Analysis of Coronary Computed Tomography Angiography for 3D reconstruction of arterial trees and plaque detection

Panagiotis K. Siogkas, Vassiliki Kigka, George Rigas, Antonis I. Sakellarios, Themis P. Exarchos, Dimitrios I. Fotiadis, *Senior Member, IEEE*

***Abstract*— In this study, we present an algorithm for the 3-Dimensional reconstruction of arterial trees (lumen, outer wall and calcified plaque) using coronary computed tomography angiography images. An initial validation of our method compared to the annotations by a medical expert is also given with a mean DICE coefficient of 0.75 and a mean Hausdorff distance of 1.75 regarding the lumen, respectively.**

I. Introduction

Coronary Computed Tomography Angiography (CCTA) has gained substantial ground during the past two decades in clinical practice due to its non-invasive nature and has evolved tremendously in terms of image quality. It is able to visualize the coronary vasculature and assess the presence, extent and type of atherosclerotic plaques and has therefore led to the development of various 3D reconstruction algorithms [1].

II. Methods and Results

A. *3D Reconstruction Process*

Our algorithm is based on an eight-step approach: a) the CCTA images are pre-processed using the Frangi Vesselness filter, which limits the region of interest (ROI) to possible vessel regions. b) The blooming effect [2] caused by intensely calcified plaques is removed. c) Using a minimum cost path approach, the 3D centerline of the vessels is extracted. d) Using a membership function of Hounsfield Units (HU) values and the distance from the centerline, an estimation of the weight function for lumen, outer wall and calcified plaque is made. An extension of active contour models [3] for e) lumen and f) outer wall segmentation are implemented. The main improvement is an additional term forcing the level set to include a prior shape. Regarding the lumen, the prior shape is a tabular mask across centerline with a small radius. g) A level set method is applied regarding plaque segmentation, taking into account calcified objects of significant size. h) Finally, the 3D surfaces for the lumen, outer wall and calcified plaques are created (Fig. 1).

Fig. 1: Final 3D model (transparent green: outer wall, brown: lumen and white: calcified plaque) of an LAD-LCx-1st diagonal branch.

B. *Validation*

An experienced cardiac radiologist performed the annotation on 12 arterial segments (lumen, outer wall, calcified plaque, mixed plaque). The 3D reconstructed models by the medical expert were then compared to the algorithm-generated models in order to validate it regarding the lumen (Fig. 2). The DICE coefficient and the Hausdorff Distance were used as validation metrics in this study (Fig. 2). The mean DICE coefficient was 0.75 (SD=0.075) and the mean Hausdorff distance was 1.75 (SD=0.55).

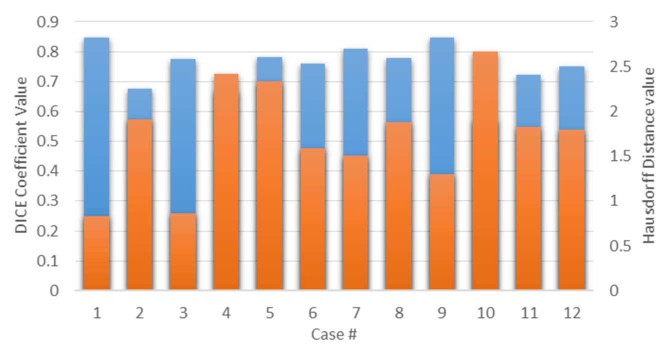

Fig. 2: DICE Coefficient (blue) and Hausdorff Distances (orange) for all 12 cases.

III. Conclusions

We have presented an algorithm for the 3D reconstruction of coronary arterial trees from CCTA images. Despite the modest size of the validation dataset, the obtained results were very promising, thus indicating the overall accuracy of the proposed reconstruction algorithm. We are currently optimizing our algorithm to improve the vessel classification along with the computational speed.

References

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Panagiotis K. Siogkas, Vassiliki Kigka and Dimitrios I. Fotiadis are with the Unit of Medical Technology and Intelligent Information Systems, Department of Materials Science and Engineering, University of Ioannina, Ioannina, GR 45110 Greece

P. K. Siogkas, G. Rigas, A.I. Sakellarios, T.P. Exarchos and D. I. Fotiadis are with the Dept. of Biomedical Research, FORTH-IMBB, GR 45110 Ioannina, Greece (corresponding author phone: +302651009006; fax: +302651008889; e-mail: fotiadis@cc.uoi.gr).