A head motion correction algorithm for arbitrary q-space sampling schemes with high b-values

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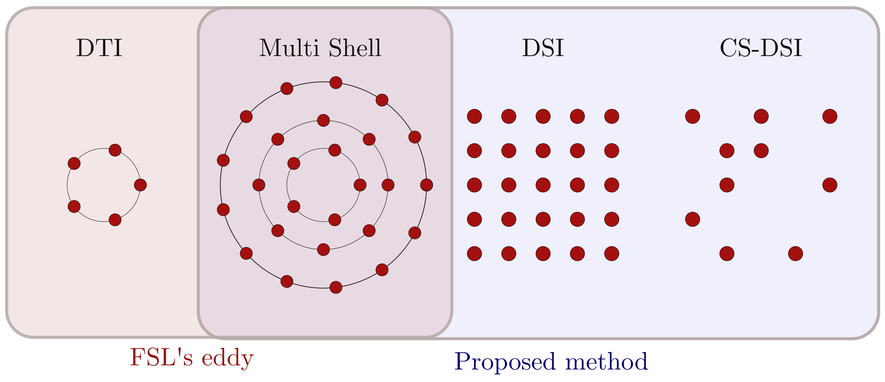
Head motion correction methods are not available for all sampling schemes

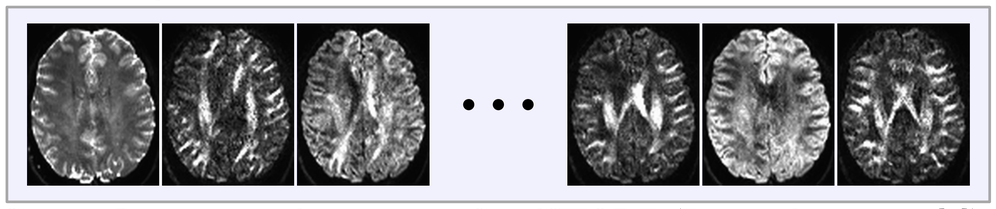


Diffusion-weighted MR images have different contrast depending on the q-space sample. Head motion correction requires a reference image. Reference images for DWIs are generated by models of the diffusion process. FSL's eddy [1] uses a Gaussian Process to this end, based on angular similarity of samples from the same shell.

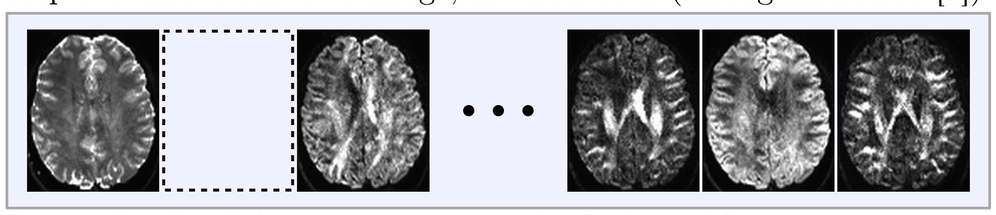
We propose using the 3dSHORE [2[bases to generate registration targets. Regularized fits to these bases have successfully reconstructed ODFs from Multi Shell, DSI and compressed sensing DSI sampling schemes. We provide an opren source implementation of this "SHORELine" algorithm as a BIDS app.

SHORELine head motion correction

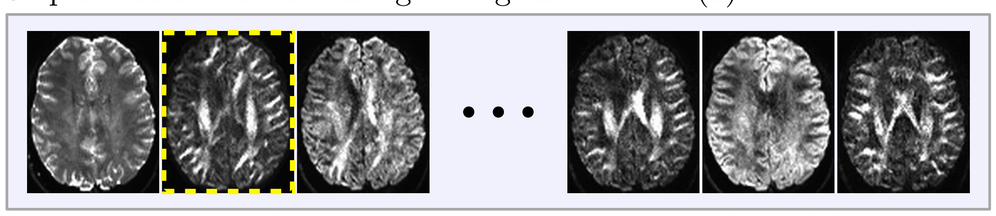
Preliminary: Collect DWI series



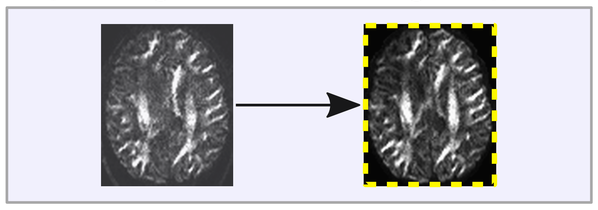
Step 1: Remove one b>0 image, fit 3dSHORE (L2 regularization [2])



Step 2: Predict left-out image using the fit from (1)

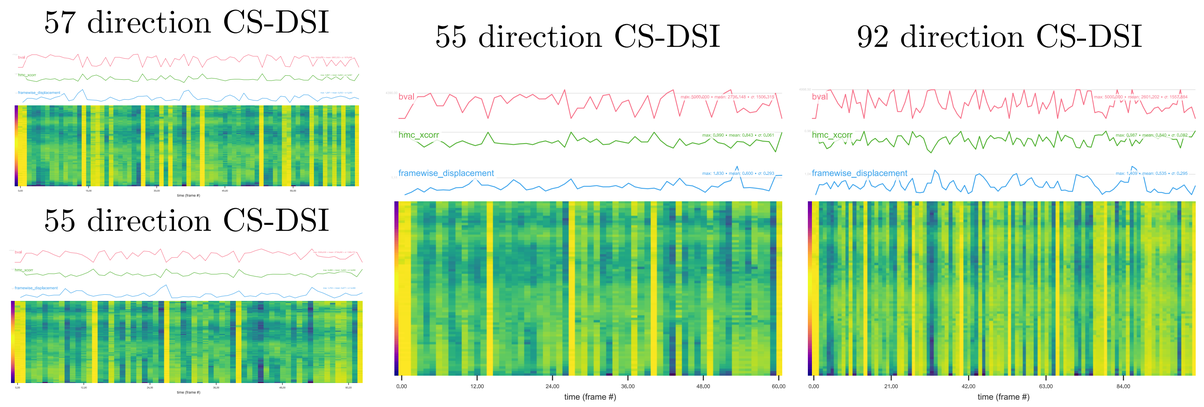


Step 3: Register left-out image to predicted image from (2)

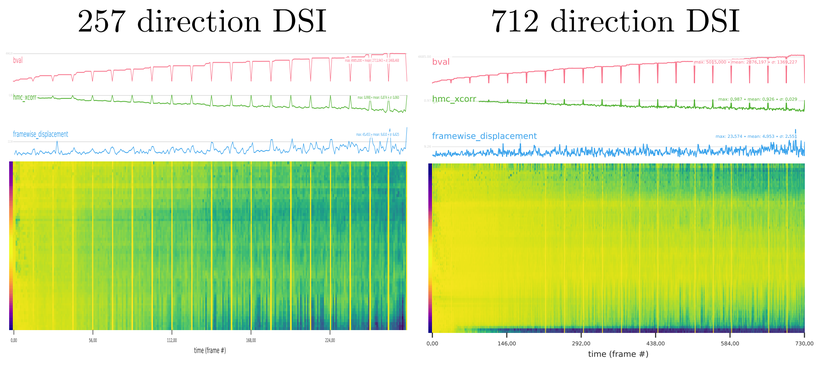


Use transformed image and its rotated gradient vector as input to a new Step 1

Head motion quantification



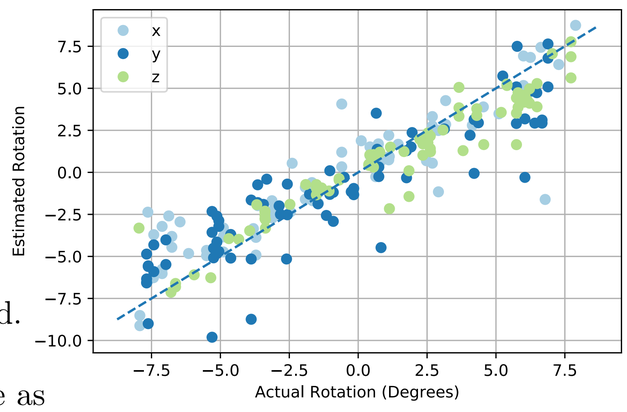
Diagnostic reports for SHORELine runs on different q-space sampling schemes. The red lines depict gradient strength, green lines are whole-brain cross correlation and blue lines are framewise displacement.



The carpetplot depicts per-slice cross correlation values (rows) over time (columns). Values are calculated after transforming the model image and mask into alignment with the uncorrected DWI volume. Slices with few in-brain voxels score the lowest.

Simulation testing

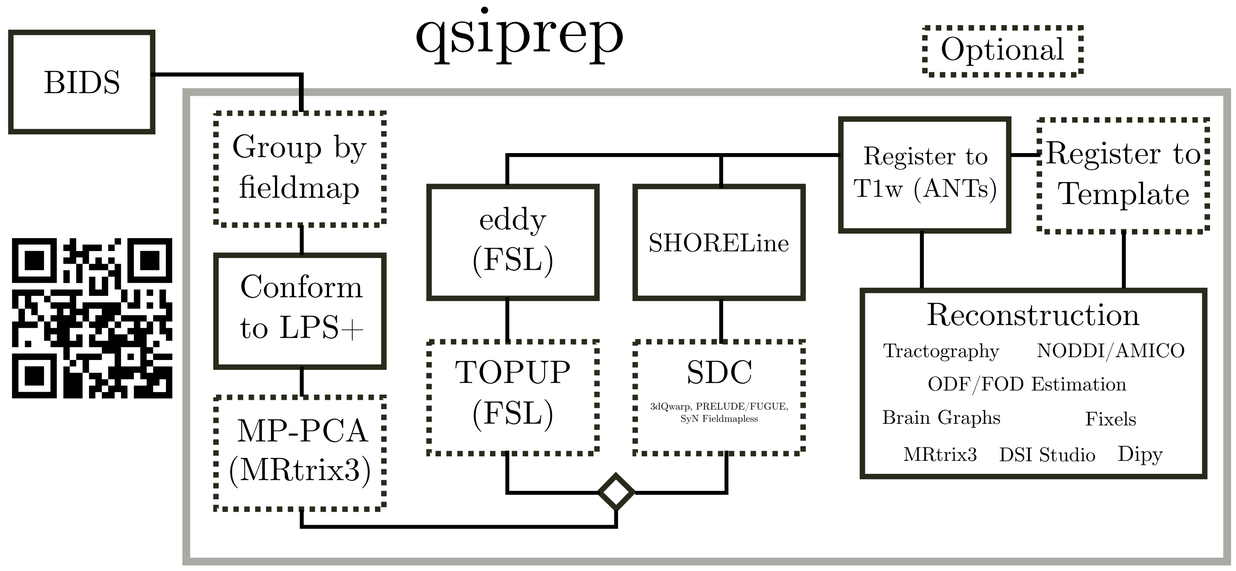
A Software phantom was simulated using FiberFox. The phantom was sampled using the 55-direction CS-DSI sequence. 25% of volumes had the fiber phantom randomly rigidly transformed before the MR image was simulated. The simulated fiber set and sampling grid were the same as those used in [3].



SHORELine on average under-estimated motion by 23% with a mean absolute error of 1.3 degrees.

Software Implementation

SHORELine is implemented in `qsiprep`, a BIDS app. In addition to SHORELine, qsiprep includes many useful dMRI preprocessing tools from MRtrix, Dipy, DSI Studio and BrainSuite. ODF/FOD reconstruction, fiber tracking and scalar estimation are also available.



References

[1] Jesper L.R. Andersson and Stamatios N. Sotiropoulos. Non-parametric representation and prediction of single- and multi-shell diffusion-weighted MRI data using Gaussian processes. NeuroImage, 122:166-176, 2015.
[2] Merlet S. et al., "Continuous diffusion signal, EAP and ODF estimation via Compressive Sensing in diffusion MRI", Medical Image Analysis, 2013.
[3] Maier-Hein, K. H., Neher, P. F., Houde, J. C., Côté, M. A., Garyfallidis, E., Zhong, J., ... & Reddick, W. E. (2017). The challenge of mapping the human connectome based on diffusion tractography. Nature communications, 8(1), 1349.