Evaluation of a multi-modal passive and active tracking approach for real-time automatic scan plane alignment in interventional MRI

Markus Neumann[1], Elodie Breton[1], Loic Cuvillon[1], and Michel de Mathelin[1]
[1]*ICube, Université de Strasbourg, Strasbourg, France*

TARGET AUDIENCE – Interventional radiologists and engineers for interventional radiology

PURPOSE – Accurate and fast automatic scan-plane alignment has the potential to severely accelerate percutaneous MR-guided interventions such as ablations, biopsies and infiltrations. Several active[1,2] and passive[3,4] tracking approaches have previously been presented for automatic scan plane alignment. Inherent drawbacks of active approaches are either dedicated tracking pulse sequences, heavy additional instrumentation, or need for an unobstructed line-of-sight when camera systems are used. Passive approaches often require dedicated tracking images, slowing down the procedure. Combining active and passive approaches would thus allow to join their individual advantages in order to compensate for their drawbacks. In this work, a hybrid tracking workflow is developed, combining MR image tracking of a passive marker and RGB-D (red green blue - depth) sensor images for real-time automatic scan-plane alignment.

Fig.1: Multi-modal tracking target consisting in a passive MRI marker surrounded by 2 pink balls.

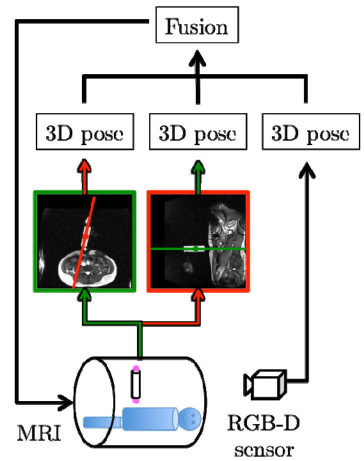

Fig.2: Multi-modal workflow: Pseudo axial (green) and sagittal (red) MR scan planes are alternatively acquired. RGB-D sensor based and MR image based detection results are fused and scan planes are accordingly aligned to the tracking target.

METHODS – All experiments are performed in a 1.5T system (MAGNETOM Aera, Siemens) using an interactive, real-time, multi-slice SSFP sequence[5] (FoV 450mm, TE/TR 2.2/4.1ms, FA 50°, ST 5mm, refresh rate 900ms). A program performs the implemented workflow (both MR and RGB-D image reception & processing, scan-plane control) on an external PC connected to the MRI console PC and to the RGB-D sensor. The RGB-D sensor is positioned in the back of the MRI scanner capturing the scene inside the MRI tunnel. The tracking target consists in a contrast-agent (Gd-DTPA) filled cylinder with 2 pink balls attached at its distal ends in order to be simultaneously detectable in MR and RGB-D sensor images (Fig.1). The proposed workflow controls 2 alternatively acquired orthogonal real-time MR scan planes aligned to the marker axis. For this purpose, the 3D marker pose is detected in both modalities and then fused using an Information Filter (IF). Based on the predicted marker pose from the IF, a marker-aligned scan-plane is calculated and the corresponding command is sent to the MRI console PC (Fig.2). One strength of the workflow is that when detection fails in one modality, the IF uses the available measurements from the other modality. A dynamic online registration procedure is performed in the beginning of the workflow in order to transform detected 3D marker poses from the RGB-D sensor to the MRI frame: 20 detected marker positions are acquired in both modalities (matched points) in order to determine the rigid transformation between MRI and RGB-D sensor frames. As this transformation is unknown in the beginning of the workflow, tracking is performed based on MR images only[6]. As soon as a valid transformation has been found, the workflow switches to hybrid mode, where tracking is performed by fusing measurements of both modalities. Quality of the registration depends heavily on the spatial distribution of the matched points. Therefore, during the entire intervention, the 20 matched points that are used for registration are evaluated with respect to newly acquired points and replaced if registration quality is improved. Registration quality is assessed with the root mean square error (RMSE) between the point set acquired in the MRI frame and the corresponding one in the RGB-D sensor frame, back projected to the MRI frame with the current rigid transformation.

RESULTS – Registration quality of 14 workflows (mean duration 1.5 min) performed by a user displacing the tracking target was evaluated by computing the RMSE of the 20 matched points used for registration. A mean RMSE of 7 mm was obtained. Note that this RMSE characterizes the registration quality and not the overall tracking performance of the system. An initial rigid transformation was typically obtained after ~70 s, depending on the displacement of the user.

DISCUSSION – The proposed hybrid workflow combines the high frame rate of an RGB-D sensor with a slower MR image based tracking approach that allows for online registration and can function independently in case of camera obstruction. This workflow could be easily integrated in the clinical workflow as only little additional instrumentation is needed (RGB-D sensor and wireless marker) and no explicit calibration step has to be performed. Dynamic registration allows using the workflow as a passive tracking system until registration has converged and the system is switched to multi-modal operation.

CONCLUSION – The presented hybrid workflow combines through an IF the tracking performance of a passive approach based on MR images and an active approach based on an RGB-D sensor. Promising experimental results in terms of registration quality between MRI and RGB-D sensor frames have been obtained. The tracking target could be used as a real-time imaging probe.

REFERENCES – 1. Qing K. et al. "A multi-slice interactive real-time sequence integrated with the EndoScout tracking system for interventional MR guidance," ISMRM 2010:1860; **2.** Viard R et al. "Needle positioning in interventional MRI procedure: real time optical localisation and accordance with the roadmap" EMBC 2007:2748-2751; **3.** de Oliveira A et al. "A New System for Passive Tracking of a Prostate Biopsy Device with Automatic 3D Needle Position Estimation." ISMRM 2008:3003; **4.** Maier F et al. "3D Passive Marker Tracking for MR-Guided Interventions" ISMRM 2011:3749; **5.** Pan L et al. "An Integrated System for Catheter Tracking and Visualization in MR-Guided Cardiovascular Interventions", ISMRM 2011:195; **6.** Neumann M et al. "Evaluation of an Image-based Tracking Workflow with Kalman Filtering for Automatic Image Plane Alignment in Interventional MRI", EMBC 2013: 2968-2971