An MRI Compatible Surface Scanner

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Purpose: Deterioration of images due to motion is a continuing problem in medical imaging, especially fMRI, diffusion and dynamic PET where SNR is challenging and motion can be confounded with physiological change. Many motion correction techniques have been suggested but no single device or method solves the problem in routine clinical use. In this work, we propose the hardware design of an optical surface scanner for in-bore monitoring and markerless tracking of surfaces. It is the first remote structured light scanner that transmits projected patterns onto the subject and captures their images through optical fiber bundles. This technology, together with fast surface reconstruction algorithms and algorithms that separate rigid and non-rigid transformations, allows e.g. real-time motion correction feedback without the use of MR navigators or optical markers.

Methods: The presented device is designed to produce real time in-bore surface scans. To achieve a compact, RF noiseless, and low attenuation device, the electronics are separated from the optical end by two 670×500 image fibers of 2.7 m. Only a minimum of components are located in-bore, while the potentially RF emitting and ferromagnetic components are kept out of the bore.

The system consists of four parts: 1) a computer located outside the magnet room, 2) a power management unit, also outside the scan room, 3) a system box comprising a CCD camera with a near infrared (NIR) sensitive sensor, a DLP light projector, reengineered to project invisible NIR light, and optical data extenders, 4) two image fibers, and camera optics which extend from the system box into the magnet bore and transfer the projection image into the bore and the captured image out.

The system box is shielded for RF and is placed behind the magnet. It is custom made with a wooden frame covered by a 1 mm copper shield. The system box also contains fiber-optic data connections to and from the computer. 5/12 V DC power is supplied through capacitive filters, to avoid high frequency RF noise.

The system was set up on the Siemens mMR Biograph 3T scanner to demonstrate its feasibility in the narrow in-bore geometry further challenged by the limited view of the standard mMR head coil. The MRI compatibility of our system was initially tested by acquiring MPRAGE and EPI sequences of a phantom with the surface scanner: off/out-bore, on/out-bore, and on/in-bore, respectively.

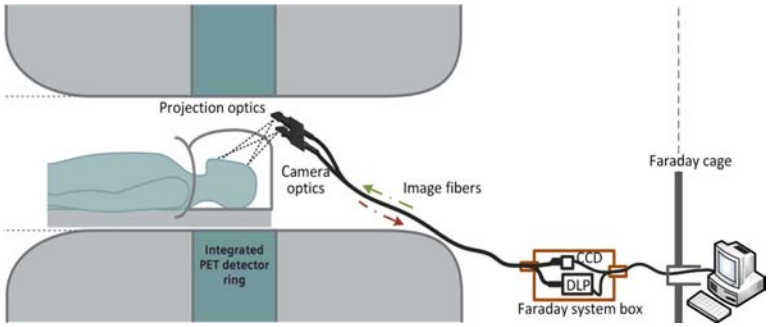

Fig. 1. Drawing of the developed structured light system integrated with the mMR Biograph. In-bore: the optical end facing a subject's head through the coil. Out-bore: optic fibers transmit images to and from the RF shielded system box (located outside if permitted by the room layout).

Results and Discussion: Fig. 2 shows two snapshot surface scans of a volunteer obtained using our device. The reconstructed point clouds are based on the non MRI compatible system [1]. Fig. 3 shows the effect on a MPRAGE sequence of having the surface scanner off/out-bore (left) compared to on/in-bore (mid). The difference image (right) shows no signs of suceptibility induced distortion. The effect on the uniformity is investigated by determining the SNR from two EPI volumes with equal sequence parameters [2]. The SNRs are 227.3 (off/out-bore), 227.7 (on/out-bore), 226.3 (on/in-bore), i.e. no impact on image SNR.

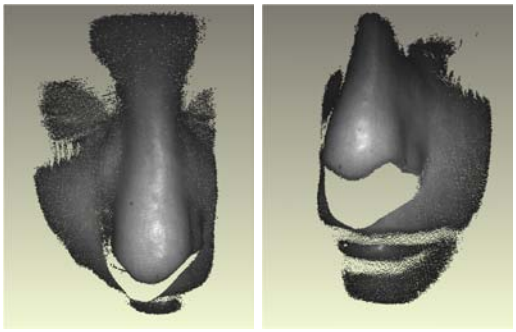

Fig. 2. In-bore surface scans of a volunteer's face (point clouds with texture overlay).

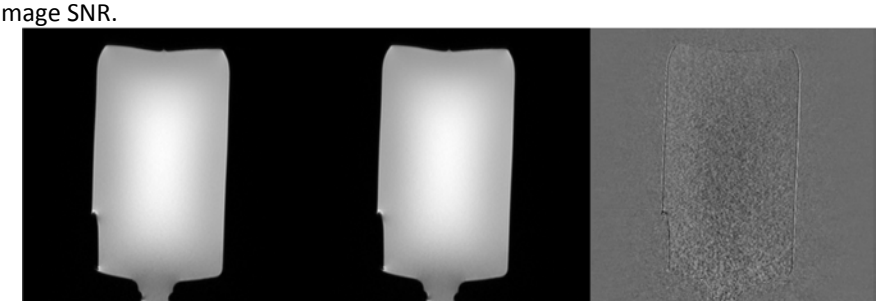

Fig. 3. MPRAGE images of a cylindrical phantom. Left to right: surface scanner off/out-bore, on/in-bore, difference of the first two images (normalized scale as the original scale

Conclusion: We have presented a remote surface scanner suitable for in-bore applications. The system design was shown to be MRI compatible and functional on the Siemens mMR Biograph.

References:

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2. Quality assurance methods and phantoms for magnetic resonance imaging: Report of AAPM nuclear magnetic resonance Task Group No. 1, *Medical Physics,*1990; 17: 287; doi: 10.1118/1.596566.