AORTIC SEGMENTATION VIA SYNTHETIC DATA AUGMENTATION STRATEGY FROM PC-MRI SMALL DATASET

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Introduction

Modern non-ionizing imaging methods such as three-directional phase contrast magnetic resonance imaging (3D PC-MRI) have the capability to provide three-directional velocity information throughout the cardiac cycle. The blood flow dynamics at any location in the acquired volume allows the quantification of hemodynamic parameters used in clinical setting for the assessment of cardiac and vascular diseases. Segmentation of 3D PC-MRI is a very demanding processing step due to the nature of the MRI datasets. In literature, several studies have proposed neural networks (NN) to perform segmentation [1] by using large image dataset. However, the availability of large patient data is limited making the training of the NN, a challenging process. The objective of this work is to develop and to evaluate the integration of real and synthetic PC-MRI images to enhance the segmentation of thoracic aorta using DL. The synthetic dataset is created by calculating velocity fields from computational fluid dynamic (CFD) simulations.

Materials and Methods

Synthetic high-resolution (HR) 4D velocity images (Fig. 1a) were obtained by analysing 250 CFD simulations from both healthy and pathological subjects. The CFD simulations are performed on synthetic aortic geometries generated using a Statistical shape model [3] able to cope with the complexity of the entire aorta and to include also the supra-aortic vessels. Transient CFD simulations were performed in OpenFOAM by adopting patient-specific boundary conditions: a 2D velocity profile was imposed at the inlet, while a 3-element Windkessel model was used to control the pressure at each outlet. Each CFD case was processed to obtain the corresponding low-resolution (LR) velocity maps following a four-step procedure [2]. Firstly, a fast Fourier transform (FFT) algorithm has been used to interpolate and filter-out high-frequency noise from the images in the Fourier domain, obtaining half-dimension data, and a zero-mean white gaussian noise was added (Fig.1b). Finally, an inverse FFT was applied to revert to the spatial domain (Fig.1 c-d). A specific 3DU-Net was set up and trained with the related 3D PC magnetic resonance angiography (PC-MRA) datasets combing both synthetics (250) and real (50) cases. A total of 10 real PC-MRA were used as test set. The effect on the DICE score (DS) was evaluated on four different combination of training data: only real data (*No_Synth*), and three combinations of synthetic and real data namely *Synth$_{40_50}$*, *Synth$_{40_100}$*, and *Synth$_{40_250}$*.

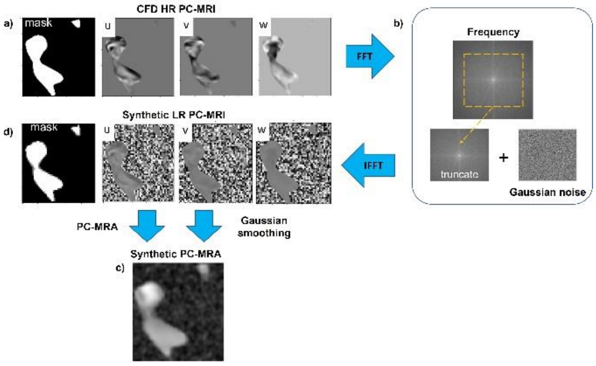

Figure 1: Workflow for the synthetic dataset

Results

The results obtained from the trained 3DU-Net, reported as DS score and standard deviation (SD) values, show an improvement in the segmentation performance in all the synthetic augmented cases compared to the only real one. Among all of them, the best accuracy improvement between augmented and only real training results was 28% and 20% for DS and SD respectively (Table 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 Conclusions

The findings show the benefits of using synthetic data augmentation for the 3DU-Net segmentation task. By expanding the synthetic dataset and utilizing novel synthetic data creation techniques.

References

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Acknowledgements

MeDiTaTe Project has received funding from the EU's Horizon 2020 research (No. 859836).