Motion insensitive imaging using 3D PROspective MOtion (PROMO) correction with region-of-interest tracking

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Introduction

Patient motion during an MRI scan can cause significant imaging artifacts including blurring and ghosting. Prospective, navigated methods attempt to address the problem at its source. Patient motion is tracked during the ongoing scan, and data acquisition parameters are updated in real-time in order to maintain k-space sampling in the patient-centered coordinate system as close as possible to the no-motion condition [1, 2, 3]. However, prospective methods requiring adherence to the rigid body assumption will yield inaccurate motion estimates if regions within the imaging field of view (FOV) move non-rigidly relative to each other (e.g. the jaw, neck, orbits, and brain in a head scan). In this case k-space may be sampled incorrectly, resulting in residual motion artifacts. Here we present a region-of-interest (ROI) tracking technique that minimizes the adverse effects of non-rigid motion by essentially ignoring regions in the FOV that can move non-rigidly relative to the ROI. To demonstrate its effectiveness, we included it as a component of PROMO [3], a prospective motion estimation and correction system that operated during *in vivo* high-resolution, 3D, T1-weighted, brain scans.

Methods

Image acquisition: All parameters for the 3D inversion recovery spoiled gradient echo (IR-SPGR) pulse sequence were as described in [3]. Acquisition matrix was 192x192x170, with voxel size=1.2x1.2x1.2mm. All scans were performed on a 1.5T GE Signa Twin Speed scanner.

Spiral navigators: The navigators were three orthogonal, single-shot spiral acquisitions (S-Navs) [3]. Five sets of S-Navs were inserted in the IR-SPGR sequence prior to each IR-SPGR slice acquisition. Reconstructed S-Nav images (see Fig 1) were used as inputs to the motion correction system. Each S-Nav acquisition (3 planes) was ~40 ms in duration.

PROMO motion estimation and correction system: PROMO relies on an Extended Kalman Filter (EKF) for estimating the 6 rigid body motion parameters- x,y,z translation and rotation about the x,y,z axes- from the sequence of S-Nav images. A reconstructed S-Nav (3 image planes) near the start of the IR-SPGR acquisition was used as a reference, and estimates of S-Nav image data at each time step were constructed via 2D interpolation of the reference image planes. The EKF's motion estimate at a given time step was calculated as a function of the difference between the current S-Nav images and the estimated images. IR-SPGR slices and S-Navs were repositioned in real-time based on these motion estimates.

ROI (brain) masking: A 3D atlas was constructed from individual, smoothed proton density-weighted acquisitions that were acquired previously. These individual volumes were co-registered with rigid-body registration into atlas space and averaged together. The contrast properties of the individual volumes and the spiral navigators were similar. A 3D brain mask, in spatial register with the atlas, was constructed manually. Immediately prior to the start of an IR-SPGR scan, a series of 20 S-Navs was acquired, a process requiring ~10 s. The PROMO motion estimation system was used to estimate the relative translation and rotation between the 3D head atlas and the subject head orientation in the S-Nav images. During this process, the 3D head atlas served as the reference, and S-Nav image estimates were constructed via 3D interpolation of the atlas. After the atlas-to-navigator translation and rotation values stabilized, the values were used to project the 3D brain mask onto the three orthogonal S-Nav image planes (Fig 2). The EKF's measurement covariances for all S-Nav image locations outside of this projected mask were then assigned very large values relative to the values for locations inside the projected mask. For motion tracking this forced the EKF to essentially ignore data from regions outside of the projected mask.

Results

As shown in Fig 1, the projected brain mask (bottom row) fits closely around the brain region in the three navigator images (top row). Note that the mask does not include the neck and jaw regions in the sagittal image. Images from a volunteer IR-SPGR scan with PROMO are shown in Fig 2 (top row). The subject rotated around the inferior-superior axis 12 degrees, and translated 5 mm to subject's left during the scan. Some blurring is evident in the neck region. This was expected as this region was outside of the brain mask. Images from an IR-SPGR scan without PROMO are shown in Fig 2 (bottom row). The subject moved similarly as in the PROMO "on" scan.

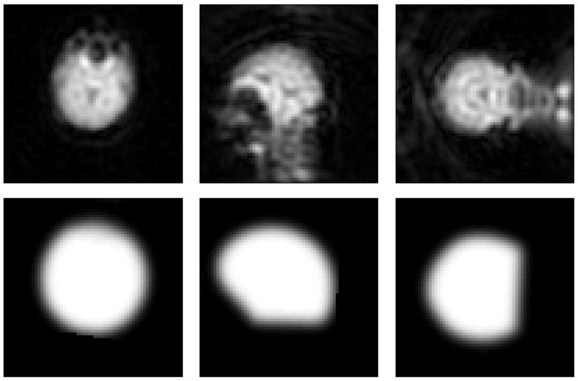

Figure 1: Navigator images (top row) and projected brain mask (bottom).

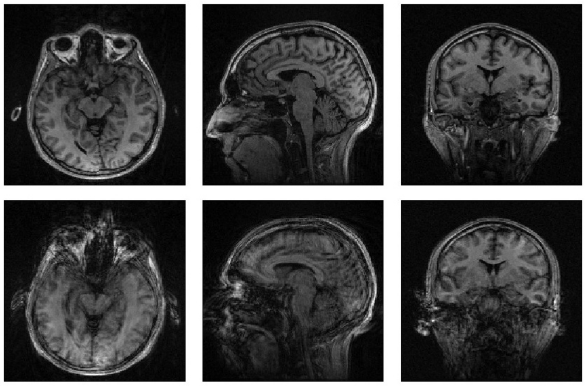

Figure 2: IR-SPGR scan with PROMO (top row), and no PROMO (bottom row).

Discussion

This study demonstrates the effectiveness of integrating ROI masking with a rigid-body motion correction system for MRI when non-rigid motion may occur within the FOV. This system will be used in upcoming studies involving patient populations in which motion during scans is a significant concern.

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References

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