Deep Learning-based age prediction models from retinal Optical Coherence Tomography images

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Abstract

Optical Coherence Tomography (OCT) has emerged as a valuable tool for assessing microstructural characteristics in the retina. This study explores the use of Deep Learning models for age prediction based on OCT images. We employed three pre-trained ResNet architectures (ResNet-18, ResNet-50, ResNet-152) to predict retinal age from macula raster and peripapillary scans of 517 control subjects. The best performance was achieved by ResNet-18 applied to macula B-scan 12, yielding a Mean Absolute Error (MAE) of 4.423 years. These findings suggest that central macula raster scans, particularly B-scan 12, provide informative features about age-related changes.

Keywords: Optical Coherence Tomography, Deep Learning, Age Prediction.

1. Introduction

Optical Coherence Tomography (OCT) has emerged as a powerful imaging modality for assessing retinal changes associated with aging. In this context, the concept of 'retinal age gap' is known to be a relevant metric, as a retina that appears biologically older may reflect alterations that diverge from normal aging processes.

Accurately characterizing the variation of retinal structure across healthy population is essential to establish a reliable baseline. However, current knowledge in this area remains limited due to several factors. Firstly, there are relatively few studies that leverage OCT

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images for age prediction (Munk et al., 2021; Shigueoka et al., 2021; Chueh et al., 2022; Chen et al., 2024). Secondly, among these studies, the model achieving the best performance using two-dimensional B-scans reports a Mean Absolute Error (MAE) of 5.625 years (Munk et al., 2021) between the predicted and the chronological age, which leaves room for improvement in accuracy. To address these limitations, a comprehensive comparison of OCT B-Scan based Deep Learning age-prediction models has been proposed.

2. Methodology

A total of 517 control subjects were recruited from Cruces University Hospital (Barakaldo, Spain). Prior to the study, they underwent a screening process where exclusion criteria encompassed heavy smoking, diabetes, uncontrolled hypertension, obesity, medications known to induce retinal toxicity, chronic inflammatory diseases, traumatic brain injury, and neurological disorders. The OSCAR-IB consensus (Tewarie et al., 2012) was also followed to ensure OCT quality. All procedure adhered to the principles of the Declaration of Helsinki and written informed consent was documented from all participants.

When available, both eyes of each participant were included. Given the longitudinal design of the study, multiple imaging sessions were conducted for certain individuals. This approach eventually resulted in a dataset comprising 1180 eyes. Images were acquired with a Spectralis spectral domain OCT scanner (Heidelberg Engineering), employing two distinct patterns: macula raster scans (25 horizontal B-scans in the macula) and peripapillary scans (a single circular B-scan around the optic nerve head). The dataset was divided into train, validation and test sets (8:1:1, respectively), preserving the distribution across groups in terms of age and sex. All eyes from a single subject were assigned to the same split.

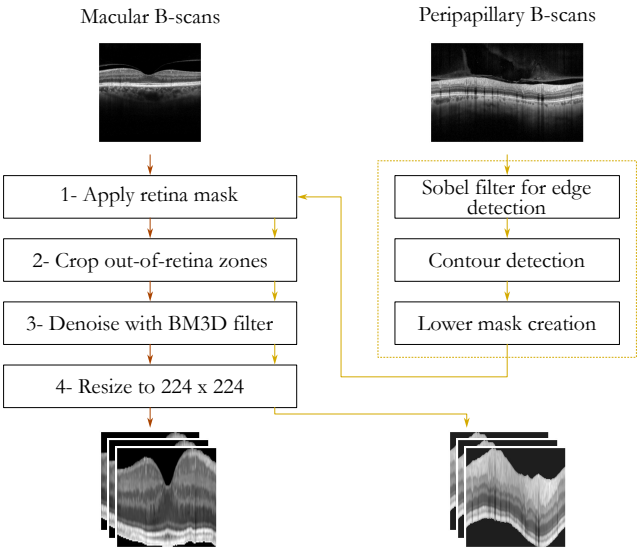

Figure 1: Image preprocessing pipeline.

Images underwent a standardized preprocessing pipeline (Figure 1). Scans corresponding to the left eyes were horizontally flipped to ensure consistent laterality across the dataset. For peripapillary B-Scans, additional steps were required due to the limited availability of

segmentation-data for defining the outermost retinal boundary. Hyperparameters of pre-trained ResNet18, ResNet50 and ResNet152 networks were optimized through a grid search over the validation set using Optuna, a framework designed to automatically identify suitable configurations. These hyperparameters included batch size, learning rate, optimizer, weight decay, dropout rate, pooling type and the number of frozen layers during training.

3. Results

Table 1 summarizes the results, focusing on the three top-performing macular B-scans and the peripapillary scan.

Table 1: MAE comparison across macular B-Scans and peripapillary scan.

Scan-pattern	**ResNet-18**	**ResNet-50**	**ResNet-152**
Macula raster	4.423 - B-Scan(12)	4.627 - B-Scan(12)	4.932 - B-Scan(11)
Macula raster	4.713 - B-Scan(11)	5.002 - B-Scan(11)	5.184 - B-Scan(12)
Macula raster	5.148 - B-Scan(13)	5.376 - B-Scan(10)	5.570 - B-Scan(13)
Peripapillary	6.478	6.602	7.251

The best performance corresponds to ResNet-18 with macular raster B-scan number 12, achieving a MAE of 4.423 years. It was trained with a batch size of 32 using the Adam optimizer (initial learning rate = 1×10^{-4}, weight decay = 0.001). The model employed global average pooling and a dropout rate of 0.3, and followed a full fine-tuning strategy. This MAE slightly improves upon previous works that have been collected in the literature about age prediction models trained with OCT images (Munk et al., 2021; Shigueoka et al., 2021; Chueh et al., 2022; Chen et al., 2024).

4. Conclusions

The central B-scans consistently demonstrate superior performance, suggesting that the B-scan 12 provides informative features for predicting retinal age, likely due to its richness in foveal structural details. These findings reinforce the relevance of central macular scans in age-prediction models, highlighting their potential for improving accuracy. However, the robustness of the proposed model could be further enhanced by training on larger datasets, which may better exploit the capacity of deeper architectures with increased layer complexity such as ResNet-50 and ResNet-152. The outcomes of this study supports the promise of retinal OCT as a valuable imaging modality for non-invasive age prediction. Moving forward, our framework could further enhance its clinical utility to determine whether retinal age deviations reliably reflect atypical aging patterns.

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