

FID navigator triggered acquisition of imaging navigators for retrospective head motion correction

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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 mitigate motion effects on brain MRI exams. The FIDnavs are employed to monitor motion and, when detected, to trigger the acquisition of a low resolution image navigator volume for co-registration to a reference. Obtained head motion parameters are subsequently used to correct the motion-corrupted MRI retrospectively.

Materials and Methods

An FIDnav was sampled (64 points in 0.2 ms) after an additional non-selective excitation pulse at the end of the GRE block of an MP-RAGE sequence ($T_{\text{FIDnav}} = 1532$ ms, $T_{\text{I}}/T_{\text{R}}/T_{\text{E}}/\alpha/T_{\text{A}} = 900\text{ms}/2300\text{ms}/2.86\text{ms}/9^\circ/9:50\text{min}$, matrix $256 \times 256 \times 176$, 1.0 mm^3 isotropic). The FIDnav signal was used online to monitor motion: exceeding an empirical threshold triggered the acquisition of a low resolution image navigator (IMGnav) in the next repetition. The IMGnav used a recently proposed multi-echo segmented 3D-GRE [2] ($\alpha/T_{\text{A}} = 9^\circ/1.5\text{sec}$, echo-spacing 8.6ms, 10 echoes, matrix $40 \times 48 \times 44$, voxel size $6.5 \times 5.4 \times 5.4 \text{ mm}^3$, bandwidth 4170 Hz/px). Its parameters were designed to acquire a whole-brain volume with very similar properties as the GRE block of the MP-RAGE, specifically with respect to the acoustic noise and its impact on longitudinal magnetization. After obtaining written consent, 3 healthy volunteers were scanned at 3T (Magnetom Trio a Tim System, Siemens AG, Germany) using a commercial 32ch head coil. The subjects were instructed to change their head position five times during a scan following frequently observed motion patterns [3]: translation in head-feet direction (all subjects), nodding (2 subjects), and head-shaking (2 subjects). An additional dataset without voluntary motion was acquired for each subject, resulting in a total of 10 MP-RAGE volumes. The FIDnav monitoring signal was calculated by combining the signals from all coil elements in two different ways, one to detect fast and the other to detect slow head movement:

$$FID_{\text{nav}}^{\text{fast}}(n) = \text{avg max}_{3C} \frac{|\bar{s}(n)| - |\bar{s}(n-1)|}{|\bar{s}(n-1)|}; FID_{\text{nav}}^{\text{slow}}(n) = \text{avg}_c \frac{|\bar{s}(n)| - |\bar{s}(3)|}{|\bar{s}(3)|}.$$

Here, $|\bar{s}(n)|$ is the absolute value of the complex average of all points from one single FID read-out acquired in the n^{th} repetition, and c denotes the coil element. The avg max_{3C} operator takes the FIDnav from those three coil elements where the signal change is maximal and averages them. An empirical threshold of 6% signal change for $FID_{\text{nav}}^{\text{fast}}$ and 5% for $FID_{\text{nav}}^{\text{slow}}$ was chosen to trigger the acquisition of an IMGnav (Figure 1(a)). The IMGnavs were retrospectively co-registered to obtain translational and rotational motion parameters. The motion trajectory between the time points when IMGnavs were triggered was extrapolated as proposed in [4], i.e. the motion parameters known from the IMGnavs were used to train a linear model relating the complex raw FID signal changes to motion parameters (Figure 1a); the model was then employed in conjunction with the FIDnavs to estimate the motion parameters in imaging-only repetitions where no IMGnavs were available. Subsequently, the image data was corrected for motion by adjusting the k-space lines according to the extrapolated motion trajectory. In addition, a Bloch simulation of the longitudinal magnetization was conducted to show the effect of replacing the normal MP-RAGE read-out train by the IMGnav acquisition.

Results and Discussion

Qualitative improvements (less blurring and ghosting) were consistently observed in all acquired images. The improvement in images corrupted by translational motion in head-feet direction was more evident than in images where the subject was performing head shaking and nodding, presumably due to difficulty of interpolating missing k-space data. The retrospective motion correction result for one case can be seen in Figure 1(b). The Bloch simulation revealed that the effect on the longitudinal magnetization steady state is negligible (3% signal difference before the subsequent inversion pulse), i.e. the MP-RAGE contrast is not affected by the IMGnavs. The chosen FIDnav threshold triggered the acquisition of the IMGnav reliably; however in acquisitions where the subject was asked to stay still, few triggering events occurred, indicating that the chosen thresholds might require further optimization.

Conclusion

In this proof-of-concept study, we show that FID-based motion *detection* in combination with a motion *quantification* method can be used for retrospective motion correction. The present approach extends recent work on MR-based motion correction [5] in the sense, that the motion is monitored with practically no penalty (fast, low-impact FIDnavs) and the imaging navigators are employed only when needed. Such a concept may be extended to other imaging protocols [6] and has the potential of providing a very efficient MR-based motion correction. Remaining limitations of the retrospective approach are mainly the adaptation to parallel imaging reconstructions, improvable interpolation of missing k-space data due to rotational motion, and the choice of appropriate thresholds for the FIDnavs. Future work will aim at the implementation of an automatic FIDnav threshold adaptation in combination with prospective motion correction. A possible strategy of reducing the scan time overhead due to IMGnav acquisition can be a motion prediction approach as reported in [4].

References

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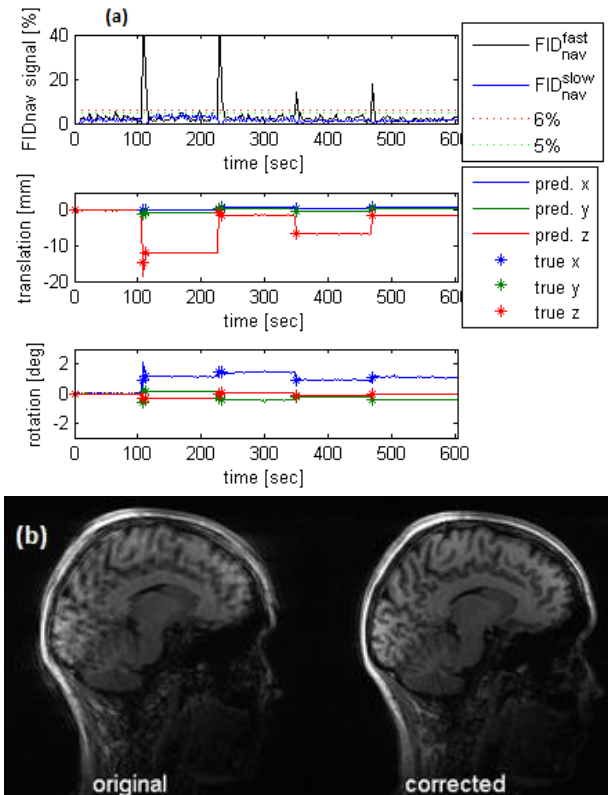


Figure 1 (a) Exemplary FIDnav signal with extrapolated motion trajectories (top) for translational (middle) and rotational motion (bottom). (b) Sagittal view from one subject before and after correction after performing translations in head-foot direction.