Robust Computer Assisted Catheter Tracking Algorithm in MR using Gradient Based Signatures and Mean Shift Localization

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Introduction: MR guided intervention is becoming an attractive imaging modality for the guidance of endovascular interventions. These interventions can be greatly facilitated by the incorporation of an automatic MR image acquisition and visualization scheme. In order to achieve this autonomy, an automatic detection and tracking of the interventional instrument is necessary. A common approach to perform the tracking is to rely on passive markers such as nano-particles [1] and resonant circuits [2]. Unlike active tracking [3] methods, passive tracking is easy to implement with low cost but it lacks the ability to provide an automatic feedback of the absolute catheter coordinates. We present a robust algorithm to automatically track catheters marked with resonant circuits during interventions.

Material and Method: The approach proposed here is a probabilistic approach where a probability map is generated over each MR frame acquired during the catheterization. This probability map is based on the similarity to given marker model (template) and it indicates the likelihood of the existence of the catheter tip at a particular location. The method to assess the similarity between the marker template image and the different sites on each MR frame is based on features extracted from the gradient image, Speeded-Up Robust Features (SURF) [4]. Once the probability map is generated it can then be used in a stochastic localization. In this algorithm it was employed in a Mean Shift localization [5] to track the catheter in the sequence of MR images.

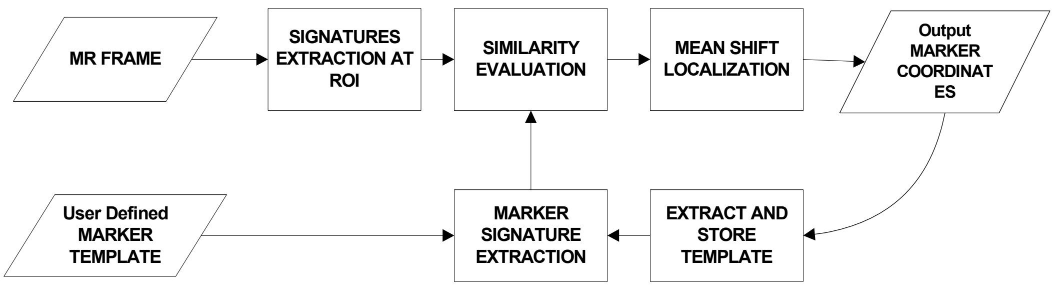

Figure 1: Schematic diagram of the tracking Algorithm

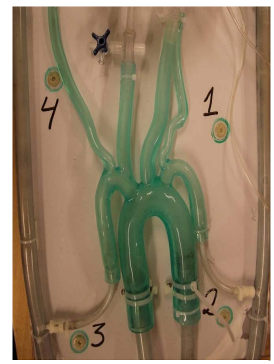

Figure 2: phantom used in tracking

The algorithm developed was tested on LC resonant markers tuned to the larmor frequency of a 3T scanner (128 MHz). A circuit configuration of single loop coil with rectangular shape is assumed (length=2.5cm, width=0.35cm, wire diameter=0.35mm). The coil was soldered to a 47 pF capacitor and the resonant circuit was attached to the tip of a 5F size catheter. The catheter was then introduced into a vessel-like phantom filled with water. The catheter was slowly moved inside the phantom while a series of images was acquired.

The images acquired are RF spoiled T1-weighted FFE (TR/TE/FA= 2.1ms/1.2ms/2 degrees) with a field of view of (400 x 400 mm) and construction matrix of size (400 x 400) yielding a resolution of (1 mm). The Slice thickness was set to (4 cm), and a de-phasing gradient (of 1 cycle per 2 cm thickness) was applied after the excitation to weaken the background signal. Parallel imaging (SENSE) was used and the images were acquired at a frame rate of (352ms). The detection and tracking algorithms was performed on the images off-line.

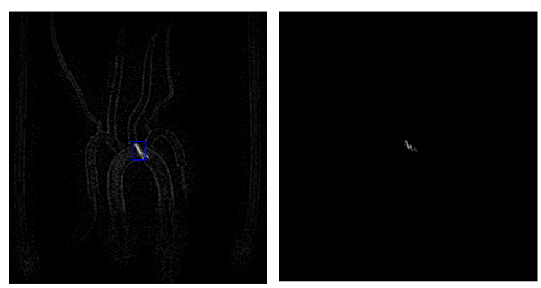

Figure 3: MR frame (left) and the associated probability map (right)

Results and Discussion: The results showed that the tracking algorithm was quite robust, and a discrepancy between the automatic algorithm output and manual human localization on each MR frame was (2.7 mm) on average. Given the relatively large slice thickness used in imaging, this result can be considered acceptable and sufficient for guiding an automatic image acquisition. Also difficulties in detecting the marker's location that may arises if the background signal is relatively high can be overcome by reducing the thickness of the projection. The processing time of the algorithm was about (400 ~ 500 ms). The overall processing time can even be reduced further and brought closer to real time with a specialized processing engine, and by reducing the resolution of the image processed.

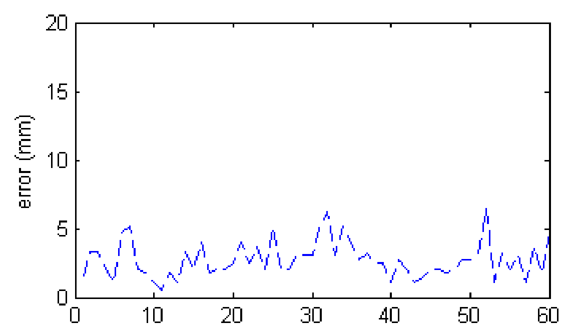

Figure 4: The distance between the output of the automatic tracking and the human manual localization at each time MR

Future Work: In the next step, we will test this algorithm on MR images acquired online and we will use the output of the tracking to drive the MR scanner and control the image acquisition. In addition we are working on registering the output of the catheter tracking into 3D vessel model. This model is generated from pre-operative MR and is being updated and deformed in real time from intra-operatively acquired MR images.

References: [1] Seppenwoolde JH, et al. Magn Reson Med 2003; 50:784–790. [2] Quick HH, et al. Magn Reson Med 2005; 53:446-455. [3] CL Dumoulin, et al. Magn Reson Med 1993; 29: 411-415. [4] Bay H, et al. CVIU 2008; 110(3):346-359. [5] Yang C, et al. CVPR 2005; 1063-6919.