Retrospective Rigid Body Motion Correction of Interleaved Slice-Selective Acquisitions

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Target Audience: Researchers interested in image reconstruction and motion correction.

Purpose: Retrospective motion correction of slice-selective acquisitions is challenging in the presence of through-plane motion because each interleave of a 2D slice readout contains information from different locations along the slice-dimension. This renders a slice-by-slice reconstruction unfeasible. Thus far, motion correction of slice-selective acquisitions has been limited to in-plane-only correction of interleaved acquisitions [1] or in- and through-plane correction of single-interleave acquisitions [2]. Here, we describe a generalized reconstruction of interleaved slice-selective acquisitions in the presence of in- and through-plane motion, which is a substantial extension to [1, 2].

Methods: • *Reconstruction:* Through-plane motion in a slice-selective acquisition causes the acquired data to contain information from multiple slices. Thus, one must use all the k-space data from all slices simultaneously to reconstruct a full 3D volume. We propose an iterative SENSE-like approach [3] (**Fig. 1**). Notice, the slice-selection profile is similar to coil sensitivity profile. Specifically, just like the effect of coil sensitivity profiles of a multi-channel receiver coil, the slice selection profiles get multiplied by the image to reduce the field-of-view and decrease scan time. Similar to [1], the slice-select profiles and k-space trajectories were counter-rotated and counter-translated according to the detected motion to reflect the "actual" slice selection and readout in the patient frame of reference (**Fig. 1**). Thereafter, all the data from all slices was used in a conjugate-gradient-based iterative reconstruction scheme to reconstruct a full 3D volume (**Fig. 1**). Specifically, for each iteration, these steps were applied: **1)** The 3D volume was multiplied by the motion-corrected slice profiles. **2)** The images were 3D Fourier transformed, and gridded onto the 3D motion-corrected k-space trajectory. **3)** The resulting k-space data was gridded to Cartesian, followed by inverse Fourier transformation to image space. **4)** The previous 3 steps were repeated for all interleaves/slices/NEX, and the resulting image volumes were summed up, put through the conjugate-gradient optimizer to obtain the next volume in the iteration. • *Simulations:* Simulations were carried out using a 3D-SPRG brain image. Data were simulated using a 4-interleave spiral sequence, 128x128 in-plane resolution, 128 slices, NEX=4. For each interleave/slice/NEX, the volume was randomly rotated in the through-plane direction with a range of ±20°. For the purpose of showing the effects of through-plane motion, only through-plane rotations were simulated. The volumes were reconstructed using both the traditional gridding and the proposed iterative method.

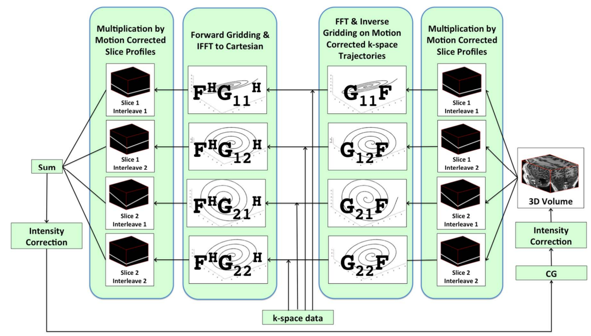

Figure 1 Iterative conjugate-gradient based reconstruction to correct through plane motion in a slice-selective interleaved acquisition. The method is very similar to iterative SENSE where coil sensitivities are replaced by 3D slice profiles. **G** and **F** refer to gridding and Fourier Transformation, respectively.

Results: The results are shown in **Fig. 2**. Axial, coronal, and sagittal slices are shown for the original, the motion-corrupted, and the motion-corrected datasets. Without motion correction, the through-plane motion resulted in significant motion artifacts (**Figs. 2 d,e,f**). The proposed correction scheme removed most of the motion artifacts (**Figs. 2 g,h,i**). The remaining artifacts on the motion-corrected images were due to the amplitude modulation introduced by the rotated slice-selection profiles and due to the undersampling caused by motion.

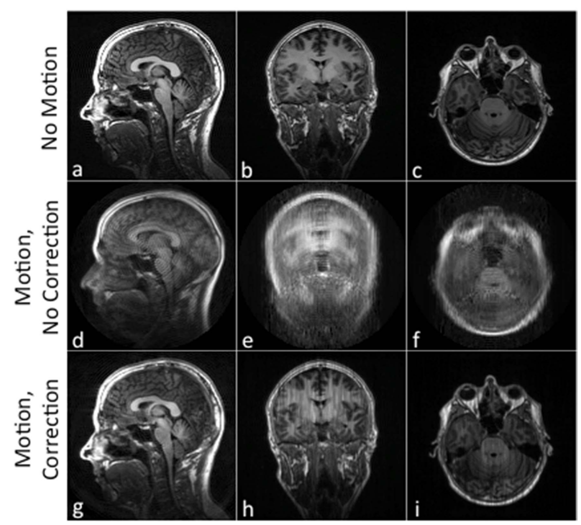

Figure 2 Results of motion simulations using a 3D SPGR in-vivo dataset. Without correction, motion artifacts are visible (d,e,f). After the proposed correction, these artifacts are significantly removed (g,h,i). The remaining artifacts are due to the amplitude modulation introduced by the rotated slice-selection profiles and due to the undersampling caused by motion. No spin history effects were simulated in this case.

Discussion: Results show that it is possible to correct for through-plane motion in a slice-selective interleaved acquisition. It must be noted that the slice profiles need to be measured using a separate calibration scan for his approach to work. Potential limitations: 1. Counter rotation results in undersampling in image space such that some parts of the volume are not sampled. – Multiple acquisitions (NEX) are required to mitigate the undersampling [2]. 2. Spin history effects (i.e., re-excitation of already excited spins due to motion) cannot be corrected. – If motion is assumed to be small and rescanning is allowed, spin-history effects can be prevented up to a certain degree. 3. Future work will investigate the robustness of this algorithm in the case of thicker slices and anisotropic voxels.

Conclusion: An iterative method aimed at correcting through-plane motion in a slice-selective interleaved acquisition was introduced and demonstrated substantial improvements in image quality.

References: [1] Bammer et al, MRM, 2007 [2] Jiang et al, IEEE Trans Med Imag, 2007 [3] Pruessmann et al, MRM, 2001. Acknowledgements: NIH (2R01 EB00271108-A1, 5RO1 EB008706, 5R01 EB01165402-02), the Center of Advanced MR Technology at Stanford (P41 EB015891), Lucas Foundation, Oak Foundation, GE Healthcare.