Philips Hamburg (Hannes Nickisch) **Coronary Artery Tree Segmentation from CT Angiography Data**

Background

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Coronary centerline tracing and coronary artery lumen segmentation are key base technologies for subsequent stenosis assessment and CAD-RADS reporting.

A classical algorithmic pipeline for coronary analysis proceeds sequentially: The coronary centerlines are traced using a previously computed cardiac chamber segmentation as initialization and boundary condition. The coronary lumen is then computed as a third step. In such a staged algorithmic pipeline, errors potentially accumulate and amplify and fixing of issues is cumbersome as there are multiple possible failure modes.

In recent years, MICCAI hosted challenges to push coronary artery extraction: In 2008 on centerline tracking (CAT), in 2012 on stenosis assessment (STEN) and in 2022 on coronary tree segmentation (ASOCA) [5]. These data sets can serve as testbeds for coronary artery segmentation methods.

On the other hand, CNN-based architectures, in particular the U-Net [1] and its self-configuring variant nnU-Net [2] have demonstrated outstanding performance on a wide range of medical image segmentation benchmarks. Furthermore, these models -- if coupled with enough curated data -- can segment 100+ anatomical structures at once with excellent accuracy [4], recently even from MR images.

Coronary arteries are structures where these general-purpose public domain tools show significant performance gaps for several reasons. First, there is no sufficiently large annotated and publicly available image cohort. Second, the coronaries are very fine-grained structures with dimensions at the edge of the image resolution of a CT system. Third, the topology of coronary trees (in particular in presence of coronary artery disease) is highly variable and renders integration of prior shape knowledge challenging. Fourth, the loss functions used for training general purpose segmentation systems are less adequate as coronary trees have a much large surface-area-to-volume ratio (SA/V) than other anatomical structures.

More adequate loss functions such as the centerline DICE [5] and the skeleton recall loss [6] were conceived to deal with the SA/V as well as the tree topology but their efficacy for coronary artery trees still remains to be demonstrated.

As a consequence, we propose to quantify the benefit of tailored loss functions [5,6] together with generic CNN frameworks such as nnU-Net for the segmentation of coronary artery trees directly from the CTA images in a single analysis step. In particular, benchmarks shall cover a wide range of quality criteria a) centerline completeness, b) lumen mask accuracy (DICE, Hausdorff), c) lumen accuracy, d) runtime, etc.

Outline

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The candidate will use the ASOCA dataset and in-house data cohorts to train nnU-Nets with both generic (cross-entropy etc.) losses and domain-adapted losses and quantify and analyze the potential improvements using appropriate scoring metrics. Computations will be done on the Innovative Technologies Hamburg cluster using an in house deep learning framework.

Timeframe

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Two months preparatory internship for setup tasks such as dataset curation and analysis tool preparation (can be negotiated if sufficient prior experience available), followed by six months of master thesis work. The last month is reserved for thesis writing. If the results are promising, publication (MICCAI/MIDL/SPIE/ISBI) is an option.

References

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[0] https://communities.springernature.com/posts/unveiling-the-potential-of-asoca-dataset-advancing-cardiovascular-diagnostics-and-treatment

[1] https://arxiv.org/abs/1505.04597

[2] https://github.com/MIC-DKFZ/nnUNet

[3] https://arxiv.org/abs/2404.09556

[4] https://github.com/wasserth/TotalSegmentator

[5] https://github.com/jocpae/clDice

[6] https://arxiv.org/pdf/2404.03010v1