (Fig. 4). In conclusion, the proposed method allows online calculation of diffusion maps in the presence of substantial subject motion at the cost of only slightly increased scan time.

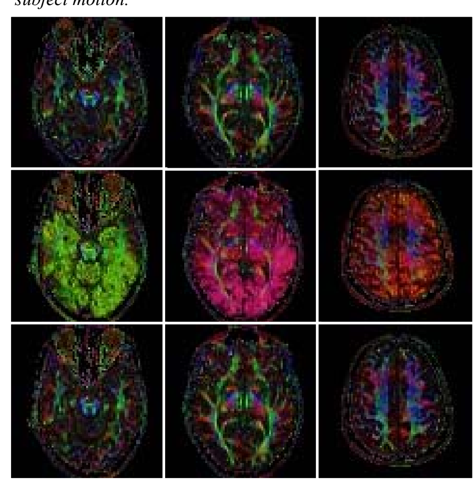

***Figure 4**: Color coded FA images from exp. 2a (top row) and 2d (middle row: data without reacquisition; bottom row: data with reacquisition).*

Acknowledgments

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References

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