"3D Synthetic Generation of Coronary Arteries: Integrating TopoGAN and Semantic Diffusion in PyTorch"

Project Management and Software Development
for Medical Applications

General Info

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Project Abstract

The objective of this project is to produce realistic synthetic data to train a vessel segmentation network. Our primary focus is on generating synthetic images of coronal arteries that also depict the soft tissue of the heart. The generation should commence from a centerline map, resulting in a synthetic image that encodes the input vessel centerline.

Background and Motivation

Recent advancements in image generation have been notable, with technologies such as the Denoising Diffusion Probabilistic Models (DDPMs) and the Generative Adversarial Networks (GANs) leading the way. DDPMs, particularly the recent Semantic Diffusion Model, have shown remarkable performance in image generation, at times beating GANs. This model emphasizes semantic image synthesis by processing both the semantic layout and noisy image, enhancing the image's quality and semantic interpretability.

On the other side, while GANs excel at producing realistic images based on CNN-derived features, they sometimes falter in preserving the complex structural attributes found in actual images. This preservation is crucial in scenarios where an image's structure, like neurons, vessels, or road networks, has significant semantic implications. The TopoGAN addresses this by concentrating on the topology of real images, leading to synthetic images that are both realistic and topologically accurate.

Our project is driven by the fusion of these advanced models. By harnessing the strengths of both the Semantic Diffusion Models and TopoGAN, we intend to generate synthetic data that captures the structural and semantic essence of real coronary artery images, thereby fulfilling the training requirements of a vessel segmentation network.

Student’s Tasks Description

1. 3D Mapping: Begin by adapting the existing 2D codes of TopoGAN and Semantic Diffusion into the 3D domain.

2. Data Processing: Utilize the available CTA images of the heart, paired with the ground truth segmentation of the coronal artery. This data will serve as the foundation upon which the synthetic generation processes will be built.

3. Synthetic Generation: Train the 3D-adapted models to produce synthetic 3D images of the coronal arteries. The key focus should be on preserving the topological and semantic properties of the input labels.

4. Qualitative Evaluation: Subject the generated synthetic images to a qualitative assessment,

comparing them against the real CTA images to ascertain their structural and visual accuracy.

During this practical course, the student will delve deep into the intersections of advanced image generation techniques and medical imaging. Through hands-on implementation and evaluation, they will gain proficiency in the intricacies of 3D image synthesis, adapting 2D models to 3D contexts, and the nuances of topological and semantic image generation.

Technical Prerequisites

1. Deep Learning Fundamentals: Understanding of principles related to Generative Adversarial Networks (GANs) and preferably Denoising Diffusion Probabilistic Models (DDPMs).

2. Programming in PyTorch: Proficient coding skills in Python, particularly with the PyTorch framework.

3. Medical Imaging Insight: Familiarity with Cardiac Computed Tomography Angiography (CTA) images.

References

[1] Wang, Fan, et al. "Topogan: A topology-aware generative adversarial network." *Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part III 16*. Springer International Publishing, 2020.

[2] Wang, W., Bao, J., Zhou, W., Chen, D., Chen, D., Yuan, L., & Li, H. (2022). Semantic image synthesis via diffusion models. *arXiv preprint arXiv:2207.00050*.

[3] https://theaisummer.com/diffusion-models/

[4] https://asoca.grand-challenge.org

Please send the completed proposal to ardit.ramadani@tum.de, lennart.bastian@tum.de and tianyu.song@tum.de. Please note that this proposal will be evaluated by the BMC coordinators and will be assigned to a student only in case of acceptance.