2D-UNET BASED APPROACH FOR 3D SEGMENTATION OF CORONARY ARTERY FROM COMPUTED TOMOGRAPHY ANGIOGRAPHY

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Introduction

Coronary computer tomography angiography (CCTA) is an imaging technique which provides invaluable detailed anatomical information of coronary arteries, that are essential in the pre-procedural analysis and diagnostic process. To support and improve the diagnosis, accurate segmentation of the coronary arteries is a crucial step, for the purpose of stenosis detection and quantification of stenosis severity (e.g., with fractional flow reserve). Segmentation is typically manually performed by expert operators; however, this is a tedious and time-consuming work, that carries bias introduced by the radiologist [1]. Thus, an accurate, fast and fully automated segmentation pipeline is highly desirable, but challenging due to the relative complexity and high inter-subject variability of coronary anatomy [2, 3]. In this work, we describe the development and evaluation of a fully connected convolutional neural network (CNN) based pipeline for the automatic segmentation of the coronary lumen from CCTA images.

Methods

Overall, 168 CCTA scans of patient with at least one stenotic coronary were retrieved. The right and left coronary lumens were manually segmented, including the main branches, by expert operators.

The original volumetric images and segmentations were sliced along the axial, coronal and sagittal direction (**Figure 1a**), in order to obtain 3 different datasets of 2D images with the corresponding segmentation mask. Each of the resulting dataset included ~40k couple of images and masks. The three dataset was randomly split into a training set and a test set (based on a typical 80/20 subdivision), then a CNN was implemented, based on the 2D U-Net architecture. Data augmentation was performed, including contrast and intensity adjustment and random affine transformations. Due to high class imbalance between the foreground (i.e., the coronary arteries) and the background, dice focal loss (DFL) was used to train the model, which is defined as a weighted sum between focal (FL) and dice (DL) loss: $DFL = \lambda_{DL}DL + \lambda_{FL}FL$. $\lambda_{DL}=0.3$ and $\lambda_{FL}=0.7$ were used in this work. After the training phase, three models were obtained, for every slicing direction.

To achieve coronary 3D reconstruction of a subject, the trained models were applied along each respective direction on one single CCTA acquisition. The final layer of the CNN for each of the three model was extracted and the three predictions were averaged. Finally, the activation function (i.e., softmax) was applied to obtain the 3D segmented volume.

Results

After the training, the CNN segmentation yielded a mean dice score (DS) of 0.754 along axial direction, 0.732 along the coronal direction and 0.745 along the sagittal direction, with respect to the manual ground truth segmentations. The main branches such as the left descending anterior artery, the left circumflex artery and the right coronary were generally precisely detected. Experimental results on different slices are shown in **Figure 1b**. The 3D reconstruction of the coronary arteries obtained combined the three models prediction is shown in **Figure 1c**.

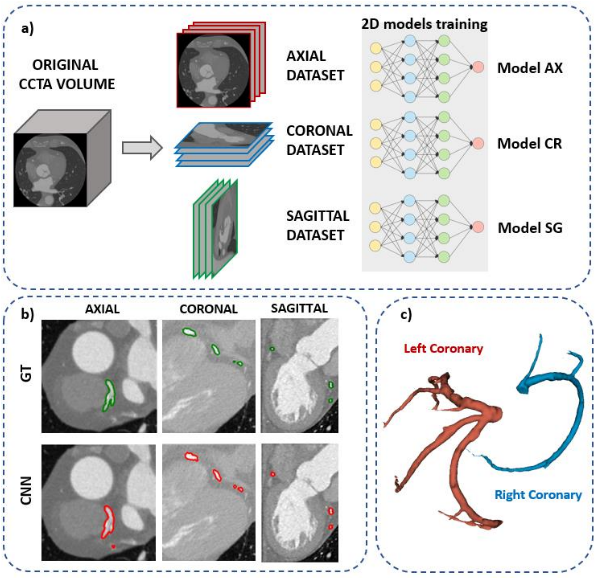

Figure 1. a) Slicing of the original dataset volumetric CCTAs and training of the models along; b) Prediction of the CNN (red) compared to ground truth (green); c) 3D reconstructed model.

Discussion

We developed a CNN-based automated pipeline for the automated segmentation of standard and stenotic coronary arteries from CCTA imaging. This tool has the potential to support stenting pre-procedural planning in a real clinical setting.

References

1. Leipsic et al. 2014, *J. Cardiovasc. Comput. Tomogr.*
2. Pan L. et al., 2021, *Scientific Reports*
3. Gu et al., 2021, *Artificial Intelligence in Medicine*