Adaptive Combination of Phased Array Signals for Diffusion Imaging

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Introduction

Diffusion-weighted MR images (DWI) typically exhibit low SNR due to the diffusion gradients, which are applied during image acquisition. This effect is pronounced at low field strength, when using high b-values or high spatial resolution. Higher field strength and phased array coils can be used to regain SNR. The use of phased array coils has the additional benefit of enabling parallel imaging techniques such as sensitivity encoding (SENSE) [1] or generalized auto-calibrating partially parallel acquisitions (GRAPPA) [2] for increased imaging speed and reduced susceptibility distortion artifacts. However, combination of signals from the coil elements is typically performed as sum-of-squares (SoS), which is near optimal only in the case of high SNR.

In this study, we present the advantages of an alternative reconstruction method based on matched filtering [3] here called adaptive combination (AC) for tractography in low SNR imaging conditions.

Methods

Imaging was done on a 1.5 T MR scanner (Siemens Avanto, Siemens Medical Solutions, Erlangen, Germany) using a custom-made 23-channel head array coil [4]. Two EPI DTI scans were performed, the first using the sum-of-squares approach, the second using the adaptive combination approach. The imaging parameters were as follows: TR = 6.3 s, TE = 97 ms, 36 slices, matrix size 208x208, 208 mm FoV, 1.0 mm slice thickness without gap, bandwidth 1046 Hz/Px, 10 non-diffusion-weighted and 60 diffusion-weighted images with a b-value of 700 s/mm^2, acceleration factor 2 using GRAPPA, scan time 7:27 min:s. Two volunteers were scanned at the same slice locations using auto-align [5]. Additionally, two series of 30 non-diffusion-weighted images were acquired with SoS and AC reconstruction method, respectively, on a spherical water phantom for SNR measurements according to [6].

For each subject, a background mask was created from the mean non-diffusion-weighted AC volume and applied to SoS and AC data sets. This was done to eliminate spurious background tracts. After tensor calculation, whole volume fiber tracking was performed on the acquired slab i.e. seed points were planted in every voxel not excluded by the mask. The tracts within several length ranges were counted. Tracts with a length of less than 3 mm were excluded from analysis because they mostly represent spurious fibers. Fiber tracking results were visually checked for artifacts and outlying tracts.

Results and Conclusion

Contrast-to-noise in the middle of the phantom was higher when using AC reconstruction compared to SoS reconstruction (Figure 1). Background signal intensity (SI) level in the SoS images was noticeably higher than in the AC images (Figure 2). This applies to non-diffusion-weighted and diffusion-weighted images. Images for subject 2 looked comparable. An increase in the number of fibers was found when using AC (Table 1). An example of fiber tracking for both methods shows the larger number of tracks found using the AC data (Figure 3). While it could be argued that amplification of noise signal in the dark areas of SoS images is diagnostically irrelevant because only voxels with an SNR above 20 are considered useful, we found that the reduction of such noise is important for image processing methods such as tractography.

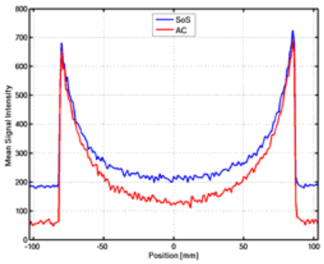

***Figure 1**: Mean signal intensity (SI) over 30 images for middle line through spherical water phantom for SoS and AC reconstructions, respectively. Background noise SI is higher for SoS reconstruction. SI of SoS reconstruction in the middle of the phantom nearly reaches noise floor whereas SI of AC reconstruction does not reach noise floor.*

***Table 1**: Number of fibers found for each length range [mm].*

	Subject1			Subject2		
Length	SoS	AC	Ratio	SoS	AC	Ratio
03-10	192888	193167	1.0	194622	188534	1.0
11-20	63451	68658	1.1	69965	77679	1.1
21-30	20125	24584	1.2	24270	32661	1.3
31-40	5118	7300	1.4	7653	11979	1.6
41-50	716	1788	2.5	2795	5339	1.9
51-60	151	586	3.9	1049	2131	2.0
61-70	41	149	3.6	338	896	2.7

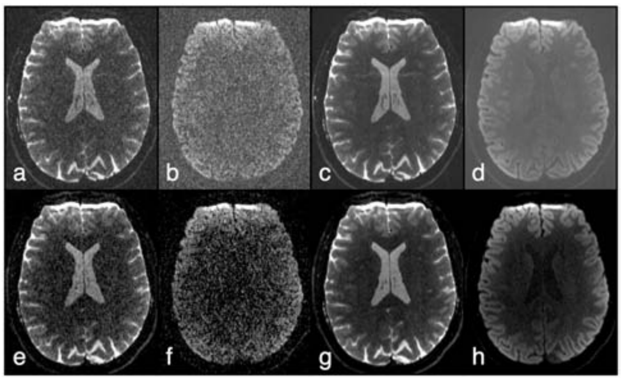

***Figure 2**: SoS scan (top row) and AC scan (bottom row) of subject 1. Non-DWI (a, e), DWI. (b, f), mean non-DWI (c, g) and mean DWI images (d, h). Signal intensities (SI) are adjusted to the maximum of the corresponding SoS image.*

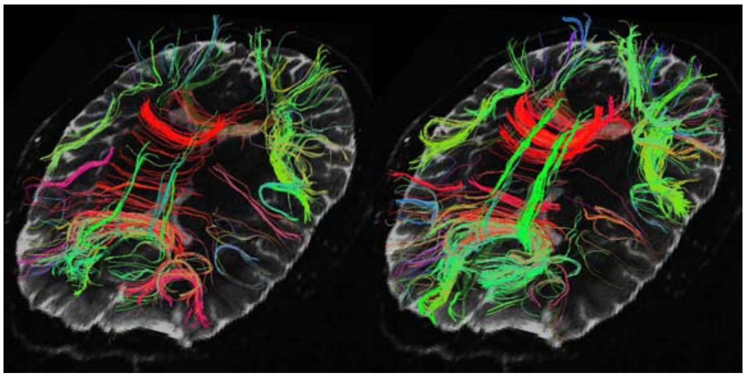

***Figure 3**: Fiber tracking result for subject 1 using SoS (left) and AC (right) data. Shown are all fibers with a length greater than 40 mm. The AC reconstruction results in a larger number of fibers which is noticeable e.g. in the cingulum fiber bundles.*

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References

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