An embedded single tracking camera which calculates 6DoF within the MRI

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Purpose:

Most present solutions of optical tracking systems for motion correction in MRI perform the image processing and position calculation on an external computer. This generates additional time delays. By reducing the time delay between movement and detection, faster movements could be corrected. Our first version of an embedded tracking system already contains integrated image processing and sends the calculated marker positions to an external computer for further calculations [1].

This system is based on three cameras, where each camera calculates the position of one retroreflective marker and sends the calculated positions to an external computer for further processing.

The real time behavior and integrability of the tracking system can be clearly improved by avoiding the external computer and reducing the three camera system to a single camera system.

The measurements show that it is possible to develop an MR-compatible embedded single tracking camera with integrated image processing and calculation of 6 DoF.

Methods:

The test system is essentially based on hardware of our first tracking system. The firmware was developed to improve the tracking behavior of the three-camera-system. It is based on Daniel F. DeMenthon's POSIT algorithm [2] and calculates the 6 DoFs of a three-point-marker model. The current microprocessor can perform the algorithm up to 260 times per second.

The embedded single tracking camera was mounted on a plastic ring which was fixed above an 8-channel head coil (Rapid, Wurzburg) at the patient's table of a 7T MR scanner (Siemens Magnetom) and a three point marker model was mounted on a phantom inside the coil.

For initial testing, we performed a cross calibration and corrected phantom movements between scans (translation in z-direction (11 mm) and rotation around y and z (7 deg)) using the position lock functionality of the Xpace Library.

Results:

Without scanning, the standard deviation (SD) of the tracking noise is less than 20 µm for the translations in X- and Y-direction. In Z-direction it is about a factor 4 worse. The rotation around the Z axis has a SD of 0.05°, the rotations around X and Y-axis have SDs about a factor 4 worse. Due to the high SDs of the Pitch and Yaw angles and the Z translation, artifacts are produced in the MR image, when prospective motion correction of a resting phantom is done using the Xpace library [3]. The calculation of the rotations is not yet optimal and has a deviation of up to +- 4 ° over the whole area of the image sensor.

The tests using the position locking between separate scans result in corrected images with shifts of <4 mm (correction of a 11 mm translation in z-direction) and <2 deg (correction of a 7 deg rotation around y and z) relative to the original images due to non-optimal calibrations.

Discussion and Conclusion:

The application of a simple three-point-marker model may be an alternative to the present methods of optical systems. By replacing the current image sensor with 60Fps with an image sensor with e.g. 240Fps, it will be possible to average the positions and thus reduce the tracking noise to an acceptable level while keeping the current latency. Also, more advanced methods to calculate the positions of the markers could be applied e.g. by considering the diameters of the marker. Additionally, more than 3 markers could be tracked.

The current lens has a high radial and tangential distortion which could not be removed completely by the distortion correction.

Reference:[1] Schulz et al., MAGMA 2012 [2] D. DeMenthon and L.S. Davis, International Journal of Computer Vision, 15, pp. 123-141, June 1995 [3] Zaitsev et al., Neuroimage 2006