

POCS-ICE: POCS based Inherent Correction of phase Errors for multi-shot spiral DWI

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

PURPOSE: SENSE self-navigating strategy [1, 2] has been proposed for inherent motion correction in multi-shot DWI without navigator echo acquisition, using either EPI or spiral technique. Since the motion induced phase errors are estimated from data of each shot using SENSE, the shot number, equivalent to the acceleration factor, is limited by the element number of phased array coil used. Consequently, its capability of improving spatial resolution and shortening readout duration is compromised. This work aims to develop a new reconstruction method to improve the image quality of high resolution spiral DWI without extra navigator acquisition, using a relatively large shot number.

METHODS: Projections onto convex sets (POCS) based Inherent Correction for motion-induced phase Errors (POCS-ICE) is proposed for multi-shot spiral DWI.

POCS-ICE consists of four steps: POCS operation, channel combination, shot average and phase recovery, as illustrated in Fig. 1. Step 1 is POCS operation interpreted by the right box of Fig. 1; Step 2 is channel combination using a SNR optimal reconstruction. The first two steps are similar to POCSENSE [3], but here they are executed for each shot. In Step 3, images of different shots are averaged after removing their low-resolution phase to improve SNR. To be noted, the low-resolution phase includes motion induced phase errors which are different from shot to shot and thus should be removed before averaging. In Step 4, the complete phase of each shot is recovered by multiplying its low resolution phase, to get new estimation for the next iteration. The whole process automatically eliminates phase errors during iteration.

In vivo brain DWI data using spiral without navigator were acquired on a Philips 3T scanner. Two experiments (A and B) were carried out using either 8-channel or 32-channel head coil. The imaging parameters are shown below.

A. 8 channels, 8 shots, TE/TR=46/2900ms, FOV=210×210mm², resolution=0.86×0.86mm², slice thickness=3mm, *b*-value=800s/mm², directions=15, NSA=3, readout duration=30ms.

B. 32 channels, 12 shots, TE/TR=49/2500ms, FOV=220×220mm², resolution=0.9×0.9mm², slice thickness=4mm, *b*-value=1000s/mm², directions=6, NSA=2, readout duration=18ms.

The acquired data were reconstructed using two methods, SENSE+CG [2] and POCS-ICE. Auto-linear off-resonance correction without field maps [4] was taken to reduce blurring artifacts. Fractional anisotropy (FA) maps were calculated from these DTI images.

RESULTS AND DISCUSSION: Representative results of the two experiments are shown in Fig. 2 and Fig. 3 respectively. In experiment A, POCS-ICE shows higher SNR and also presents less aliasing artifacts in both DW images and FA maps. Those artifacts are mainly caused by inaccurate phase error estimation from the 1st step of SENSE+CG, since large acceleration factors are used. The same superiority of POCS-ICE can also be observed in experiment B. Moreover, in experiment B, corona radiata can be seen more clearly in POCS-ICE result (pointed by the white arrows in zoomed FA maps). The two experiments verify that POCS-ICE outperforms SENSE+CG when a large shot number is used. However, POCS-ICE takes more iterations than SENSE+CG (~80 vs. ~20 here) because of the slow convergence of POCS algorithm. Better constraints should facilitate the convergence speed.

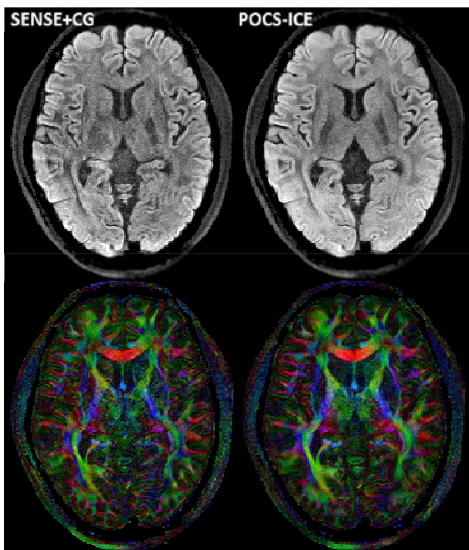
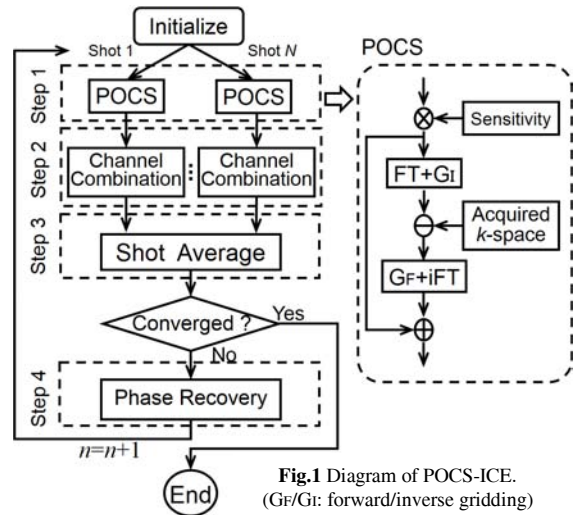


Fig. 2 DW image and FA maps of experiment A, 8 shots were acquired using 8 channels.

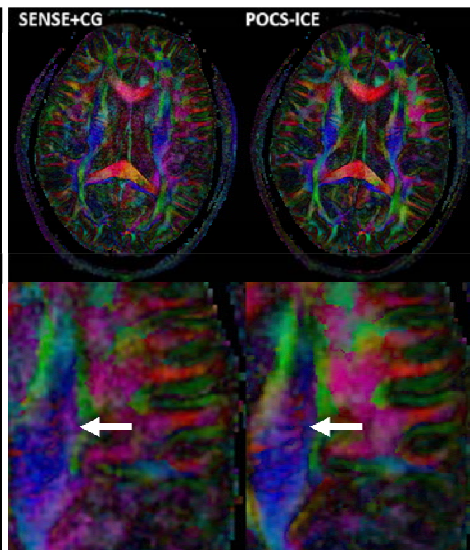


Fig. 3 FA maps of experiment B, 12 shots were acquired using 32 channels. Arrows show corona radiata.

CONCLUSION: POCS-ICE is proposed for the reconstruction of multi-shot spiral DWI without navigator echoes. *In vivo* experiments show that it can generate high quality DWI images using relatively large shot number, such that readout duration is shortened and high spatial resolution can be achieved.

Future work can include combining POCS-ICE with parallel imaging to reduce scan time and adding in appropriate constraints to accelerate reconstruction.

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