Common-Information enhanced SPIRiT for high resolution VDS DWI reconstruction

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TARGET AUDIENCE: Researchers and clinicians interested in high resolution DWI/DTI

PURPOSE: Multi-shot variable density spiral (VDS) technique [1] has shown its capability for high resolution DWI. However, it requires long scan time especially in diffusion tensor imaging (DTI) which acquires a series of images of different diffusion directions. Parallel imaging using simultaneous phase correction and SENSE reconstruction (CG-SENSE) [2] has been proposed to reconstruct DW images from partially acquired data. However, acceleration, i.e. reduction factor, is limited by SNR penalty. When multiple diffusion directions are acquired, besides anisotropic diffusion resulting from restricting cellular structures, there also exist components of isotropic diffusion in regions with light directional constraints. Therefore, different diffusion encoding provides similar signal levels in such regions. For image reconstruction, this common information among different directions should be sharable to increase the image SNR. In this study, we propose to use common information to optimize sampling trajectory and enhance image reconstruction.

METHODS: A shifted interleaved acquisition scheme is proposed to provide complementary information for reconstruction. SPIRiT [3] is used as a specific reconstruction example in our implementation. Hence, the method is called Common-Information enhanced SPIRiT (CI-SPIRiT).

(1) *Shifted Interleaved acquisition*

To maximize the information from all acquisitions, a novel interleaved acquisition scheme is used: adjacent diffusion directions, which are complementary in k-space can be combined to generate a synergistic fully sampled or oversampled k-space. Fig. 1 illustrates this idea with a specific example.

(2) *CI-SPIRiT Reconstruction*

The reconstruction method, CI-SPIRiT, includes preprocess, data sharing reconstruction and iterative reconstruction, as shown in Fig. 2. Firstly, the partially acquired k-space data are preprocessed for each direction individually using simultaneous phase correction and SPIRiT reconstruction, such that the phase errors among different shots are eliminated and an expanded full k-space center is reconstructed by SPIRiT. Secondly, Image Ratio Constrained Reconstruction (IRCR) [4], a data sharing method, is used to generate the initial reconstruction of each direction, interpreted by the dashed box in Fig. 2. Specifically, the full center k-space reconstructed in previous step is used to generate I_n^{low}, and the synergistic full k-space from adjacent directions is used to generate I_C^{low} and I_C^{high}. Using the accurate initialization by IRCR, SPIRiT is then used to generate the final reconstruction iteratively.

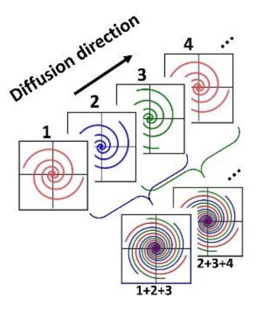

Fig. 1 An example of shifted interleaved acquisition for VDS DTI. The numbers and colors denote diffusion directions

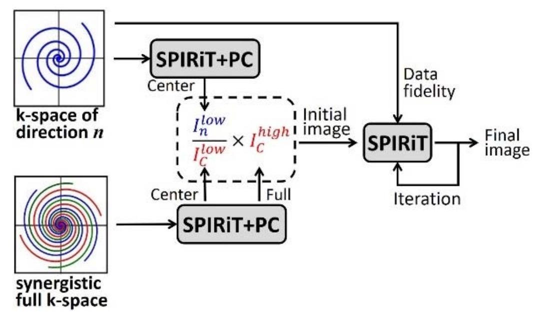

Fig. 2 CI-SPIRiT. 1) SPRiT and Phase correction (PC); 2) IRCR using low resolution images I_n^{low} and I_C^{low} from k-space center and high resolution image I_C^{high}, where '*c*' denotes synergistic k-space. 3) Iterative reconstruction using SPIRiT.

Fully sampled *in vivo* brain VDS DTI data were acquired on a Philips 3T scanner using an 8-channel head coil, with shot number=18, α=4, TE/TR=70/2000ms, FOV=220×220mm^2, spatial resolution=0.86×0.86mm^2, slice thickness=4mm, *b*-value=1000s/mm^2, diffusion directions=6, NSA=2. The acquired data were artificially undersampled using interleaved acquisition scheme with different reduction factors (3, 4 and 6), and then reconstructed using three methods, CG-SENSE, SPIRiT and CI-SPIRiT. After that, FA maps were calculated accordingly for all the methods.

RESULTS AND DISCUSSION: The reconstructed FA maps from undersampled data (R=4) using three methods are shown in Fig. 3. Compared to CG-SENSE, SPIRiT and CI-SPIRiT preserve detailed structures better (white arrows). Furthermore, CI-SPIRiT shows higher SNR than SPIRiT alone. NRMSE for different undersampling are shown in Fig. 4. Again, CI-SPIRiT presents lowest NRMSE. One obvious concern about this method is that the reconstruction may be vulnerable to inter-direction motion. However, the inherent navigator provide by VDS may relieve this problem through iterative calculation. Here we only used VDS DTI as a demonstration example, the proposed method is extendable to other diffusion imaging techniques.

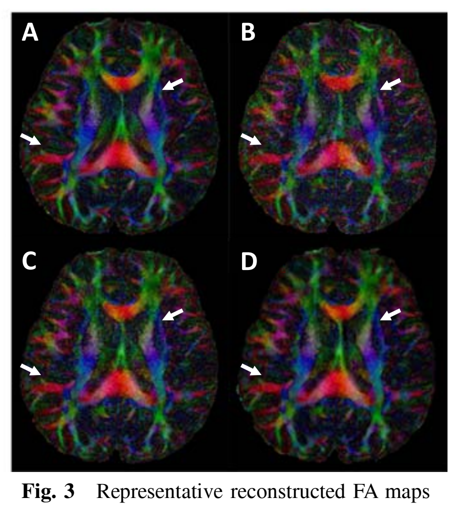

Fig. 3 Representative reconstructed FA maps using R=4. A) Fullsampled B) CG-SENSE C) SPIRiT D) CI-SPIRiT

CONCLUSION: Preliminary results using VDS DWI shows that CI-SPIRiT improves data sampling efficiency and image quality, especially in high resolution imaging.

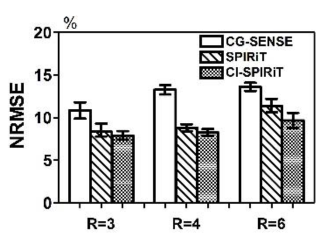

Fig. 4 Mean NRMSE of reconstructed DW images in all directions using three methods

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