Imaging of Freely Moving Objects by Means of Real-Time Image Coordinates Update Using an External Optical Motion Tracking System

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Introduction

Subject motion appears to be a limiting factor in numerous imaging applications. For head imaging most often the subject's ability to maintain the same head position for a considerable period of time places restrictions on the total acquisition time. For healthy individuals this time typically does not exceed 10 minutes and may be considerably reduced in case of pathology. In particular, head tremor, which often accompanies stroke, may render certain high-resolution 2D and 3D techniques inapplicable. Several navigator techniques have been proposed to circumvent the subject motion problem. The most suitable for head imaging appears to be the orbital (1) or spherical (2) navigator methods. Navigators, however, not only lengthen the measurement because of the time required for acquisition of the position information, but also require additional excitation RF pulses to be incorporated into the sequence timing, which disturbs the steady state. Here we demonstrate the possibility of interfacing the MR scanner with an external optical motion tracking system, capable of determining object's position with sub-millimetre accuracy and the update rate of 25Hz. The information on the object position is used at no time penalty to update the position of the imaging volume during the acquisition of *k*-space data.

Methods

The prospective motion correction technique was implemented on the Siemens Magnetom Trio 3T whole-body system (Siemens Medical Systems GmbH). The product TSE sequence was modified to enable real-time line-by-line feedback from the image reconstruction computer. The later was communicating to the optical motion tracking system and generating the feedback information for the measurement. Imaging parameters were: FoV=256mm, 128^2 mage matrix, TE=150ms, TR=525ms, phase-encoding dimension was vertical (AP). The optical motion tracking system, called EOS, developed by Fraunhofer Institute for Computer Graphics, Darmstadt, Germany, was based on a stereoscopic reconstruction of rigid bodies from grey scale images. The system set up consisted of two progressive scan cameras synchronised by a frame grabber card in a standard PC. The cameras were equipped with infrared lenses to block the visible light and the scene was illuminated with infrared light beamers attached to the cameras. EOS was able to detect and to track models, consisting of three retro-reflective markers with fixed distances with quoted positional accuracy of 0.3mm. In order to track position of the subject's head the mouthpiece with 3 retro-reflective markers was used. Subjects were instructed to bite the mouthpiece tightly to make sure it is remains in contact with the upper jaw in order to make the system of 3 markers and the scull a rigid body.

In vivo imaging experiments were performed in healthy volunteers. All experiments with human subjects were performed in accordance with local IRB regulations; informed consents were obtained prior to measurements. No head fixation pads were used in order to enable exaggerated motion during the imaging experiments.

Results

In Figs. 1 and 2 a slice through the brain of a normal volunteer is presented, acquired in 4 measurements. In the first two experiments (Fig. 1) the volunteer was instructed not to move the head. Fig. 1a was acquired with the coordinate update disabled and is to be used as a reference for image quality. Fig. 1b was acquired with coordinate update enabled. Given the absence of subject motion the increase of noise and slight artefacts in phase encoding dimension in Fig. 1b are due to the uncertainty of the position determination by the optical motion tracking system. Similar effects were observed in phantom experiments (data not shown). Fig. 1b demonstrates the maximum achievable quality of motion correction for the given accuracy of the tracking system. In the further two experiments the volunteer was instructed to move the head during the acquisition. Fig. 2a displays the resulting image quality with the motion correction disabled. Fig 2b presents the image acquired with imaging coordinates updated for each *k*-space line. The corresponding motion patterns are presented in Figs. 3a and 3b. As seen, for comparable motion patterns, the motion artefacts are much reduced, when prospective motion correction is performed.

Discussion

The results show the feasibility of using an external optical motion tracking system to correct for subject motion during the acquisition of the single image on a line-by-line basis. Even though the image in Fig. 1(right) displays minor image quality reduction due to the noise in the position data delivered by EOS, it is good enough to motivate the efforts of performing the motion correction. Indeed, the corrected image acquired in the presence of motion (Fig. 2, right) shows considerable quality improvement in comparison to the image acquired in the presence of comparable motion without correction (Fig. 2, left). The remaining artefacts appear to be due to the limitations of current implementation of the positional feedback, where the motion information is received by the reconstruction computer and then transferred to the measurement control unit, which results in the lag of ~1 TR (independent of TR). The effects are much reduced in phantom experiments, where it is possible to induce "discrete" motion.

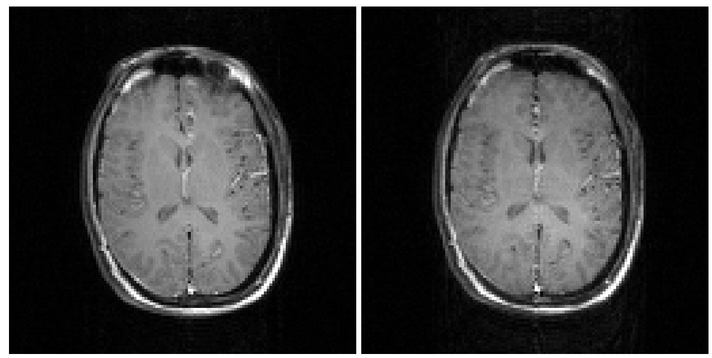

Fig. 1. *Brain spin-echo images in the absence of subject motion with motion correction disabled (left) and enabled (right). Slight contrast changes, noise and artefacts increase visible in the image on the right are due to the random errors in the position determination.*

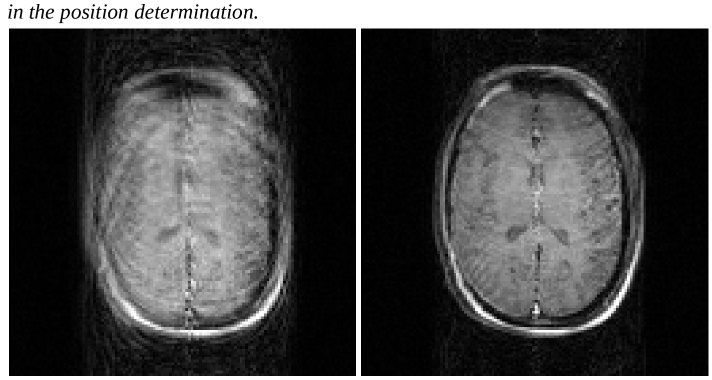

Fig. 2. *Brain spin-echo images in the presence of strong subject motion with motion correction disabled (left) and enabled (right). Corresponding motion patterns are presented in Fig. 3. Significant reduction of artefacts by the motion correction is apparent. The remaining effects may be attributed to the feedback delay in the current implementation.*

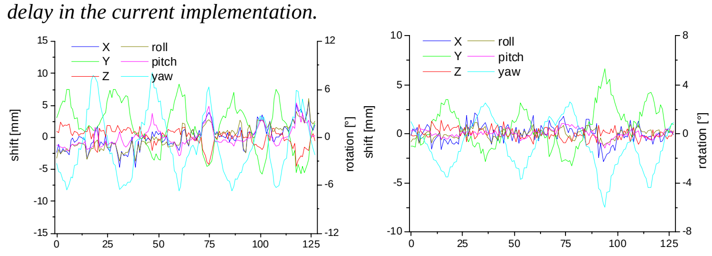

Fig. 3. *Motion parameters delivered by the optical motion tracking system corresponding to the experiments in Fig. 2.*

References

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