A Method for Automatic Localization of Wireless MR Reference Markers: Feasibility and Accuracy

H. Busse[1], R. Trampel[1], W. Gründer[2], M. Moche[1], and T. Kahn[1]

[1]Diagnostic and Interventional Radiology, Leipzig University Hospital, Leipzig, Germany, [2]Medical Physics and Biophysics, Leipzig University, Leipzig, Germany

Introduction/Purpose

Magnetic resonance (MR) imaging can provide excellent image guidance for dedicated interventions. Most percutaneous interventions, however, may not be performed under real-time imaging control inside the magnet because of the spatial confinement in closed-bore scanners. Partially working outside the scanner requires the co-registration between the patient anatomy and the MR image coordinates and suitable reference elements, in particular, inside the magnet. Most MR reference markers are the result of research developments and require the choice of an appropriate signal source/receiver (material with special magnetic properties, contrast medium, RF coil) and the design of corresponding pulse sequences and image processing algorithms. We propose a novel method for the 3D localization of wireless passive MR markers (inductively coupled RF coils [1]) in combination with a self-developed 2D morphological image processing. The purpose of this work is to evaluate the feasibility and accuracy of such an approach.

Materials and Methods

Inductively coupled RF coils tuned to 63.9 MHz and wound around a tube filled with contrast solution were used as signal source (Fig. 1, inset). The experimental setup consisted of three reference markers that could be accurately positioned on a 2D base plate placed over a background phantom (two bottles filled with doped water). All experiments were performed on a whole-body 1.5 T scanner using the body coil and two conventional gradient echo sequences (FLASH, TR/TE=14-20/6.9 ms and TrueFISP, TR/TE=3651/2.85 ms) with a 300-mm FOV, a 512-matrix, and a slice thickness of 300 and 200 mm, respectively.

The automatic localization algorithm is based on locally fitting 2D Gaussian profiles to signal distributions in previously segmented regions of a fully reconstructed MR image (Fig. 2). The precision of the 2D algorithm was estimated by analyzing 30 MR images of the same marker using three number of signal averages at 10 flip angles in the previously optimized 0.5-1.4° range. Reliability and accuracy were evaluated by comparing the measured with the selected marker positions at different (n=72) distances (max. 130 mm) from the isocenter by moving the markers along the *x* and *z*-direction, respectively (Fig. 1). The error in 3D position was estimated by data from orthogonal planes, the angular offset by the normal vectors of the respective planes defined by three markers.

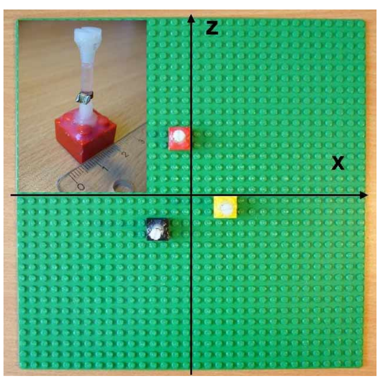

Fig. 1: Experimental setup and inductively coupled RF coil (inset).

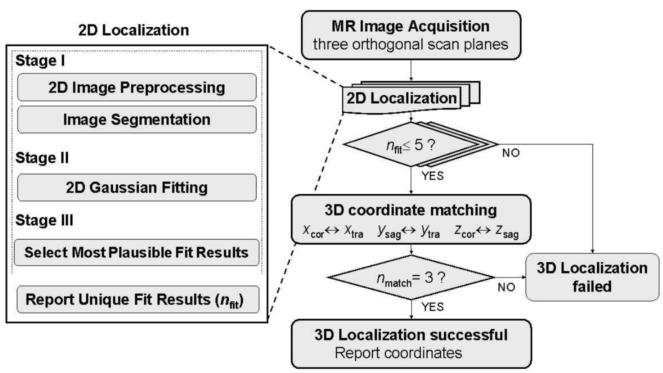

Fig. 2: Flow chart of 3D localization algorithm. Morphological 2D localization is performed for three orthogonal scan planes.

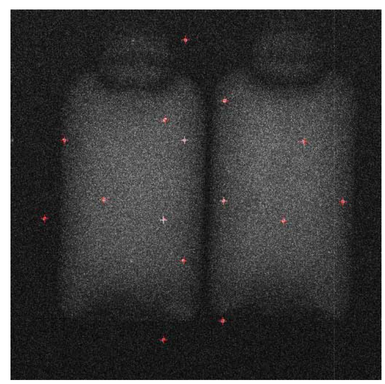

Fig. 3: Overlay of localized markers at different FOV positions.

Results

Marker detection was very reliable and exactly three markers were detected in all coronal images (Fig. 3). The reproducibility of localizing a single marker yielded an average (maximum) deviation in 2D position of 0.05±0.03 (0.15) mm, much smaller than the pixel dimension (0.59 mm). The measured accuracy of the marker configuration at different positions within the FOV yielded absolute deviations in 2D of 0.51±0.29 (1.20) mm. The estimated error in 3D position was 0.86/1.65 mm (average/maximum) for up to 100 mm from the isocenter; the maximum angular offset was 0.44° at a 165-mm distance of the marker centroid (not shown here).

Discussion and Conclusion

A 2D morphological image processing based on 2D Gaussian fitting of segmented signal distributions is a feasible solution to reliably determine the 3D localization of appropriate MR reference markers. It should be noted, that the implemented algorithm makes no assumption on the number nor the position of the markers. The localization concept yielded very precise and accurate results which make it a promising and simple solution for MR-guided interventions, in particular, because no dedicated pulse sequences or imaging coils need to be used. In its present form, it is not suited for tracking applications because of the time requirements for the acquisition and full reconstruction of a 2D image. In comparison with active MR markers, however, inductively coupled RF coils are considered a flexible (no strings [2]) and safe (wireless, i.e., no RF heating [2,3]) approach for patients.

References

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