Hybrid Prospective & Retrospective Head Motion Correction System to Mitigate Cross-Calibration Errors

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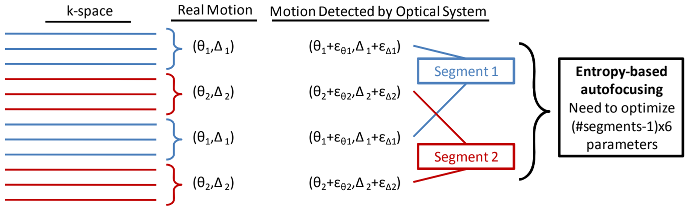
INTRODUCTION – Correction of head motion artifacts is essential for clinically acceptable image quality. This is especially important for long scans, such as DTI, fMRI, and high-resolution structural scans. Prospective motion-correction using stereovision systems [1,2] have been suggested to perform real-time head motion-correction without necessitating the acquisition of additional MR-based navigators. This enables real-time tracking of head motion with little or no changes to the pulse sequence. However, the accuracy requirements on the motion tracking of such systems necessitate long and meticulous scanner-camera cross-calibration times [1,2], which may not be available during clinical routines. In this study, we combine monovision-based, MR-compatible prospective motion-correction system [3] with retrospective motion-correction to mitigate residual artifacts that remain in the image after prospective motion-correction.

MATERIALS and METHODS – (a) Prospective correction: For prospective motion-correction, one camera was mounted on a head coil and used to track head motion. Tracking was accomplished using a checkerboard marker that was attached to the patient's forehead. Scanner-camera cross calibration was accomplished using agar filled holes that were attached to the marker. The pose data were estimated using an external laptop and sent back to the MR sequencer in real-time to update slice orientation and placement [3]. **(b) Retrospective correction** Tracking data from the monovision system was used to divide k-space into segments within which the patient position was approximately the same (Fig.1). Thereafter, these segments were registered to each other using an entropy-based autofocusing criterion [4]. Basically, each segment was rotated and translated individually until image entropy was mimumum (cost-function). This, in turn, gave the sharpest image. **(c) Experiments**: A 3D SPGR sequence (TR/TE=9.5/4.1, α=20°, 128x128x96 resolution, slice thickness = 1.5mm, FOV=240mm) with adaptive motion-correction added was used to test our approach in phantom and *in-vivo* experiments. For both cases, after the initial scanner-camera cross-calibration, the camera was slightly perturbed on purpose to simulate inaccuracies due to cross-calibration errors.



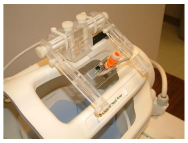


Figure 1. *Retrospective Motion-Correction*. The pose data obtained from the camera was used to divide k-space into segments with comparable pose. The relative motion between segments is found using entropy-based autofocusing, which aims to give the sharpest image.

RESULTS – Figure 2 shows the results for the phantom and *in-vivo* experiments. For both cases, not running the prospective motion-correction system causes significant artifacts, which were mostly cleared out if the motion tracking was turned on. However, due to the fact that the cross-calibration between scanner-frame of reference and camera frame of reference was inaccurate, the prospectively motion corrected images showed residual artifacts. These artifacts manifested themselves as smearing in the phase-encoding direction for the phantom experiments and as double lines /ringing artifacts for the *in-vivo* cases. These artifacts were mostly removed after the application of entropy-based autofocusing.

DISCUSSION – In this study, we presented a system that uses prospective optical motion-correction in concert with entropy-based retrospective autofocusing to mitigate cross-calibration errors. Using prospective motion-correction eliminated largely all gross motion artifacts and, thus, helped to minimize gaps in k-space due to rotational motion. The tracking data also allowed us to segment k-space in a few segments and helped decreasing the number of motion parameters to be determined for autofocusing. So far, entropy-based autofocusing has been limited to 2D only, mostly due to the large number of unknowns in 3D acquisitions. However, using tracking data to segment k-space allowed us to apply autofocusing also in 3D. Subtle artifacts that remained after autofocusing-based artifact reduction are most likely due to the limitations of k-space density-compensation and gaps in k-space following rotational motion correction of individual segments which haven't been accounted for. On the other hand, k-space data with similar, but not identical motion were binned into the same group. Thus, an alternative explanation could be some uncorrected 'pose-jitter' which could be further mitigated by using a larger number of bins.

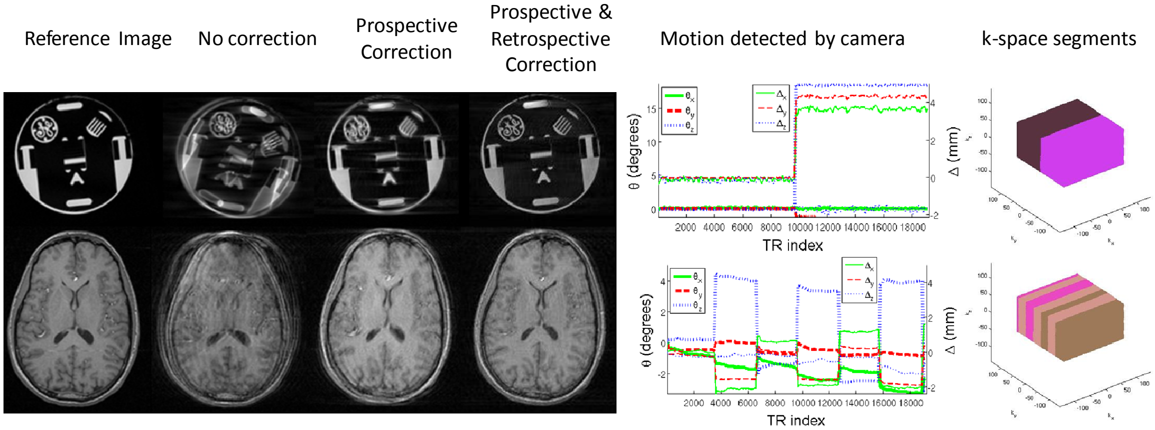


Figure 2. *Results of phantom and in-vivo experiments*. Without any correction, there are significant artifacts in the images. Running the optical tracking systems clears most of these artifacts. However, residual errors remain due to the fact that the scanner-camera cross-calibration was not accurate. These errors were significantly removed after retrospective autofocusing was applied. The motion detected by the optical system and the k-space segments for both experiments are also shown.

References [1] Zaitsev *et al.* NeuroImage, 31:1038-1050, 2006 [2] Qin *et al.* MRM, 62:924-934, 2009 [3] Aksoy *et al.* ISMRM, 2008 [4] Atkinson *et al.* IEEE Trans. Med. Imag. 16:903-910, 1997 **Acknowledgements** This work was supported in part by the NIH (1R01EB008706, 5R01EB002711, 1R01EB006526, 1R21EB006860), the Center of Advanced MR Technology at Stanford (P41RR09784), Lucas Foundation, Oak Foundation and GE Healthcare.