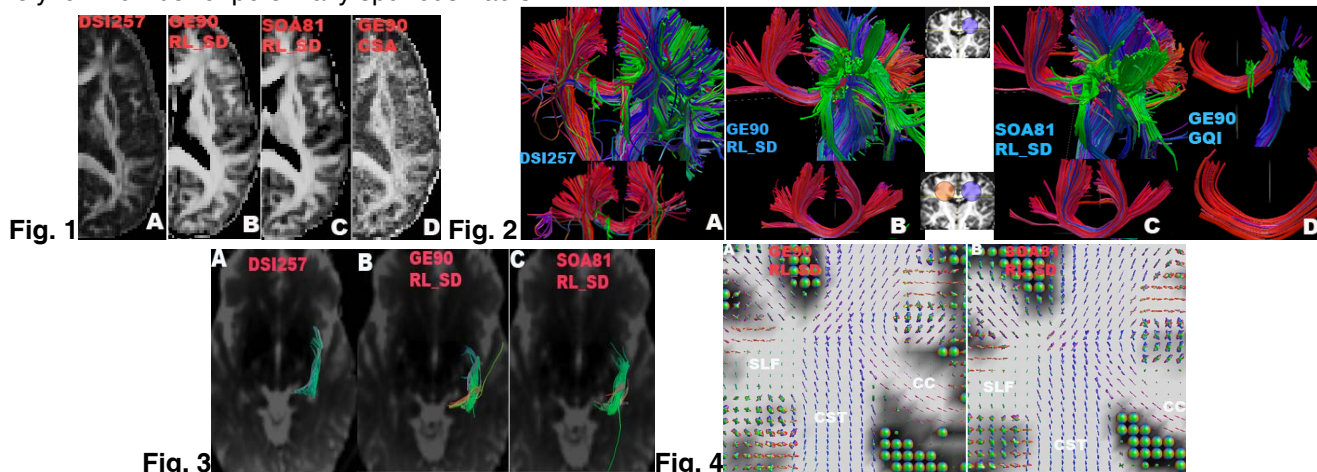


Tractography of Richardson-Lucy Spherical Deconvolution under Rician noise of Sparse Multiple q-shell Diffusion Imaging

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Introduction: Spherical deconvolution (SD) methods have demonstrated promising results to recover the fiber orientation distribution (FOD) from high angular resolution diffusion imaging (HARDI) data [1]. Notably, a recent variant of the Richardson-Lucy (RL) SD algorithm [2] has been shown efficient in the low and medium SNR range [3]. The novelties introduced in this new methodology [3] are: (1) it is based on the assumption that the noise follows a Rician distribution, as is expected in real data and (2) prior information about the underlying spatial structure of the fiber bundles is introduced in the form of a total variation regularization term. Remarkably, recent studies have shown that only 20-30 measurements optimally spread on several b-value shells [4,5,6,7] are sufficient to characterize the diffusion signal, which significantly shortens scan time for HARDI acquisition. However, the impact of these sampling schemes on SD methods has not yet investigated. To achieve that aim, we evaluate the performance of the **RL-SD** implementation [3] on HARDI human brain data acquired on multiple q-shell using sparse optimal acquisition (**SOA**) [1] and uniform coverage on the sphere based on a novel generalization of electrostatic (**GE**) repulsion [2]. The scan time for these sequences is less than 15 minutes to be suitable for clinical settings. We qualitatively compare the results against other state-of-the-art methods including diffusion spectrum imaging (**DSI**) [8], generalized Q-ball imaging (**GQI**) [9] and constant solid angle (**CSA**) QBI [10]. **Methods:** Two sets of HARDI data, including SOA81 directions (9 shells with 9 directions in each shell, $b_{max}=3000$ s/mm²) and GE90 directions (3 shells with 30 directions uniformly distributed in each shell and $b=1000, 2000,$ and 3000 s/mm²), as well as DSI257 ($b_{max}=4000$ s/mm², half-hemispheric, 257 directions) were acquired on a healthy volunteer using a 3T GE MR750 clinical scanner with 32 coils. For the RL_SD reconstruction the dictionary of diffusion signal was created imposing a set of diffusion tensors with diffusivities equal to $[1.4; 0.4; 0.4] \times 10^{-3}$ mm²/s and oriented along with 724 spatial directions on the sphere. Two additional isotropic terms to account for intra- and extra-axonal diffusion were included. We evaluated the quality of generalized fractional anisotropy (GFA) maps and reconstructed tractograms, including the crossing complex fibers at the junction of the bodies of corpus callosum (CC), superior longitudinal fasciculus (SLF), corticospinal tracts (CST), and dorsal cingulum bundles; and the auditory pathways interconnecting medial geniculate nuclei of thalamus and primary auditory cortex, where diffusion tensor imaging usually fails. **Results and Discussion:** Fig. 1. shows the GFA reconstructed using DSI257 (A), RL_SD on GE90 (B) and SOA81 (C) and CSA on GE90 (D), demonstrating RL_SD created sharper delineation between WM, GM and CSF than CSA and DSI. Fig. 2 shows the tractograms of the crossing fibers at the junction of CC, SLF and CST (purple seed in the center of top panel) and the fibers of the bodies of CC (bottom panel) by placing another ROI (yellow sphere in the bottom) and filtering. LR_SD perform similarly on GE90 (B) and SOA81 (C) data and better than GQI (D). LR_SD was relatively inferior to DSI257 (A) (which used about 3 times more data and higher b-values) in delineating some tracts, although it revealed a relatively low number of potentially spurious tracts.



The reconstructed auditory pathways (Fig. 3) were similar among DSI257 (A) and RL_SD on GE90 (B) and SOA81 (C). Fig. 4 shows the FOD reconstructions in a coronal slice with fiber crossings between CC, CST and SLF. The background image is the GFA map. The FOD reconstructions using different sampling schemes were very similar. In summary, the results suggest the new RL_SD technique performs well on sparse multiple q-shell diffusion imaging.

Reference: [1] Parker G.D. et al., *Proc ISMRM* 2012. [2] Dell'acqua F., et al., *Neuroimage* 2010. [3] Canales-Rodríguez E J et al., http://hardi.epfl.ch/static/events/2013_ISBI 2013. [4] Koay et al., *Med Phys.* 2012. [5] Caruyer E, et al., *MRM* 2013. [6] Merlet S. et al., *Medical Image Analysis* 2013. [7] Merlet S. et al., *Medical Image Analysis* 2013. [8] Wedeen et al., *MRM* 2005. [9] Yeh F-C et al., *IEEE TME* 2010. [10] Aganj I et al. *MRM* 2010.