Deep learning-based 3D vessel reconstruction

1. General Info

Project Title: Deep learning-based 3D vessel reconstruction

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2. Project Abstract

Coronary artery reconstructions are often computed based on triangulation between matching vessel points in contrasted X-ray images obtained from at least two C-arm angulations [1]. However, interventions during which such images are acquired are highly dynamic and movements such as cardiac as well as respiratory motion make the development of accurate as well as automated reconstruction algorithms challenging. Consequently, state-of-the-art methods rely heavily on manual annotations to correct such movements or require an initial well-aligned estimate. To overcome these challenges, we propose using deep learning that automatically reconstructs an initial model of the coronary arteries from 2D DRR (Digitally Reconstructed Radiograph) images. The project includes an implementation of two 3D reconstruction pipelines:
1) modeling the vasculature with B-splines and using a differentiable rendering pipeline that enables end-to-end training of our model,
2) image-to-graph convolutional network that achieves deformable registration of a three-dimensional (3D) organ mesh for a low-contrast two-dimensional (2D) projection image [2].
The results would be compared in terms of reconstruction quality as well as the reconstruction time.

3. Background and Motivation

Three-dimensional vasculature reconstruction from interventional X-ray images has many possible applications, including 1) intravascular navigation and 2) diagnosing vasculature diseases such as stenosis [3]. The gold standard for navigating catheters and guidewires within the vasculature remains real-time X-ray imaging and X-ray Angiography (XA). However, the projective nature of the imaging process leads to a loss of valuable 3D information, requiring physicians to navigate and assess the diseased vasculature solely on 2D information [4]. Alternatively, a 3D reconstructed model could increase physicians' perception and reduce the amount of radiation exposure, the contrast agent used, and the overall duration of interventions [5].
The overall goal of the project is to construct a pipeline for 3D reconstruction of the cardiac vasculature from 2D X-Ray (DRR) images.

4. Technical Prerequisites

- Good background in deep learning
- Good background in computer vision (3D reconstruction experience)
- Good skills in Python
- Good skills in PyTorch

5. Benefits:

- Possible novelty of the research
- Possible publication

6. Students' Tasks Description

Students' tasks would be the following:

B-spline vessel representation and differential renderer

- Understanding the underlying methods
- Generating a dataset using a DRR generator from the ImageCAS CTAs
- Implementing the B-spline representation of the vasculature
- Implementing the 3D reconstruction pipeline, including a differential renderer
- Running the evaluation metrics on a generated dataset.
- Testing and documentation.

IGCN+

- Understanding the underlying methods
- Generating a dataset using a DRR generator using the ImageCAS dataset
- Implementing a deformation method for the DRR generator.
- Re-implementing the existing method [2]
- Running the evaluation metrics on a generated dataset.
- Testing and documentation.

7. Work-packages and Time-plan:

	Description	#Students
WP1	Familiar with the literature, DRR generator, and existing 3D reconstruction methods.	4
WP2	Familiar with PyTorch, and TensorBoard. Building classes for pre-processing and evaluation metrics. Come up with a detailed time-plan (gantt)	4
WP3	Implementation of B-spline vasculature representation	4
WP4	Reimplementation of IGCN+ [2]	4
M1	Intermediate Presentation II	4
WP5		4
WP6	Implement a reconstruction pipeline, including the differential renderer, to reconstruct 3D vasculature mesh	4
WP7	Implement a deformation method for the DRR generator and test method from WP4	4
WP8	Testing and Documentation	4
M2	Final Presentation	4

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[2] Nakao, M., Tong, F., Nakamura, M., & Matsuda, T. (2021). Image-to-graph convolutional network for deformable shape reconstruction from a single projection image. In Medical Image Computing and Computer Assisted Intervention–MICCAI 2021: 24th International Conference, Strasbourg, France, September 27–October 1, 2021, Proceedings, Part IV 24 (pp. 259-268). Springer International Publishing.

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