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Few-shot retinal layer boundary segmentation adaptation for regressing novel retinal layers visible on high-resolution OCT

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Introduction

With the **advent of high-resolution optical coherence tomography (OCT)** devices, retinal layers previously non-distinguishable are becoming identifiable.

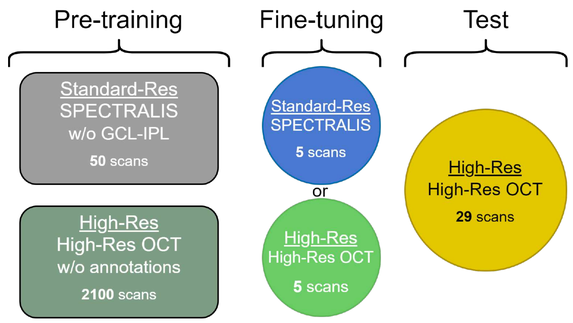
The challenge we address is how to efficiently **adapt retinal layer boundary segmentation algorithms to high resolution** and to additionally regress **novel retinal boundaries** as part of their output.

We illustrate this in the **simulated case of segmenting boundary between Ganglion Cell Layer (GCL) and Inner Plexiform Layer (IPL)**, which is typically weakly distinguishable.

Materials and Experiments

Datasets
Patients with **age-related macular degeneration (AMD)**:
- 50 patients with standard resolution OCT scans (**SPECTRALIS** SD-OCT, Heidelberg Engineering, DE)
- 34 patients with both high resolution (**High-Res** SD-OCT, Heidelberg Engineering, DE) and standard resolution (SPECTRALIS SD-OCT) scans.
  - 5 patients for (few-shot) fine-tuning
  - 29 patients as a test set

In both datasets, the main **retinal layers have been manually annotated**.
- 2100 **High-Res** SD-OCT scans from patients with various conditions, without retinal layer annotations



SD-LayerNet

SD-LayerNet is the **state-of-the-art retinal layer segmentation algorithm** proposed by our lab [1].
- It has **topological constraints** on the possible layer positions which can be applied **even without annotations**.
- Uses a **resolution consistency constraint**, which assures that the predictions on the high-resolution scan are the same as on the standard resolution one

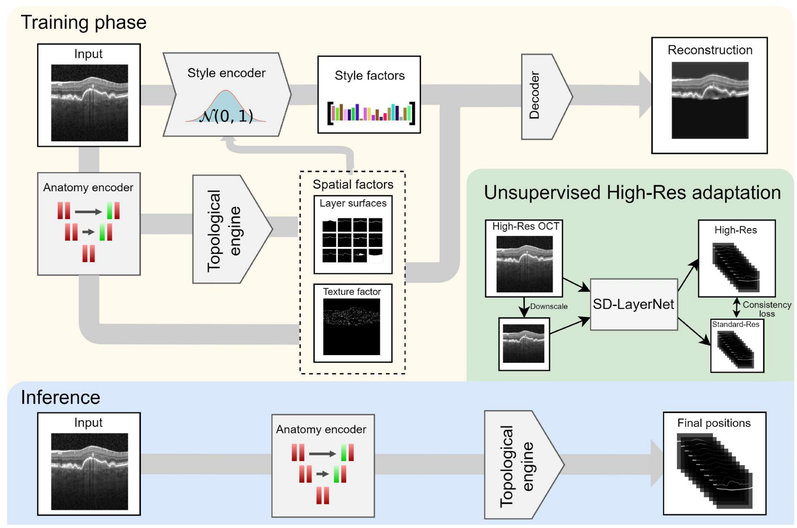


Figure 1. The model consists of two input branches. Initially, an anatomy encoder yields two output branches for feature extraction. An underlying topological mechanism ensures the accurate sequence of layers and generates spatial maps. The second input branch is linked to a style encoder, producing style factors that encode intensity values of anatomical features. The decoder then reassembles a reconstructed image using these style and anatomical factors. Depending on the presence of layer annotations for the input image, the network minimizes either a supervised loss or a self-supervised loss.

Topology preservation:
- Target boundary cannot cross the adjacent boundaries.
- Used to restrict the possible location of the new layer without annotations
- Makes few-shot learning possible

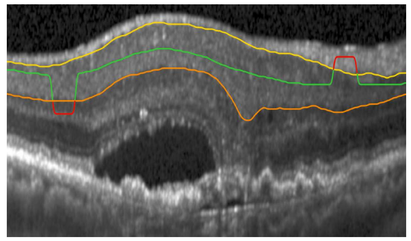
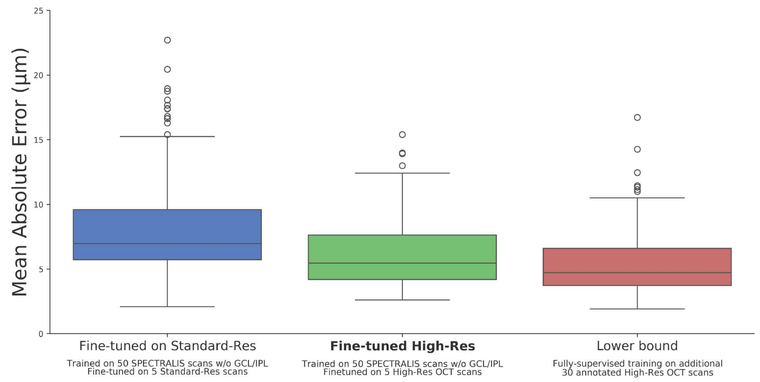


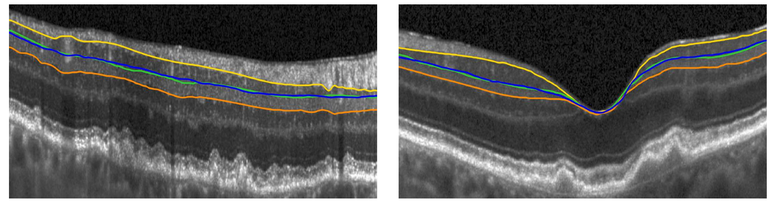
Illustration of GCL-IPL segmentation

Results

Quantitative:



Qualitative (proposed method):



Conclusions

- Our SD-LayerNet demonstrated very **efficient fine-tuning properties** for regressing potentially novel retinal layers on High-Res OCT.
- This is an important step toward **expanding the repository of retinal layers** that can be automatically segmented with the introduction of **high-resolution OCT devices.**

References

[1] B. Fazekas, G. Aresta, D. Lachinov, S. Riedl, J. Mai, U. Schmidt-Erfurth, H. Bogunović, SD-LayerNet: Semi-supervised retinal layer segmentation in OCT using disentangled representation with anatomical priors, *In Proc. MICCAI 2022*, https://arxiv.org/abs/2207.00458

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