Real-time Motion Detection for Structural Brain Imaging Using Multi-Coil FID Navigators

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Introduction

Subject motion is frequently affecting quality and reliability of conventional MRI protocols. Extending previously suggested methods[1-4] and work[5], we propose a motion-detection technique for use with receive coil arrays. Proof of concept is shown by means of an MP-RAGE implementation for structural brain scans.

Theory and Methods

The free induction decay (FID) MR signal as received by a local coil element is sensitive to the position of the object, i.e. moving the object may influence the FID MR signal strength. The proposed motion detection approach is based on repetitive FID measurements and analyzes changes in the FID signal from multiple receive coils to determine subject motion.

Five subjects were scanned on a 3T scanner (Magnetom Trio a Tim System, Siemens, Germany), equipped with a 32-channel head receive coil. Subjects rehearsed a reproducible head movement (trans < 5mm, rot < 6º) during an initial EPI acquisition (100 frames); motion parameters were derived by registration of the EPI-volumes to a reference volume. Subsequently, two 3D head scans were acquired with a modified MP-RAGE sequence (256x256x160 matrix, 1mm isotropic voxels, TR/TI/TE/flip 2200ms/900ms/2.8ms/9°). The sequence is extended by a 9° navigator excitation with 83 us FID readout located 50 ms after the inversion pulse (see Fig. 1). Four minutes after the start of the 1st scan, subjects were asked to produce the trained movement and to return to the original position 1 minute later (see purple bar in Fig. 2). During the 2nd scan, subjects were asked to perform no motion.

The real-time motion detection was implemented on the scanner: each TR, FIDs from all 32 coil elements were combined to one navigator signal by complex averaging. Navigator signals from the first 5 TRs served as reference for normalisation. To correct for system-induced signal drifts (approximated as being linear), navigator signals of subsequent scans were compared to a value linearly extrapolated from all preceding points. If the incoming navigator signal differed more than ±3*sd (sd of preceding points after linear drift compensation) from the extrapolation, the corresponding TR was labelled 'motion-corrupted' and rescanned at the end of the measurement when the subject had moved the head to the original position (see pink bar).

From the first MPRAGE scan, 2 volumes were reconstructed using (a) the k-space data including the motion-labelled lines and (b) the k-space data where motion-labelled lines had been substituted by the re-scanned lines.

Results

All subjects were able to perform a reproducible head motion. Volume registration of the EPI scans revealed motion parameters ranging between 1-5 mm translation and 2-6° rotation across subjects. The respective navigator signal changes in the MPRAGE scans with motion ranged between 2 and 9% (see an exemplary time course in Fig. 2). Navigator signals from the scans without motion showed excellent temporal stability (on drift-corrected navigator data: mean sd 0.34%, mean peak-to-peak amplitude 0.02%).

Fig.3 shows a detail of a sagittal image reconstructed with (3a) motion-corrupted k-space lines and (3b) the repeated lines. Similar results were observed in all 5 subjects. Extrapolation of the navigator changes based on the EPI motion parameters yielded a sensitivity of the method of 1 mm and 1°.

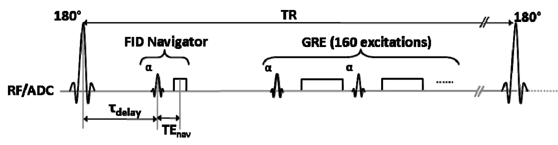

Fig 1 Diagram of the modified MP-RAGE sequence. One FID navigator excitation is added τ_{delay}=50ms after the inversion pulse. Its flip angle α is the same as the one of the imaging scans, navigator echo time TE_{nav} is 1ms. No gradients are applied in the navigator module, yielding a whole-volume FID

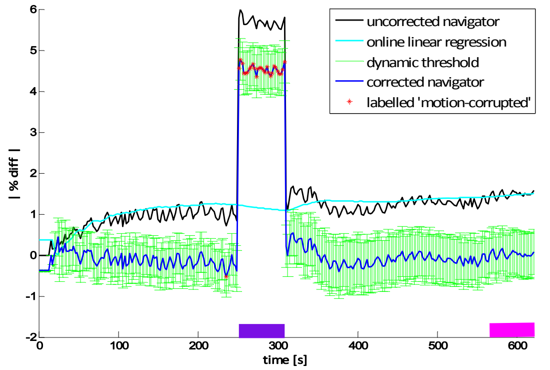

Fig. 2 Uncorrected (black) and corrected (blue) navigator signal of an MP-RAGE measurement. Head position was changed during the period marked violet. The green bars show motion threshold at that moment, red points mark motion-corrupted TRs, which are rescanned at the end (pink bar). Cyan shows the online regression time course.

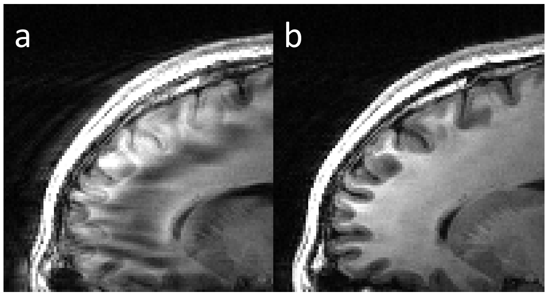

Fig. 3 Reconstructed images from measurement shown in Fig. 2 using (a) uncorrected and (b) repeated k-space lines. A detail of the frontal lobe is shown for better visibility of the improvement obtained (equal windowing in both images).

Conclusions

The results (i) confirm that motion induces changes in FID signals of local coil elements, and (ii) demonstrate the feasibility that this concept can reliably detect motion ≥1mm/1°. For demonstration purposes, corrupted k-space lines were rescanned after subjects performed a trained motion pattern and and were able to returned to the original head position. In more realistic scenarios, the method could be used to provide a quality index or to trigger control scans, to update the scanning coordinate system in real-time. Since this technique can be implemented without significant time or signal penalty and as it is contrast-independent, it could be applied to various imaging and spectroscopy techniques prone to motion artefacts (Diffusion, CE-perfusion, etc.). Combining FID signal changes and coil sensitivity maps may even allow back-calculation of absolute motion parameters.

References [1] Pipe JG, 1999, MagnResonMed,42(5),963-969; [2] Thesen S, 2000, MagnResonMed,44(3),457-465; [3] Welch EB, 2002, MagnResonMed,47(1),32-41; [4] Van Der Kouwe AJW, 2006, MagnResonMed,56(5),1019-1032; [5] Kober T, 2009, Magma,22(Supp1),270-271

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