

Deep Learning for Retinal Blood Flow Segmentation

Situation

In ophthalmology (Augenheilkunde), the analysis of eye structures helps to assess diseases such as retinal vascular occlusion or glaucoma, which can lead to blindness if left un- treated. Thanks to a newly developed method in Switzerland, even dynamic visual patterns of blood flow in retinal vessels can be acquired. Specifically, this new method makes it possible to track retinal blood flow in videos of non-invasive optical coherence tomography (OCT) images.

Previously, only static OCT scans were used at single points in time.

The blood flow in the new OCT videos is a time-intensive manual process conducted by trained experts conducting the analysis manually. By automating the blood vessel identification process, clinicians and researchers can save valuable time and resources, enabling faster and more precise assessment of vascular abnormalities. Ultimately, this leads to improved patient outcomes and quality of life.

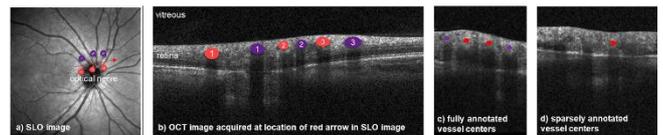


Figure 1: Retinal images: paired SLO optic nerve head image (a) and OCT scan (b), with arteries shown in red and veins in purple. Examples of fully vs. sparsely annotated vessel centers (c, d).

Goals / Methodology / Tasks

The goal of this project is to develop and evaluate automated methods to (i) segment blood vessels in OCT videos, (ii) classify vessels into arteries vs. veins, and (iii) analyze blood-flow dynamics and abnormalities across patient groups. Specific research questions are:

- Which deep learning methods and metrics best support vessel centerline segmentation and classification in OCT videos?
- How can incorporating the time dimension improve vessel segmentation and flow analysis?
- How can positively sparsely annotated labels be used to improve segmentation performance without penalizing error metrics?
- Can a priori shape or topological information enhance segmentation quality?
- Does integrating other imaging modalities (e.g., SLO) improve segmentation and classification performance?
- Which quantitative biomarkers can be derived from the segmented vessel maps to characterize vascular structure and blood flow?
- How do blood flow patterns and abnormalities differ between patient groups, and how do they relate to ECG (heart-rate) signals?

From a dataset of 1000 spatio-temporal OCT videos (512 frames, 496×1024 pixels, 85 kHz) from three cohorts (60 healthy, 30 unhealthy patients, Eye Clinic University of Basel), including SLO images and ECG signals, a representative subset of 100 videos is used for preliminary analysis. For two cohorts, ≈200,000 vessel centers were annotated as artery/vein landmarks.

Required Skills

Interest in medical image segmentation, data analysis (data wrangling, data exploration, visualization).

- Deep learning
- Python

Tasks for the Master Student

The student project can build on existing 2D/3D segmentation (U-Net, nnU-Net), DinoV3-based segmentation, error metrics, and blood-flow profiling. We propose the following project phases, with Phases P7–P8 recommended for a smaller subset and Phase P9 for the full dataset:

P7: Centerline segmentation in OCT images with sparsely annotated labels (e.g., U-Net, <https://arxiv.org/html/2508.18186v1>)

P8: Extend a model with temporal information to improve segmentation stability and capture blood-flow dynamics

P9: Extract quantitative vascular and flow biomarkers to analyze blood-flow patterns and their relationship to ECG signals

Full/Parttime: Full time study
 Part time study

Location: FHNW Brugg-Windisch

Advisor: Prof. Dr. Susanne Suter

Collaborators: Philippe Valmaggia, Peter Maloca, University (Hospital) Basel