Automatic scan-plane prescription by optical instrument tracking: proof of concept in a closed-bore MRI

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Introduction/Purpose

MR fluoroscopy allows the radiologist to guide and control percutaneous interventions in the magnet of wide-bore [1] and open scanners [2]. Usually, slice position and orientation are adjusted manually when the instrument is moved out of the scan plane [2]. If orientation and position of the instrument are continuously determined, this information can be used to automatically position the slice along the instrument. This essentially requires a tracking system and a real-time pulse sequence with an (external) update mechanism for the slice geometry. In comparison with previously implemented systems [3, 4], we present a passive optical tracking concept with a special referencing scheme that permits to flexibly adjust the camera position (even during scanning) to establish proper line-of-sight for instrument tracking.

Materials and Methods

Figure 1 illustrates the optical tracking technique and special referencing scheme. A test system was implemented in a conventional 1.5-T scanner (Fig. 2, Magnetom Symphony, Siemens). Near real-time MR tracking was based on a dedicated pulse sequence with real-time control of various scan parameters (Siemens, BEAT IRTTT, FOV=300×300 mm, TR/TE=4.3/1.9 ms, slice thickness 8 mm, acquisition time 600 ms). An external workstation (Localite, St. Augustin, Germany) continuously received the tracking coordinates of the instrument (here: 16G, 115 mm coaxial needle, Invivo) and computed corresponding MR scan planes according to a selected needle plane. These MR parameters were sent every 600 ms to the real-time pulse sequence via a TCP/IP socket interface (Siemens). The near real-time images were then displayed on the in-room console (Fig. 2).

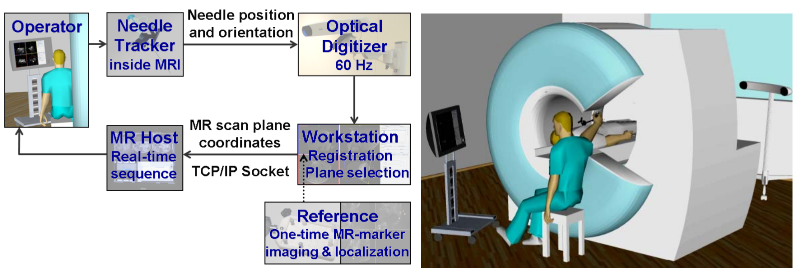

Fig. 1: Left: Fundamental principle and related components. The needle is attached to an optical tracker with three reflective spheres. A commercial digitizer (Polaris Spectra, NDI) tracks the instrument coordinates with respect to a set of reference markers in the bore. MRI registration of the board position was established by a one-time, fast (<30 s) and automatic localization of three MR markers [5]. **Right:** Schematic overview of in-room components for test implementation in a closed-bore scanner. The camera stand was placed at the scanner's front end and could be rolled to establish line of sight with the optical reference.

Fig. 2: Proof of concept for automatic scan-plane prescription. **Left**: The procedure is performed from the scanner's back end and guided by near real-time MR images along or perpendicular the instrument that are displayed on the in-room console. **Right:** View from the opposite end with tracker and reference board inside the bore. Inset illustrates layout of the phantom with targets (peas, mean Ø 8.5 mm) and vessel model embedded (here: partially) in opaque glaze.

Results

For our test implementation in a closed-bore scanner, access and instrument control from the back end of the scanner did not interfere with instrument tracking from the front end. Line-of-sight problems could be avoided by adjusting the camera position. Needle orientation, insertion, and approach were performed inside the scanner under near real-time imaging control using one update every 600 ms. The approach to some targets was complicated by having to avoid the puncture of one of the model vessels. A sample target approach is shown in Figure 3.

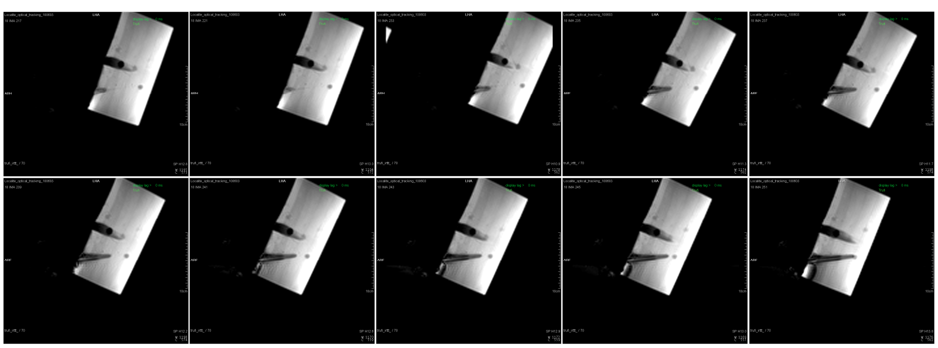

Fig. 3: Representative time series of near real-time images obtained during target approach. For image guidance, the operator could choose between three different planes (in-plane 0°, in-plane 90°, perpendicular) or an arbitrary alternation between two of them. The peas impose as hypointense round objects. On each of the images, the artifact of the coaxial needle is clearly seen with respect to the surrounding "anatomy" along the path, in particular, the model vessels (static hypointense object). Image acquisition time was 600 ms.

Conclusion

The concept of optical instrument tracking inside the bore has been described and used before, often in low or mid-field open scanners with horizontal and vertical magnet gaps. The use of cordless markers and the introduction of a specific reference set, as described here, seem to considerably add to the flexibility of such a technique. The user is not limited by the specific design of the scanner to integrate a fixed camera, by having to maintain a standard (calibrated) position of an externally placed camera, nor by potential line-of-sight problems occurring for a specific procedure or patient. The successful test of an optical MR tracking technique in a long and narrow cylindrical scanner suggests that the concept also holds promise for potential implementations in wide and open bore scanners, which are more likely to be used for real applications.

References [1] J. Stattaus et al., J Magn Reson Imaging 2008; 27:1181. [2] F. Fischbach et al., Cardiovasc Intervent Radiol 2011; 34: 188. [3] S.G. Silverman et al., Radiology 1995; 197:175. [4] J. S. Lewin et al., AJR 1998; 170:1593. [5] H. Busse et al., Magn Reson Med 2010; 64: 922.