Prospective Motion Correction with Stereoscopic Optical Tracking at 7T

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INTRODUCTION

Artifacts caused by motion during the image acquisition are a well known problem at 1.5T and 3T. In high field systems such as 7T the available signal to noise ratio leads to potentially higher resolution than in systems with lower field. Unfortunately higher resolution requires longer acquisition times without patient motion. Therefore an increased need for motion correction exists. Prospective motion correction [1] for 3T systems addresses motion during the measurement and promises to improve image quality in high resolution acquisitions. In this study an implementation of prospective motion correction on a 7T MR scanner is presented and the correction of a moving phantom and of a test person are described for different image resolutions.

MATERIALS AND METHODS

Measurements were performed on a 7T whole body MRI (Siemens Medical Solutions, Germany). The bore of the scanner is approximately 4m long. Motions of the phantom or the subject's head were traced by a stereoscopic tracking system (ARTtrack3, Advanced Realtime Tracking GmbH Germany). The distance between camera and iso-center is approximately 5m and the angle between both cameras and the target is ≈14°. Retro-reflective markers were mounted on the phantom or a lightweight bite bar. Prior to every excitation, the online correction is accomplished by recalculation of the logical orientation of the gradients and frequencies according to the current detected position and orientation of the target.

T1-weighted gradient echo sequences with different resolutions were used for the phantom. T2*-weighted gradient echo images were acquired in a human subject. Motion was applied between two scans (shot-to-shot motion) as well as during the measurement (in-scan motion). Images without intentional motion were acquired with and without active motion correction as a reference and to estimate noise propagation. No further image processing was applied to the data.

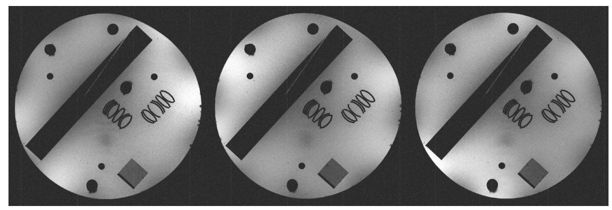

Fig.1 *T1-weighted images with 0.23*0.23*1.5mm resolution, TE 5.8, TR 100, FA 20, prospective motion correction of large angle rotations between scans (shot-to-shot). Note the changes in shading caused by inhomogeneities which are not rotated with the object.*

RESULTS

Shot-to-shot motion: The influence of the motion correction on images without in-scan motion is small (Fig. 1). Tracking based motion correction results in reproducible images by aligning the scans to the orientation of the first scan, even if the subject or phantom moved between the scans (Fig. 1). In phantom scans, this motion correction delivers artifact-free images for all resolutions (256x256, 512x512, 1024x1024). In vivo measurements deliver uncorrupted images up to a resolution of 512x512 (Fig. 2). With a resolution of 1024x1024 first residual motion artifacts appeared.

In-scan motion: An online correction of motion within a measurement is possible before excitation of each k-space line (in-scan motion correction). Phantom data were acquired at different resolutions and with comparable motion during the scans (Fig. 3).

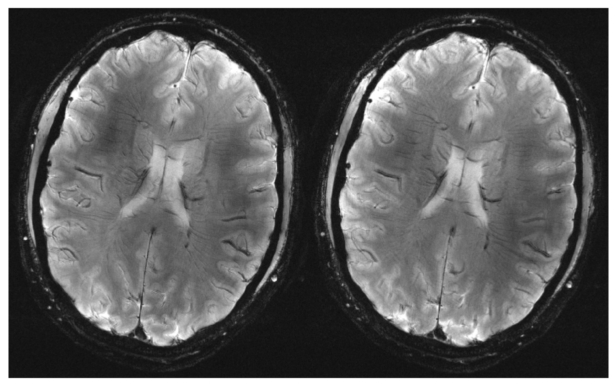

Fig.2 *T2*-weighted images with 0.44x0.44x3.0mm resolution, TE 18, TR 300, FA 25; small rotations between scans (≈7° around z-axis) are prospectively corrected based on motion data. Again inhomogeneities remain static and appear in the images rotated accordingly. Achievable resolution of prospectively corrected images depends on the accuracy of the tracking system.*

DISCUSSION

The quality of images without motion during the scan depends on the chosen image resolution and the precision (noise) of the tracking system. The results demonstrate that higher resolution requires higher tracking accuracy to avoid position-noise related artifacts, as predicted in [2]. This is visible in the comparison of high resolution phantom images and in vivo high resolution images. The tracking error in the 0.23mm resolution phantom images was approx. 0.06mm. Consistent with the prediction in [2], no artifacts are visible. As visibility is higher and distances of the markers are larger on the phantom than for the bite bar, noise increases in in vivo scans and residual artifacts start to become visible. However, the true tracking noise cannot be separated from the subject motion. Currently, tracking noise seems to limit the resolution to approx. 0.23mm for phantom scans and to approx. 0.47mm in vivo. This relation between image quality and tracking accuracy is also true for shot-to-shot correction.

Line by line correction of object in-scan motion dramatically improves image quality. However, residual artifacts are visible for high resolution acquisitions (Fig. 3). These appear larger compared to a previous implementation at 3T [1]. The improved sensitivity to motion may be caused by stronger image inhomogeneities at 7T, stronger motion induced changes in shim and higher noise in the tracking-data due to the smaller visual angle and the larger distance between the cameras and the target. Correction of very high resolution scans requires further improvement in tracking accuracy compared to the current stereovision system.

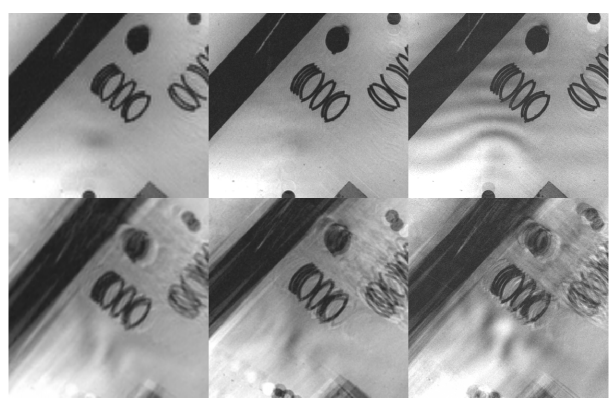

Fig.3 *T1-weighted images with motion during the scan.*
*left to right: 0.9*0.9mm, 0.45*0.45mm, 0.23*0.23mm*
top/bottom row: prospective motion correction/uncorrected;
resolution artifacts start to become visible in 1024x1024 even in the corrected version, most likely due to tracking noise.

ACKNOWLEDGMENTS

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REFERENCES

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