3D Catheter Tip Tracking in 2D X-ray Image Sequences Using 3D Rotational Angiography

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1. Introduction

Integration of pre- or peri-operative images may improve image guidance in minimally invasive interventions. In abdominal catheterization procedures such as transcatheter arterial chemo-embolization (TACE), 3D pre-/peri-operative images contain complete 3D vasculature, which is not available from 2D imaging. Image fusion and 3D/2D registration have already been addressed in the literature [1,2], particularly for X-ray guidance in abdominal interventions [3]. These methods rely on structures such as bones or the vasculature, they consist in aligning 3D vessels (extracted from 3D pre-operative image) with 2D vasculature (extracted from 2D angiographie), visualized using contrast agent. They cannot be used continuously because of the contrast agent toxicity. We propose a hidden Markov model (HMM) to track the 3D catheter tip position, using 2D fluoroscopic sequences (with no contrast) and a 3D vessel tree obtained from 3D Rotational Angiography (3DRA). Such a tracking facilitates display of the catheter in the 3D anatomy, and enables roadmapping in 2D imaging (Fig. 1).

2. Methods

Our method consists in tracking the catheter tip inside a 3D vessel tree, where the catheter position in 2D is obtained from the X-ray images. As the catheter is assumed to be in the vasculature and as its displacement is small between subsequent 2D images, we model the catheter motion within the 3D vessel tree using HMM. Each 3D point of the vessel centerlines represents a Markov state that denotes the probability that the catheter tip is at that location. Each state is linked with state transitions between connected close-by vessel parts. Observations based on a 3D/2D registration metric where the 3D vessel tree is aligned with the 2D catheter are used to update the HMM.

3. Experiments and Results

We acquired data of 19 TACE procedures (67 fluoroscopic sequences). A 3DRA was acquired at the beginning of each intervention. We evaluate our method on simulated data using 3D vessel tree from the 3DRA and projection geometry of the fluoroscopic sequence. The catheter tip is positioned at a proximal location in the 3D vessel tree, and over time the tip is advanced. The respiration is simulated along the cranial-caudal direction. We tracked the tip and registered all the simulated sequences. We obtained a median average of the 3D distance between the real tip and the registered tip, up to 2.9 mm. These distances increased when the catheter deformation is larger and when the tip moves faster. We also applied the method on two clinical sequences (Fig. 1). Visual checking showed a correct registration.

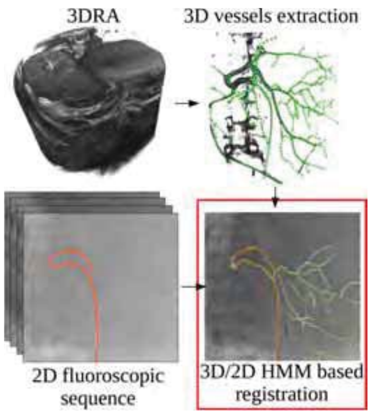

Figure 1: 3D vessel roadmap on 2D X-ray image.

4. Discussion & Conclusion

We proposed a method for tracking the 3D catheter tip in 2D fluoroscopies using an HMM and registration with the 3D vessel tree extracted from a 3DRA. According to our clinical partners, the tracking of the tip position is accurate to be used as a roadmapping and to provide the physician with an overview of where the catheter is and where to go. We evaluated the feasibility of our approach with simulated data. The method was also successfully applied in two clinical cases.

5. References

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