SEGMENTATION OF THORACIC AORTA 3D PC-MRI DATASET THROUGH SYNTHETIC DATA AUGMENTATION

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Introduction

Phase contrast magnetic resonance imaging (PC-MRI) is a modern non-ionizing imaging technique, capable of providing functional and morphological information, as well as supporting computational modellings. Segmentation of 3D PC-MRI is usually a complex and time-consuming process. In the literature, several studies leveraged neural networks (NN) to perform segmentation by using large image datasets [1]. However, the complex data post-processing and limited availability of patients' images for research purposes make the training of the NN challenging. This work aims investigating the feasibility of a pipeline for generating synthetic thoracic aorta PC-MRI data to expand the limited dataset of patient-specific images, thus improving the accuracy of neural NN even with a small real dataset.

Materials and Methods

Synthetic high-resolution (HR) 4D velocity images were created by analysing 250 computational fluid dynamic velocity (CFD) maps from two different scanners (Philips and GE). To generate high-fidelity low resolution (LR) images, a specific pipeline was developed. First, a statistical shape model [2] was used to synthesize new artificial geometries so that improving data numerosity and variability. Secondly, transient CFD simulations were performed in OpenFOAM by prescribing patient-specific boundary conditions: a 2D velocity profile at the inlet, and a 3-element Windkessel model at each outlet. Next, a fast Fourier transform (FFT) was performed with a high-frequency truncation and addition of zero-mean white gaussian noise [3]. Finally, an inverse FFT was applied to revert data to the spatial domain and final volumes were obtained using the PC magnetic resonance angiography (PC-MRA) formula. A specific 3D U-Net was set up and trained with different combinations of real and synthetic data namely $Synth_{40/50}$, $Synth_{40/100}$, $Synth_{40/250}$, with respect to the only real data case (No_Synth). A total of 10 real PC-MRA were used as the test set and the effect on the DICE score (DS) was evaluated.

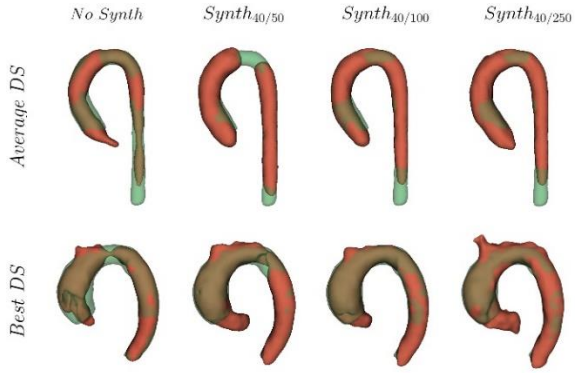

Figure 1: Comparison among different experiment reporting the average, and best results. The ground truth is displayed in green, and the predicted segmentation is in red.

Results

Table 1 shows a DS value of 0.83 for synthetic augmented experiment with respect to the No_Synth case (DS = 0.65) and a significative reduction in the standard deviation (SD). A higher accuracy and a better target reconstruction are also visible in Figure 1.

Method	Volume_R	Volume_S	DS	SD
No_Synth	40	0	0.65	0.10
$Synth_{40/50}$	40	50	0.81	0.05
$Synth_{40/100}$	40	100	0.83	0.03
$Synth_{40/250}$	40	250	0.82	0.02

Table 1: DICE scores. N.B: Volume_R = Real volumes, Volume_S = Synthetic volumes

Discussion and Conclusion

Results suggest the advantages of adopting synthetic data augmentation for the 3D U-Net such as the ability to increase the dataset in terms of numerosity and variability, thus improving the segmentation accuracy.

References

1. Berhane et al, Magn Reson Med, 84(4): 2204-2218, 2020.
2. Scarpolini MA et al, ESB-ITA, p. 13, 2022.
3. Ferdian, E et al, Front. Physics 138, 2020.

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