IMAGE REGISTRATION VIA DEEP LEARNING TOWARDS IMAGE-GUIDED INTERVENTIONS

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ABSTRACT

Clinical aim: Cardiologists highlight the need for an intra-operative 3D visualization to assist interventions. The intra-operative 2D X-ray/Digital Subtraction Angiography (DSA) images in the standard clinical workflow lack depth perception.

State-of-the-art: Compared with image-to-image registration, model-to-image registration is an essential approach taking advantage of the reuse of pre-operative 3D models reconstructed from Computed Tomography Angiography (CTA) images. Traditional optimized-based registration methods suffer severely from high computational complexity. Moreover, the consequence of lacking ground truth for learning-based registration approaches should not be neglected.

Method: To overcome these challenges, we introduce a model-to-image registration framework via deep learning for image-guided endovascular catheterization. In order to find the correspondence between a pre-operative model and intra-operative images, this framework firstly performs autonomous vessel segmentation from fluoroscopy images. A deep residual U-net architecture is employed, thanks to its fast learning convergence and efficient spatial information propagation without degradation. After that, a model-to-image matching via Convolutional Neural Network (CNN) is introduced. For this study, image data were collected from 10 patients who performed Transcatheter Aortic Valve Implantation (TAVI) procedures.

Results: It was found that vessel segmentation of test data results in median values of Dice Similarity Coefficient, Precision, and Recall of 0.75, 0.58, 0.67 for femoral artery, and 0.71, 0.56, 0.74 for aortic root. The automatically segmented network behaves better than the manual annotated one, and it recognizes part of vessels that were not labelled manually. Image matching between the transformed moving image and the fixed image results in a median value of Recall of 0.90.

Conclusions: The proposed approach achieves a good accuracy of vessel segmentation and a good recall value of model-to-image matching. The proposed framework is based on the reuse of the pre-operative model that is reconstructed from CTA images for diagnosing and size measurement, and there is no interference with the standard clinical workflow.

Future work: Future improvements include integrating augmented reality, performing user-end evaluation in the operating room, and extending to a deformable registration approach considering the vessel deformations due to the device contact during the procedure.