Comparison of MR-Navigator and Optical Tracking Methods for Adaptive Motion Correction

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INTRODUCTION

Patient motion is a primary cause of MRI artifacts and lost scanner time. A number of retrospective [1], prospective [2], or MR-navigator-based [3, 4] as well as external-based (optical) [2, 5] motion-correction techniques have been developed, each with certain advantages. Prospective approaches in which the acquisition volume follows the subject motion throughout the scan are becoming increasingly popular since they eliminate motion-artifacts directly during the imaging process. Here, we compare two different prospective motion correction methods: MRI-based PROMO (PROspective Motion correction) [3] and optical-based Retro Grate Reflector (RGR) [4].

METHODS

PROMO is an image-based prospective tracking system which we recently integrated into a short-TE PRESS (TE/TR=-30/3000ms, 32 averages, 20x20x20mm voxel) sequence [4]. Three orthogonal (axial, coronal, sagittal), low flip angle, low-resolution images are acquired during the "dead time" in the PRESS sequence (Fig. 1). The rigid-body parameters are estimated from the navigator images using a training data set and a Kalman filter [4]. Areas that can move non-rigidly with respect to the brain (e.g. neck and jaw) are masked out. PROMO operates at ~1-5 frames/sec.

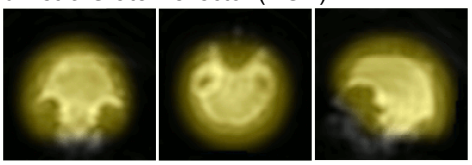

Fig. 1. PROMO navigator images

The RGR is a new technology which uses Moiré patterns to capture 3D motion with a single camera [4]. The tracking system consists of a camera (registered to the MR coordinate system) that is mounted at the head-end of the scanner, a 100x100 mm mirror and a 20x20 mm MR-safe RGR target attached to goggles worn by the subject. The camera records the target via a mirror mounted to the interior of the scanner bore (Fig.2). Images are transmitted to a workstation at 60 fps, and the images are analyzed in real-time to determine changes in head pose (3 translations and 3 rotations) with a lag time approximately 25ms.

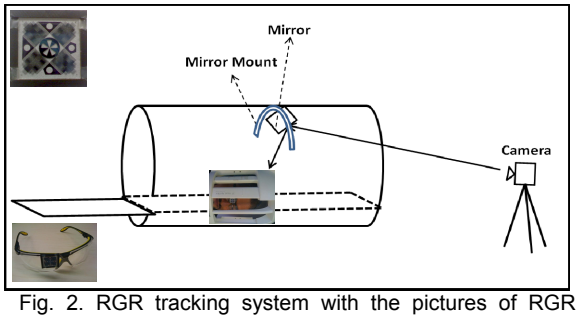

Fig. 2. RGR tracking system with the pictures of RGR target (left upper corner) and the goggle with target attached (left lower corner).

A healthy, consented volunteer was fitted with the RGR target goggles and scanned with a PROMO-supplemented PRESS sequence. The subject was instructed to perform X- ("head nod") and Z-rotations ("head shake") during the scan; these motions are the most natural head movements in the MR environment. Motion was tracked simultaneously with PROMO and RGR. Rotation matrices and RF-pulse offsets for each TR cycle were used to calculate angular and translational motion and the total rotation angles. High resolution MP-RAGE images were also collected immediately before and after each motion scan, and realigned using SPM8 to provide a "gold standard" against which the RGR and PROMO steady-state motion estimates could be compared.

RESULTS

Fig.3 plots the motion estimates from RGR (black circles) and PROMO (blue crosses) tracking, as well as SPM (red) registration for the intentional Z-rotation. In this particular run, tracking with PROMO differed from SPM in translations (x,y,z) by about (0.30, 1.08, 0.19 mm) and in rotations (0.88, 1.75, 1.07°), whereas RGR differed from SPM by about (0.36, 1.10, 0.75 mm) and (0.27, 0.21, 0.49°). However, other runs yielded differences up to 2mm and 2°. Fig. 3 also shows that PROMO tracking data lag RGR tracking data during faster movements. SPM realignment errors were approximately 20μm and 0.002°.

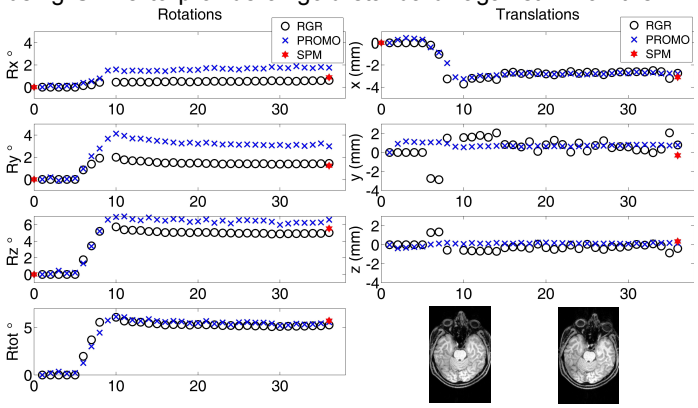

Fig. 3. Comparison of tracking with PROMO (blue crosses) and RGR (black circles) against SPM (red). MP-RAGE images demonstrate about 5° Z-rotation (left-right rotation).

DISCUSSION

In the current implementation, tracking with RGR as well as PROMO show non-negligible errors relative to the "gold standard" image registration. A prior study found more favorable results for PROMO [3] -- mean absolute steady-state error was calculated to be (x,y,z) (0.14, 0.35, 0.41mm) and (0.39, 0.25, 0.27°). These discrepancies may be due to the following factors: 1) the attachment of the RGR target to the subject by goggles, which may be displaced during facial motions, 2) registration errors of the RGR relative to the MRI coordinate system, 3) inaccuracies in the PROMO tracking algorithm and 4) unintentional subject movement during the 5-minute MPRAGE scans. Overall, these studies highlight the need for an independent method to evaluate tracking systems for adaptive MRI motion correction.

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