High-resolution in vivo MR brain imaging at 7T using an embedded optical tracking system for prospective motion-correction

Jessica Schulz[1], Thomas Siegert[1], Enrico Reimer[1], Maxim Zaitsev[2], Julian Maclaren[2], Michael Herbst[2], and Robert Turner[1]
[1]*Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany,* [2]*University Medical Center Freiburg, Freiburg, Germany*

Introduction: Researchers have been investigating prospective motion correction using information from an external optical tracking device to reduce motion artifacts in MR brain imaging [1-5]. We have designed an embedded optical tracking system to provide real-time motion information enabling prospective head motion correction for high-resolution MRI of the human brain at 7T. The standard deviation of its tracking noise is below 20 µm and the latency between motion and motion correction is (19 ± 5) ms [5, 6]. Here, we show how our system enables us to acquire motion-corrected very high resolution *in vivo* MR images.

Methods: The system consists of three tracking cameras with integrated microcontrollers. Each camera tracks the position of one of three optical markers, which are rigidly connected together. After careful calibration, the tracking system was positioned on the patient table of a 7T MR system (Siemens, Erlangen, Germany) around an 8-channel receive coil (Rapid, Wurzburg, Germany). The transform matrix between tracking system and scanner coordinates was calculated from position changes of an MR phantom with attached optical markers. Plastic spectacle frames were used to attach the markers to the volunteer. The following MR protocols were acquired with and without prospective motion correction: (1) 3D FLASH, 0.5x0.5x3.0 mm, TE=3.4 ms, TR=9.7 ms, α=15 deg, BW=260 Hz/pixel, TA=2:31 min; (2) 3D FLASH, 0.4x0.4x0.4 mm, TE=10 ms, TR=18 ms, alpha=8 deg, BW=140 Hz/pixel, TA=17:56 min; (3) 2D TSE, 0.5x0.5x0.5 mm, TE=23 ms, TR=2120 ms, BW=80 Hz/pixel, turbo factor=2, 2 averages, TA=11:26 min. The volunteer was asked to perform slow head nodding movements during protocol 1 and not to move during protocol 2 and 3. Protocol 2 was acquired in three more volunteers and the image quality was assessed using an average edge strength metric [7] to test the robustness and repeatability of the method.

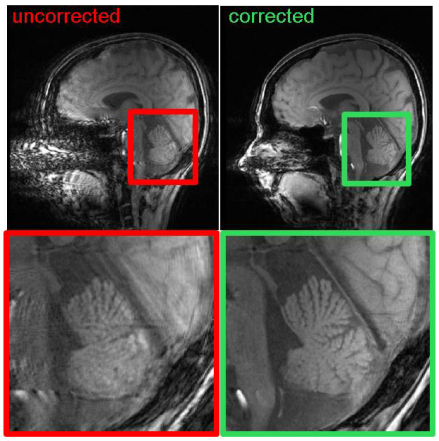

Fig. 1: The volunteer intentionally nodded (~3°, ~0.1 Hz) during acquisition of the uncorrected (left) and corrected (right) 3D FLASH images (voxel size: 0.5x0.5x3.0 mm).

Results: Figures 1, 2 and 3 show uncorrected (red frames) and corrected (green frames) MR images acquired using protocol 1, 2 or 3, respectively. Figure 2 also shows the corresponding motion time courses. Although these are comparable in the corrected and uncorrected acquisitions, the corrected images clearly show less blurring. The mean average edge strength [7] in the four data sets acquired using protocol 2 was higher in the corrected than in the uncorrected images (9 % (Fig. 2), 1 %, 14 % and 22 % (images not shown) respectively).

Discussion: The image quality of high resolution MR images was improved substantially in all volunteers using prospective motion correction with motion information from our embedded tracking system. This technique greatly improves the reliability of ultra-high resolution MRI *in vivo*. It paves the way to imaging with a level of detail comparable to post mortem studies. Work in progress is directed towards simplifying the installation and calibration procedures, integrating the prospective motion correction into more MR sequences and, ultimately, applying this method routinely for all anatomical and functional 7T MR studies at our institute.

References: [1] Zaitsev M et al. 2006, NeuroImage 31(3):1038-1050; [2] Qin L et al. 2009, MRM 62(4):924-934; [3] Aksoy M et al. 2010, Proceedings ISMRM; [4] Schulze P et al. 2011, ESMRMB; [5] Schulz J et al. 2011, ESMRMB; [6] Siegert T et al. 2011, ESMRMB; [7] Aksoy M et al. 2011, MRM doi: 10.1002/mrm.23101

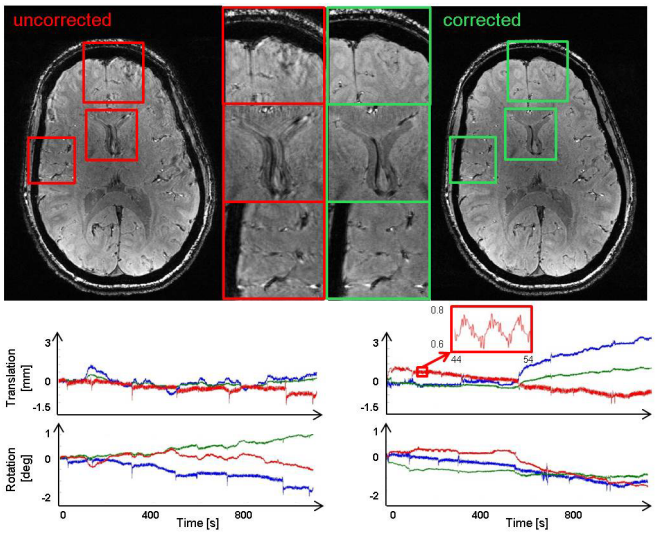

Fig. 2: The volunteer was asked not to move during acquisition of the uncorrected (left) and corrected (right) 0.4 mm isotropic 3D FLASH images. The corresponding motion time courses are shown below the MR images.

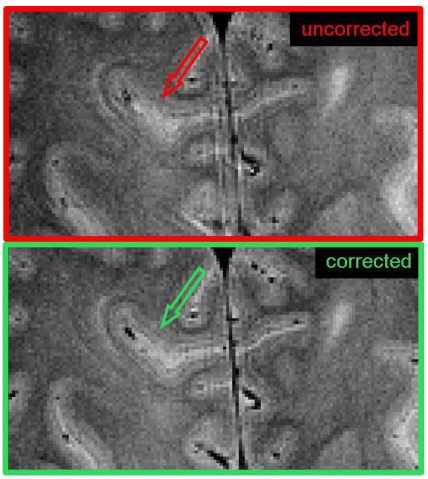

Fig. 3: Although the amount of motion was comparable in both acquisitions, it is more difficult to identify small structures in the uncorrected 0.5 mm isotropic TSE image (top) than in the corrected image (bottom), e.g. the Stria of Gennari (arrows).