Prospective Real-Time Slice-by-Slice 3D Motion Correction for EPI Using an External Optical Motion Tracking System

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Introduction

The need for motion correction in functional MRI (fMRI) time series has been well recognised. This correction may be performed in two ways: either retrospectively, by image registration after the time series has been fully collected,(1) or prospectively, when the motion parameters are measured during the time series acquisition and the corresponding changes are made to the imaging parameters. Prospective techniques differ in the way they acquire the position information. Navigator techniques(2,3) include additional pulse sequences, capable of object position determination. Image-based methods(4) perform co-registration of the measured volume data to extract motion parameters during the acquisition of the time series. Both these approaches are, however, not without problems. Navigator-based techniques slow the acquisition process considerably and perturb the steady-state because of the additional excitation RF pulses. Image-based methods require volume coverage in order to extract position information and considerable computational effort, which introduces delays. Both navigator and image-based corrections typically update positions of the slice packet once per measured volume, which may not be valid, if motion occurs while the slice packet is being acquired. Here we demonstrate a possibility of slice-by-slice 3D prospective motion correction of EPI time series using an external optical motion tracking system.

Methods

The technique was implemented on a Siemens Magnetom Trio 3T whole-body system (Siemens Medical Systems GmbH). The product EPI sequence was modified to enable real-time slice-by-slice 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, 64^2 mage matrix, 32 slices, 4mm slice thickness, 1.2mm slice gap, interleaved multislice acquisition, TE=16ms, TR=1660ms. 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 and update rate of 25Hz. In order to track position of the subject's head a mouthpiece with 3 retro-reflective markers was used. Subjects were instructed to bite the mouthpiece tightly to make sure it 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 and Discussion

Fig. 1 presents selected coronal images produced by re-slicing of the transversal EPI images without motion correction (top row) and with prospective motion correction activated (bottom row). Corresponding motion parameters for both experiments are plotted in Fig.2. As seen from the figures for the comparable motion patterns, the prospective slice-by-slice motion correction affords to avoid unrecoverable volume distortions. The remaining modulation may be attributed to the "usual" EPI geometric distortions, which are known to be position-dependent. In the experiments with less exaggerated head movements (±3mm, ±3º) these modulations are not visible. The data demonstrate advantages of using the optical motion tracking to correct for motion in echo-planar time series by not only enabling volume-to-volume correction without additional computation overhead, but also slice-by-slice correction without increasing the scanning time. The effect of the random inaccuracies in the position data on the statistical properties of the measured images is still to be evaluated.

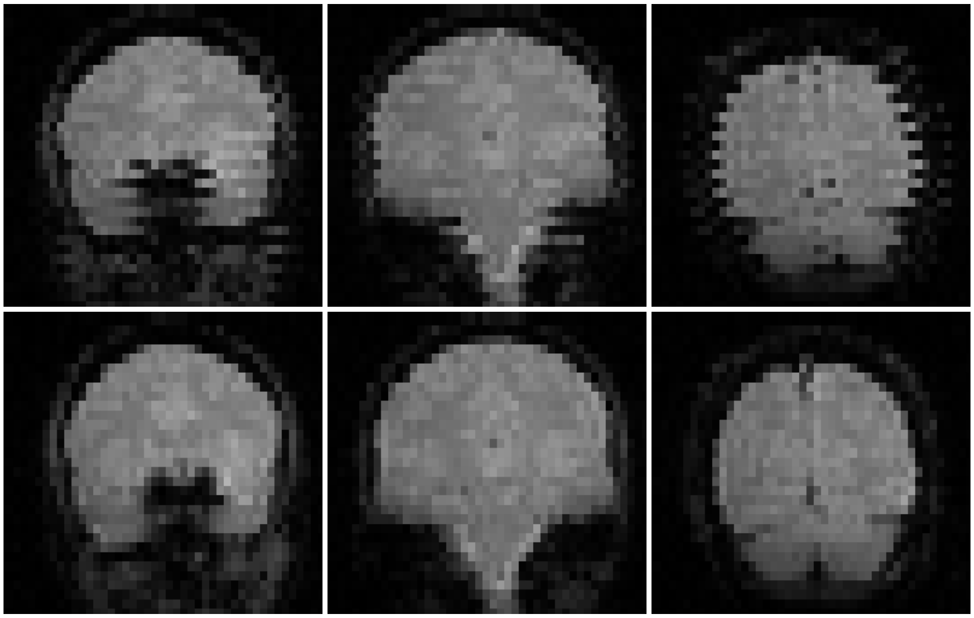

Fig. 1. *Representative coronal images produced by re-slicing transversal EPI data from the interleaved multi-slice acquisition. Severe displacements between the neighboring slices are apparent when motion occurs during the acquisition of a single volume (top row). Adjusting the position of each slice circumvents the intra-volume distortion problem (bottom row). The remaining modulation and/or step-like structures at the surface of the brain appear due to the dependency of the "usual" EPI geometric distortions on the orientation of the head.*

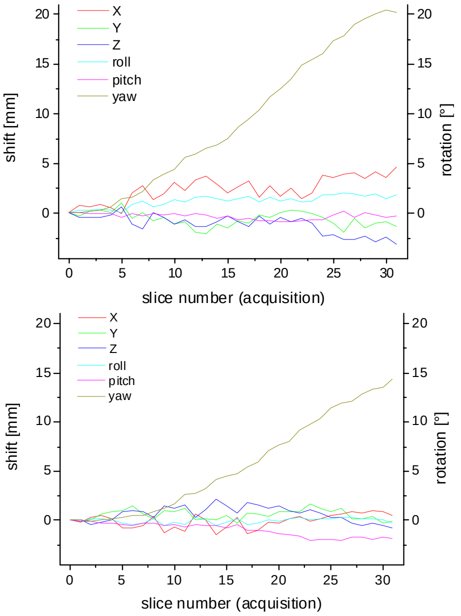

Fig. 2. *Measured positions of the head as a function of the acquired slice number for the experiment without correction (top) and with correction (bottom). The motion corresponds to a single continuous head rotation.*

References

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