FID-guided retrospective motion correction based on autofocusing

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Target Audience: MR engineers, physicists, and clinicians interested in motion correction.

Introduction

In-vivo magnetic resonance imaging (MRI) is highly susceptible to motion, which can significantly degrade image quality. The aim of this study is to explore the potential of FID navigators (FIDnavs)[1] to guide a recently proposed autofocusing-based blind retrospective motion correction technique[2] to improve both the computational performance and achievable image quality.

Materials and Methods

An FIDnav sampling (64 points in 0.2 ms) was inserted after each non-selective excitation pulse of a standard MPRAGE sequence (TR/TE/α/TA = 2000ms/2.9ms/9°/6:30min, matrix 192x192x128 with isotropic voxel size of 1.3 mm^3). One single FID read-out per TR=2000 ms was used to detect motion and to restrict the retrospective correction to motion events based on the navigator signal changes[1]. After obtaining written consent, three healthy volunteers were scanned at 3T (MAGNETOM Trio Tim, Siemens AG, Germany) using a commercial 12-channel head coil. The subjects were instructed to change their head position five times during each six minute acquisition. Frequently observed motion patterns[3] were employed: translation in head-feet and left-right direction, nodding, and head-shaking. An additional dataset without voluntary motion was acquired for each subject. In total, 14 MPRAGE volumes were acquired of which 11 were motion-corrupted. In addition to the inline reconstruction, all MPRAGE volumes were reconstructed using the recently proposed blind retrospective motion-correction algorithm based on optimization of an image quality metric (entropy of the gradients) with respect to an unknown motion trajectory[1]. The motion degradation was described as a linear process $\mathbf{y}=\mathbf{A}_\Theta \mathbf{Fu}$, with **u** being the uncorrupted image, **y** the observed data, $\mathbf{A}_\Theta$ a rigid-body transformation in the Fourier domain given a chronological set (=trajectory) of unknown motion parameters Θ. In a non-blind version of the algorithm, the FID-signal Ω was used to parameterize the motion trajectory Θ to yield a reduced set of unknowns β by piecewise constant mapping $f: (\beta,\Omega) \rightarrow \Theta$. Given the image metric φ, the optimization problem was defined as: $\beta^*=\text{argmin}_\beta[\varphi(\mathbf{F}^H\mathbf{A}_{f(\beta,\Omega)}\mathbf{y})]$. The corrected image was subsequently found by inverting the motion $\mathbf{u}:=\mathbf{F}^H\mathbf{A}_{f(\beta^*,\Omega)}\mathbf{y}$. Both corrected image sets, blind and FID-guided, were co-registered to the reference image without motion. The mean-squared error (MSE) and structural similarity[4] (SSIM) index were calculated with the non-motion image serving as reference. Moreover, a blinded qualitative per-subject ranking (1=best) and grading (1=good; 2=mild artifacts; 3=major artifacts but clinically useful; 4=very low quality and clinically not useful) of all 3x14 MPRAGE volumes was performed by two experienced observers.

Results and Discussion

Qualitative and quantitative improvements were consistently observed for both blind and FID-guided reconstructions compared to non-corrected data (example see Figure 1). The quantitative metrics, SSIM and MSE, demonstrate the highest similarity between the FID-guided and the uncorrupted volume, followed by the blind reconstruction. The qualitative ratings revealed that the FID-guided approach was ranked first by the first observer in 13 out of 14 scans (second observer: 11). Moreover, the FID-guided reconstructions provided clinically useful images in 70% of the volumes, whereas 40% of the volumes were considered clinically useful after the blind correction and only 20% without any correction. Applied to images without motion, the blind reconstruction introduced slight blurring, which is entirely absent with FID guidance. A further advantage of constraining the motion trajectory using FIDnavs is the computational speed-up by a factor of 1.5 (2mins vs. 3mins). The proposed method is currently limited to rotational motion with magnitudes <=6°; for stronger rotations, the amount of missing k-space data does not allow for artifact-free motion inversion. The reconstructed trajectory of the investigated data shows motion of up to 18 mm of translation and 5° of rotation.

Conclusion

The presented results show the potential of the combination of the two methods: a rapid FIDnav with negligible timing impact can be inserted in virtually any sequence. As shown, these FIDnavs can provide essential information to the retrospective motion correction algorithm. As also the employed retrospective correction is generally independent of the acquisition technique, the presented combination of motion detection and correction offers attractive possibilities for various clinical applications.

Figure. 1 Coronal and sagittal views from different reconstruction methods and two different subjects in comparison as well as mean and standard deviation of the observer quality ratings from all 14 series.

References

[1] Kober et al., 2011, Magn. Reson. Med 66(1):135-43; [2] Loktyushin et al., 2013, Magn. Reson. Med., doi: 10.1002/mrm.24615; [3] Gedamu et al., 2012, Journal of magnetic resonance imaging, 36(2):332–343 [4] Wang et al., 2004, IEEE Transactions on I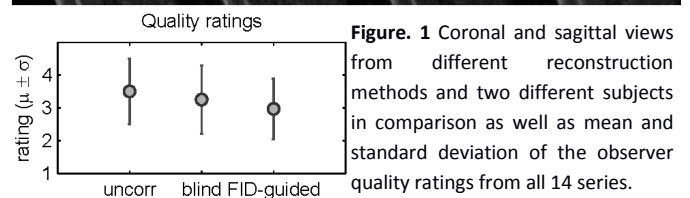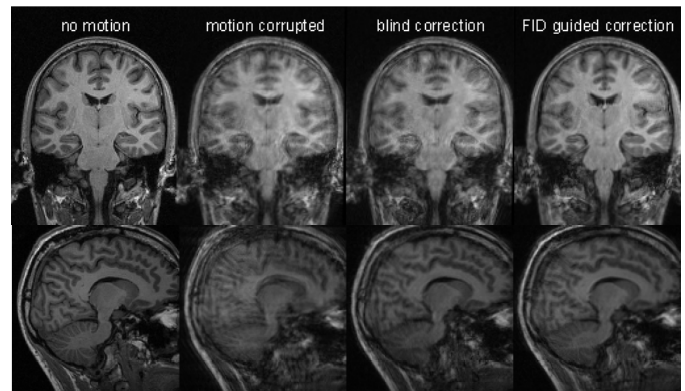mage Processing, 13(4):600-612;