Deep Learning and Particle Filter-based Aortic Dissection Vessel Tree Segmentation

Yuan Jin, Antonio Pepe, Jianning Li, Christina Gsaxner, Jan Egger
Graz University of Technology, Institute for Computer Graphics and Vision

INTRODUCTION

Aortic dissections (AD) are injuries of the inner vessel wall of (human) aorta. As this disease poses a significant threat to a patient's life, it is crucial to observe and analyze the progression of the dissection over the course of the disease. The examinations of the aorta are usually proceeded with the application of Computed Tomography (CT) or Computed Tomography Angiography (CTA), based on which, automated post-processing procedures would be beneficial for the management of critical pathologies.

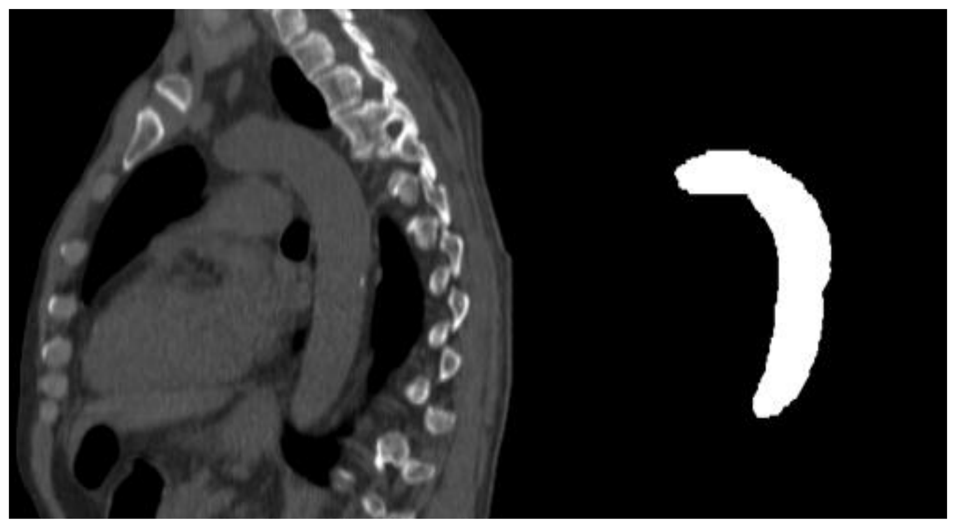

Fig. 1 Sagittal views of original (**left**) and ground truth images (**right**) for aorta segmentation. Image source from [1].

As shown in Fig. 1, the goal of our work is to explore a complete pre-operative workflow for segmenting the human aorta, with or without dissection, based on CT and CTA images from several patients.

The contribution of this work is therefore the generation of a comprehensive semantic vessel model of ADs. In doing so, it interfaces to various research fields, like patient-individual diagnosis and prognosis, finite element simulations and visual analytics. Finally, it offers radiologists the possibility to comprehensively extract and explore the multitude of aortic dissection features in order to identify discriminative patterns that are related to the course of the disease and assess their prognostic impact. The overall workflow starts with a volumetric scan of a patient suffering from AD, which will be automatically segmented, resulting in an AD segmentation mask, including the main branches, and the centerlines for true and false lumen of the aorta.

METHODS

We define a deep learning model to segment the aorta, followed by a particle filter method, which **1)** refines the initial segmentation of the deep learning method, and **2)** tracks the aortic contour to locate and segment the branches. The overall pipeline is shown in Fig. 2.

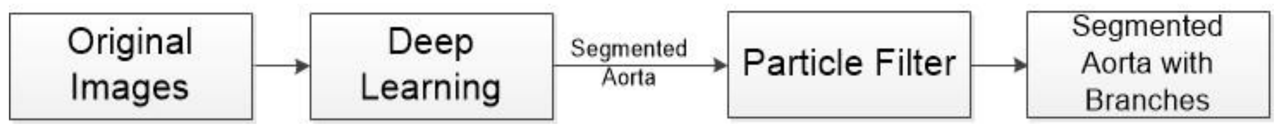

Fig. 2 Processing steps of the aorta segmentation in this work.

In the deep learning step, we employ a fully convolutional network (FCN) based on V-Net [10], in which the residual learning and dice loss function are applied to improve the segmentation performance. We also proposed one special augmentation method called aortic dissection augmentation, as shown in Fig. 3.

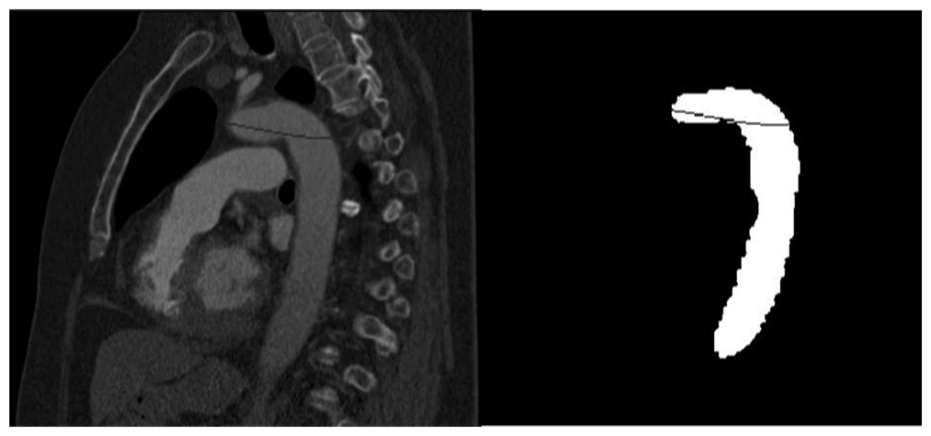

Fig. 3 Sagittal views of original (**left**) and ground truth images (**right**) with aortic dissection augmentation, in which the curve through aorta represents the dissection wall.

In the next step, we proposed to use particle filter method [14]. As shown in Fig. 4, we apply it to track voxels of aorta and branches.

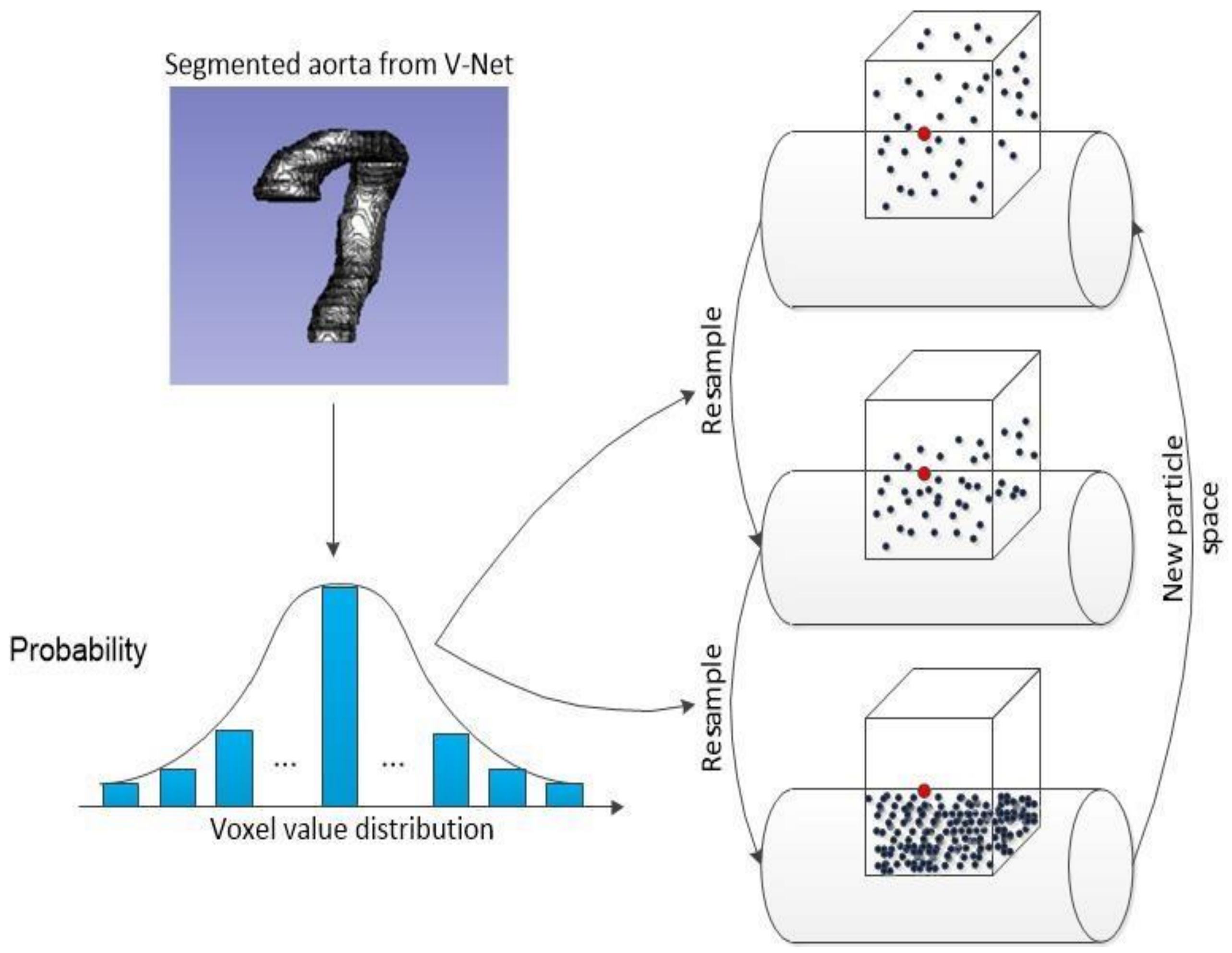

Fig. 4 Segmentation steps of particle filter method. The distribution is computed based on segmented aorta from deep learning model. The iteration of prediction and resample is repeated until most particles are on the location of vessels.

RESULTS

Fig. 5 and Fig. 6 show examples of the output from our model. Tab. 1, Tab. 2 and Fig. 8 show quantified evaluations of segmentation results based on different datasets.

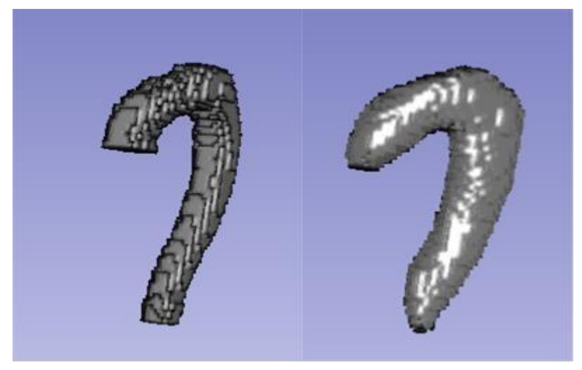

Fig. 5 Two screenshots of aorta segmentation. **Left screenshot**: Ground truth of aorta. **Right screenshot**: Segmentation results of the deep learning model.

Tab. 1 Comparison of segmentation results of the deep learning model based on different datasets.

Datasets	Augmented CT	Original CT	Augmented CTA	Original CTA
Validation error	0.243%	0.271%	0.211%	0.224%
Test error	0.255%	0.267%	0.215%	0.224%

Tab. 2. Particle filter segmentation results of CT and CTA datasets (**bottom right**)

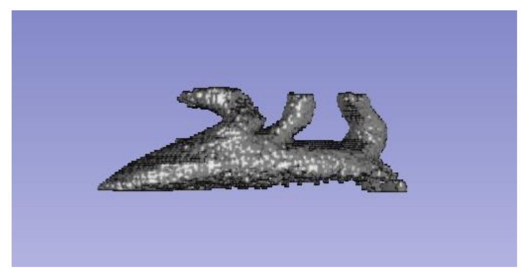

Fig. 6 Screenshot of top part segmentation for aorta with branches

Datasets	CT	CTA
Original images	40	40
Clear aorta and branches (before denoising)	28	40
Clear aorta and branches (after denoising)	40	40

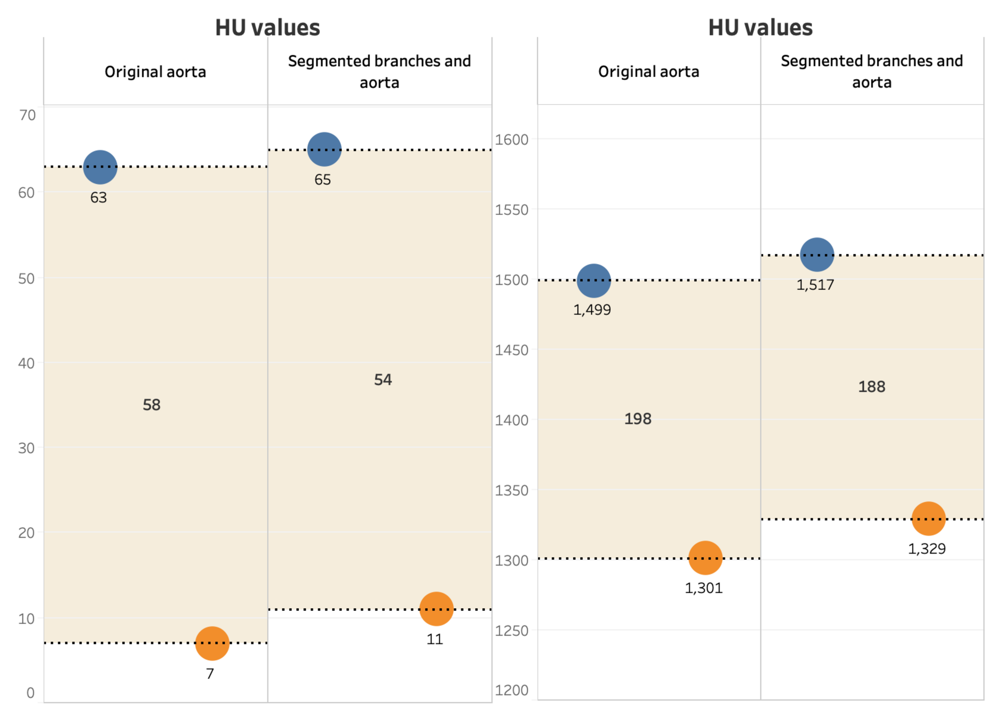

Fig. 7 HU value ranges of original aorta and segmentation result from CT (**left**) and CTA (**right**) datasets. The upper and lower dotted lines represent the maximum and minimum HU values, respectively.

REFERENCES

[1] Trullo, R. et al. "Segmentation of Organs at Risk in thoracic CT images using a SharpMask architecture and Conditional Random Fields", IEEE 14th International Symposium on Biomedical Imaging (ISBI 2017), 1003-1006 (2017).

Contact: Yuan Jin and Jan Egger (jin.yuan@icg.tugraz.at , egger@tugraz.at)