Motion Compensated Catheter Tracking

C. O. Schirra[1], R. Boubertakh[1,2], R. Razavi[1], and T. Schaeffter[1]

[1]Interdisciplinary Medical Imaging Group, Division of Imaging Sciences, King's College London, London, United Kingdom, [2]Center for Medical Image Computing, University College London, London, United Kingdom

Introduction

There is growing intrest in recent years in the use of real-time MRI instead of X-ray fluoroscopy for intravascular interventions. Since MRI is a tomographic modality, fast and reliable catheter-tracking techniques are highly desirable. Active MR-catheter tracking is based on the use of a micro-rf-coil for MR-signal reception and the acquisition of orthogonal projections [1]. Recently, a safe transmission line was proposed that avoids any rf-heating [2] and thus will enable safe determination of the catheter position in patients in the near future. A common method of visualising the real-time catheter position is to overlay it on a pre-acquired respiratory-gated 3D-dataset (roadmap). A drawback of this approach is that motion during data acquisition results in errors in the displayed position of the catheter. Navigator-techniques have successfully been applied to motion-gating [3] or for a motion-compensated image-acquisition [4]. In this work, we propose a motion-corrected catheter tracking method that allows simultaneously acquisition of the catheter position and motion state of the body. In particular, projection data received by imaging coils are used for motion gating and motion correction. The method has been tested on phantoms and in volunteer experiments.

Methods

All experiments have been performed on a 1,5 T Achieva system (Philips Medical Systems). For signal reception multi element array-coils (phantom: 2 elements volunteer: 4 elements) were used. The micro-coil of an active tracking catheter (Cordis) was connected to a separate receive channel. For catheter and motion tracking three gradient-echoes (three orthogonal directions) after an excitation rf-pulse (TR=10ms, 512 pixel, 1mm resolution) were repeatedly acquired. Long gradient slopes are used to minimize acoustic noise due to gradient switching. Continuous tracking was performed for over 30 seconds. The setup allowed simultaneous acquisition of the signals received by the micro-coil and the large imaging coils (Fig. 1). The signal of the micro-coil was used for catheter-tip localization by determining the peak position in the spatial domain. The projection signals received by the imaging coils were used to derive the object displacements by using cross-correlation function with respect to a reference time point (Fig. 3). Furthermore, in in-vivo experiments the intensity variation of the projection is used to derive a signal for ECG-gating. The estimated displacements are used either to gate the acquired data or to correct for motion using a rigid body model. The gated or corrected positions are displayed on a MIP of a 3D dataset.

Fig. 2a shows the setup of the phantom experiment, where the catheter-carrying tube was angulated 45 degree in respect to the motion direction. First, a high-resolution 3D dataset was acquired without motion. Afterwards, catheter and motion tracking was performed, while moving the catheter and the patient table. The acquired motion information was used to correct for the displacements of catheter position due to table motion. In order to test the technique in an in-vivo situation, a tube containing the catheter device was placed on the abdomen of a volunteer. A high-resolution 3D image was obtained using a breath-hold acquisition (exhale position). Afterwards, the catheter/motion tracking sequence was performed during normal breathing and moving the catheter. The obtained motion information was used for respiratory gating of the acquired catheter positions.

Results

The phantom scan shows the feasibility of the method to compensate rigid body motion to reduce catheter positioning errors due to table motion Fig 2b. Both the mean error and standard deviation between the catheter position and the center-line of the phantom tubing improved significantly (see Tab. 1). The standard deviation of the displacment error during motion compensation of 0.78 mm is in the order of the diameter of the tube (diameter 1.5 mm). Thus measurement and corection of the phantom/body motion by this technique allows accurate positioning of the active catheter.

Fig. 4 shows a MIP with the catheter position overlayed in the volunteer examination. The gated catheter position (green) remains within the tube while without gating the cather leaves the tube (red). This simulation of an "in-vivo" situation, demonstrated that projections are suitable for estimating the respiratory motion. Furthermore, the intensity variations of the projections allow the estimation of a signal for ECG-gating. For in-vivo motion correction, a motion model has to be derived [6] that correlates the displacement of the projections with the displacement of the tube.

Conclusion

Motion compensated catheter tracking improves the accuracy of the catheter trajectory. The phantom scan proved the general feasibility of motion correction, with considerable reduction in the positional error. Motion-gating was successfully applied in the in-vivo experiment. Motion correction of in-vivo scans require a motion-model that will be investigated in the future.

References

[1] Dumoulin C L, et al. MRM 29, 411-415 (1993), [2] Weiss S, et al. MRM 54, 182-9 (2005), [3] Ehman RL, Felmlee JP. Radiology 173(1):255-263 (1989),
[4] Nehrke K, Bornert P. MRM 54; 1130-8 (2005), [5] Larson AC, et al. MRM 51, 93-102 (2004), [6] Manke D, et al. IEEE Trans Med Imaging. 21, 1132-41 (2002).

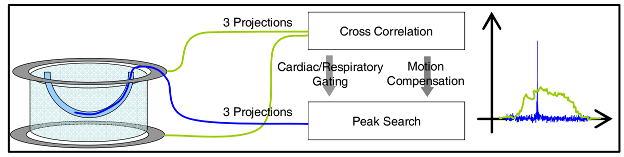

Fig. 1 Setup of phantom experiment. Peak search yields the catheter position (blue). Object motion is determined by correlating object projections (green).

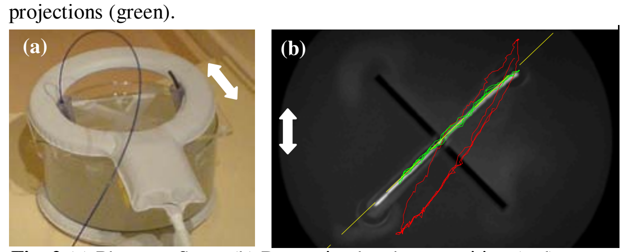

Fig. 2 (a) Phantom Setup (b) Determined catheter position (red) without motion- compensation. Motion compensation improves the position estimation significantly (green). Center line of the guiding tube (yellow).

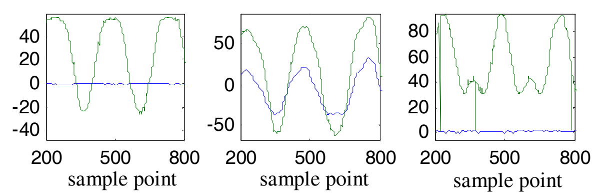

Fig. 3 Catheter positions [mm] (green) and object displacements [mm] (blue) over time (sampling τ=10ms)

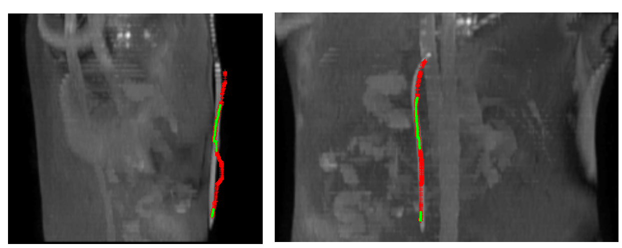

Fig. 4 The volunteer scan proves the feasibility of using projections in order to apply motion compensation. The images show an ungated (red) and gated (green) catheter trajectory.

	uncompensated	Motion Compensated
mean error/mm	15.7138	1.1937
standard deviation/mm	8.7723	0.7774
maximum error/mm	29.0701	3.6077

Tab. 1 Comparison between compensated and uncompensated catheter tracking.