Motion Correction: MRI-based ultra-fast high-resolution 3D tracking

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Introduction: For high-resolution imaging as for dental impression or functional MR imaging a simple, flexible, fast and robust 3D motion tracking method was searched. Several approaches have been elaborated recently such as PROMO [1], camera tracking [2] and the usage of active markers [3]. The most promising correction method so far deals with optical devices such as infrared and standard video tracking cameras. However, they suffer from the drawback that the devices have to be synchronized in time and space with the MRT hardware. Cross-calibration errors remain the limit in optical tracking.

The proposed method tracks marker spheres without additional equipment and uses scanner information only. Inspired by Baumgartner et. al [4], a rapid measurement method arose. It is exploited that objects exceeding a narrow phase FoV foldover on the other side of the FoV and are not lost. Two alternatingly and rapidly measured “2D projection images” from small objects include the position information. A 2D measurement of the spheres is preferable, because a cross-calibration for sphere detection in the images has a higher accuracy than a 1D profile and is less sensible to SNR.

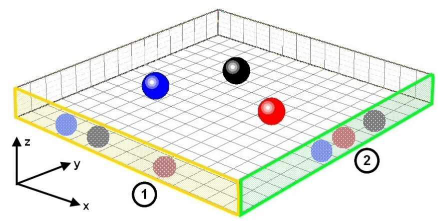

Figure 1 The three spheres of the marker tool are detected by slice projection. z is used as phase encoding direction. For image 1 x is readout and y slice direction, for image 2 the other way round.

Subjects and Methods: A rigid marker-tool was developed, holding three contrast agent-filled spheres ($T_1 \sim 15$ms) of 15mm diameter each. The markers can be attached to any phantom or patient. For marker detection in the projection images, two orthogonal crossing slices with a small phase FoV as shown in figure 1 are used (Read FoV=130mm, Phase FoV=16.5mm, Slice Thickness=500mm). The navigator sequence has parameters such as TE=2.9ms, TR=5.91ms, Flip Angle=30°, Resolution 0.7x0.9mm, TA=170ms. The built-in body coil was used to perform the tracking measurements.

The analysis of the projections comprises of filtering (zero-filling, Hanning) and a cross-correlation due to its low sensitivity for noise. One of the spheres is cut out of the image and used to detect the others. Using all information, the position can be calculated. Phase foldover hast to be recalculated.

For a testing and accuracy estimation of the method a calibrated device that performs translation and rotation was built. For a first motion correction in a corrupted image, the markers were attached to a phantom and after motion tracking corrected retrospectively.

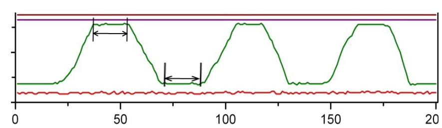

Figure 2 Position of the three spheres (no movement in sagittal plane). The marked intervals were used to calculate the accuracy of

Results: The two orthogonal slices contain all 6 degrees of freedom for 3D positioning in translation and rotation, so that the complete motion of the marker-tool can be entangled. This underlines the high accuracy of sphere detection.

Sequence and reconstruction parameters were tested and optimized. The measurements showed that a twofold zero-filling and the resolution of 0.7x0.9mm in-plane was accurate enough for marker detection, higher interpolation is only time consuming without big effort. Additionally, a Hanning filter improved the detection accuracy considerably.

With the calibrated motion device, the accuracy of the presented method was tested (results shown in fig. 2). A motion of (23.63±0.01)mm translation and a rotation of (10.75±0.10)° was performed. The tracking with the proposed method resulted in a motion detection **accuracy** of **(23.62±0.04)mm** and **(10.83±0.13)°** (standard deviation of 10 measurements in 2 positions each).

With the position information from the spheres an arbitrary movement of the phantom during a gradient echo measurement could be restored (fig.3).

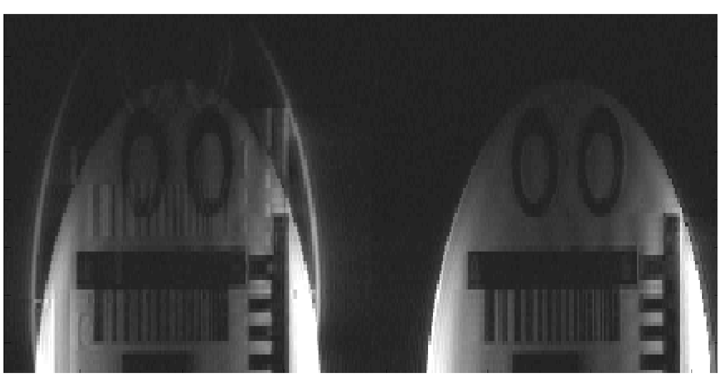

Figure 3 Motion corrupted (left) and corrected (right) image. After MoCoLoCo correction, the motion artifacts are diminished.

Conclusion: The MoCoLoCo (Motion Correction by localization of contrast-agent filled orbs) method can be implemented in every sequence as a navigator block, the slices can easily be chosen in a scout image. The spheres can be detected at very low SNR, so the body coil can be used for motion detection. A dedicated coil or any additional hardware is not needed in this case. The method allows a high-resolution and ultra-fast 3D motion tracking in the scanner. The MoCoLoCo can be used prospectively and can be implemented in every scanner software environment.

References: [1] N. White et al., *Integration The Vlsi Journal*, vol. 105, pp. 91-105, 2010. [2] M. Zaitsev et al., *NeuroImage*, vol. 31, no. 3, pp. 1038-50, Jul. 2006. [3] M. B. Ooi, et al. Magn Reson Med 62:943-954, 2009. [4] W. Baumgartner et al., *PloS one*, vol. 3, no. 10, p. e3309, Jan. 2008.