Intra-retinal cyst segmentation in optical coherence tomography images via transfer learning

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Introduction

Diabetes mellitus (DM) is a widespread global retinopathy consisted of fluid-filled spaces named retinal cysts within the retina , where early detection and intervention are crucial to prevent blindness through diabetic retinopathy. Diabetic macular edema (DME) being a significant complication of diabetic retinopathy, it is diagnosed by analyzing the retina cysts using the non-invasive Optical Coherence Tomography (OCT).

Advancements in automated cyst segmentation algorithms, powered by deep learning, have significantly improved accuracy while reducing the variability associated with manual segmentation methods. However, there is scarcity of labelled data which is required to train these deep learning models. Moreover, training larger models are computationally expensive limiting broader application.

We explored the use of transfer learning in cyst segmentation from OCT scans, aiming to adapt pre-trained models for improved training efficiency and DME segmentation accuracy.

Contributions (all worked together on all parts, but with a focus on):

- Lavsen: Model training, Fine-tuning
- Fong Chi: Data pre/post-processing, Literature review
- Zion: Data interpretation

Methodology

Data

78 retinal SD-OCT images and corresponding manual segmentations from 10 DME subjects (patients) with lateral and azimuthal resolutions ranging from 10.94 to 11.98m/pixel and 118 to 128m/pixel, respectively. The original dataset is from the open-sourced Duke DME database [1], where the OCT images are segmented into 8 different layers (classes). Here, we only focus on the fluid-filled areas (target) and other areas (non-target).

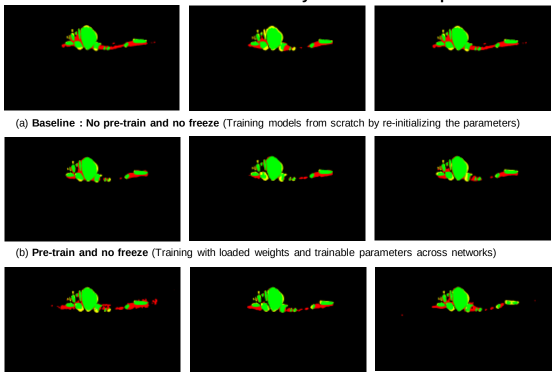
Model Architecture

We utilized three models with different architectures to adapt the corresponding model parameters pre-trained on landscape segmentation tasks. The resulting models were, trained, validated and tested on Duke retinal OCT dataset for retinal cysts segmentation.

Architecture	# Layers	# Backbone Layers	Backbone Freeze	# Trainable Parameters
Swin Transformer	322	257	No	59,865,425
Swin Transformer	322	257	Yes	32,344,727
Deep Labv3 Plus	222	147	No	43,580,644
Deep Labv3 Plus	222	147	Yes	20,053,380
MobileNetv3	273	249	No	3,282,225
MobileNetv3	273	249	Yes	310,273

Results

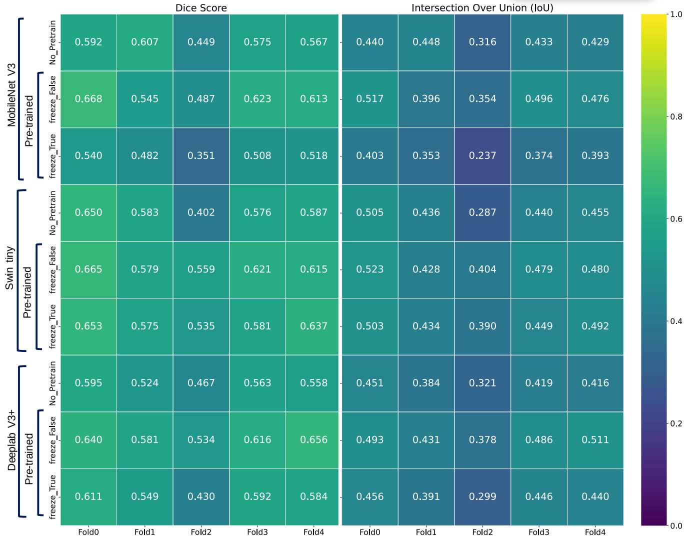
An example from Duke DME dataset with its original image, manual labelling mask (fluid regions), and image combined with the mask.



(a) **Baseline : No pre-train and no freeze** (Training models from scratch by re-initializing the parameters)

(b) **Pre-train and no freeze** (Training with loaded weights and trainable parameters across networks)

(c) **Pre-train and freeze** (Training with loaded weights and untrainable parameters except the last layer)



Source	Methods	Dice score
Literatures	ReLayNet [2]	0.36
	Language [3]	0.39
	Alignment [4]	0.56
Swin Pre-trained No freeze	Augment – Crop	0.47
	Augment – Gaussian Blur	0.46
	Augment – Gaussian Blur and Noise	0.44
	Loss – Cross Entropy and Dice	0.46

Conclusion

The OCT images suggest that the fluid-filled areas generally consist of a major fluid region and surrounded by multiple minor isolated regions. All three models can segment the major region, whereas the small parts are often either ignored or mistakenly segmented.

Comparing to the baseline (No pre-train):

- Intra-model: Performance (Dice, IoU, Sensitivity) improved by 3%-7% using pre-trained and no freeze in parameters.
- Inter-model: Swin outperformed Deeplab V3+ and MobileNet V3 in Dice and IoU.
- Fine-tuning: Swin with pre-train and no freeze achieved Dice of 0.47 with random crop in data augmentation.

Transfer Learning has demonstrated enhanced accuracy compared to training from scratch when data availability is limited.

References

[1] S. J. Chiu et al. "Kernel regression based segmentation of optical coherence tomography images with diabetic macular edema",(BIOMEDICAL OPTICS EXPRESS), 6(4), pp. 1172-1194, April, 2015

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[3] Tran, A. et al. "Retinal Layer Segmentation Reformulated as OCT Language Processing". 2020, MICCAI 2020. Lecture Notes in Computer Science(), vol 12265. Springer, Cham.

[4] Maier, H. et al. "A Line to Align: Deep Dynamic Time Warping for Retinal OCT Segmentation". MICCAI 2021. Lecture Notes in Computer Science(), vol 12901. Springer, Cham.