First experiences with a Time of Flight (ToF) Camera for marker-less motion tracking within a 7 Tesla MR scanner

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Introduction: To prevent motion artefacts in magnetic resonance (MR), prospective motion correction, i.e. the real-time adaptation of measurement parameters to rigid-body subject motion, can be applied. To measure a motion, marker-based optical tracking systems have shown great potential[1-3]. Nevertheless, to avoid the additional effort of fixing the markers to a patient and potential problems due to inadequate marker fixation, a marker-less tracking system would be desirable. Here, we report initial proof-of-principle experiments using a modified Time-of-Flight (ToF) camera within the bore of a 7T MR scanner. ToF sensors emit light pulses, and measure the distance to a surface from the phase shift of the reflected light pulse. Thus, each pixel of the ToF image contains depth information. From these images, position information for prospective motion correction can be determined.

Fig. 1: Modified and shielded ToF camera.

Methods: To achieve proper functioning of a USB-compatible ToF camera (PMD Technologies GmbH, 160×120 pixels, ≤ 90 Hz) in the MR environment, some modifications were necessary. To transfer USB 2.0 data over a distance of 12 m, a unitronic twinax 2x20awg cable with 105 Ω impedance was used.

Remote powering was realized by two 12m-long BNC cables, an external power supply outside the magnet room and a 5V linear regulator connected ahead of the ToF camera. As the original internal voltage regulator of the ToF camera was not MR-compatible, it was replaced by two MR-compatible linear regulators.

The USB 2.0 specifications require an impedance of 90 Ω, so the impedance was adjusted with 7.5 Ω resistors connected in series. The camera was placed within an RF casing shielded with a 50-µm thick aluminum film, and the shield of the casing was connected to the three cables [Fig. 1].

For the test inside the MR scanner (MAGNETOM 7T, Siemens), the camera was fixed to a mount above a head coil [Fig. 2]. A program was created to visualize the data. We tested the camera for additional RF noise, and checked whether the camera still worked during image acquisition with a standard GRE sequence.

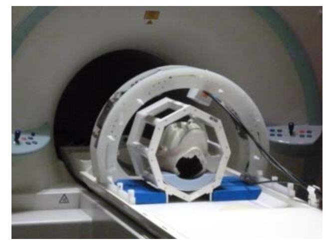

Fig. 2: The modified ToF camera is fixed to a plastic mount above the head coil and tracks a model head.

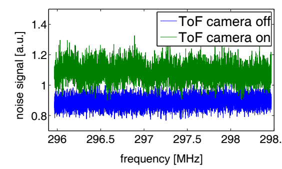

Fig. 3: Results of the RF noise tests with the ToF camera on (green) and off (blue). The average noise is increased by 22% and the standard deviation by 53% when the camera is switched on.

Results: With the modifications, the depth information could be transferred over a distance of more than 12 m via USB 2.0. The RF noise test revealed a subtle uniform increase of image noise [Fig. 3]. Moving the ToF camera into the bore of the magnet appeared to modify the depth data, which became flatter [Fig 4]. Additionally, a humming acoustical noise was audible. During the GRE measurement, increased fluctuations in the depth data were observed.

Discussion: A commercially available ToF camera was successfully modified so that depth information could be transmitted from a position close to the magnet's isocenter even during scanning. To fully understand the alterations of the depth data after positioning the camera inside the magnet and the observed humming, further investigations are required. One possible reason for both phenomena may be additional rapidly-changing magnetic fields within the sensor due to pulsating currents in the wire to the IR-LED. The noise in the depth data during scanning may be caused by eddy currents in the aluminum block which serves as a cooling element and mount for the electronics in the ToF camera. In conclusion, we believe that, in principle, prospective motion correction without markers is possible with the ToF technology.

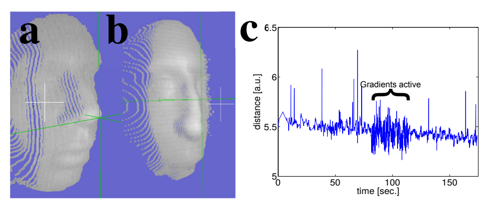

Fig. 4: Depth data outside (a) and inside (b) the magnetic field. The depth information is flattened due to interactions with the B0 field but the nose can still be tracked. (c) The tracking noise with and without active gradients.

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