Linking Function and Structure: Prediction of Retinal Sensitivity in AMD from OCT using Deep Learning

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Introduction

Microperimetry examines retinal sensitivity at specific retinal locations and is the most comprehensive test of visual function at the macular level. However, it is also time consuming and has limitations in reproducibility. To establish reliable morphologic surrogate endpoints for visual function testing, we developed and evaluated a deep learning model to predict retinal sensitivity maps (function) from OCT volumes (structure).

Data

As a representative dataset, we used 463 visits of 174 patients with a healthy retina, early or intermediate AMD, Choroidal neovascularization (CNV) or geographic atrophy (GA).

Disease	Number of patients	Number of visits	Number of sensitivity measures
Healthy	29	50	1974
Early & intermediate AMD	66	151	6307
CNV	49	186	5338
GA	30	76	1944
Total	*174*	*463*	*15563*

For each visit the following data was available:
- ❑ Color fundus image (CF)
- ❑ Monochrome fundus image (MF)
- ❑ Microperimetry examinations:
  - Nidek MP-1
  - Stimulus luminance between 0 (bad) and 20 (good)
  - registered to MF by Nidek MP-1
- ❑ SD-OCT volume scans (512x128x1024 voxels, Cirrus, Zeiss)

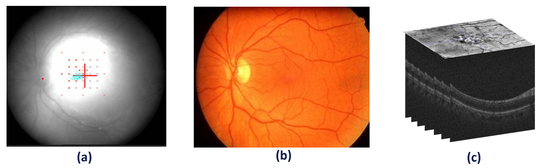


Fig 1: Visualization of the available data for each visit. MF image with registered microperimetry examinations (a). CF image (b). SD-OCT Cirrus volume with the corresponding automatically generated OCT projection (c).

Method: Deep Neural Network

First, registration of each OCT-microperimetry pair was performed:
1) Initial automatic registration of MF and CF
2) Automatic registration of CF and OCT-projection
3) Manual landmark-based correction of 1) and 2)

Then, three different deep learning models (**Fig. 2**) were trained on the registered pairs of OCT and microperimetry data. An en-face 2D retinal sensitivity map is predicted from a 3D OCT volume, assigning a retinal sensitivity value to each A-scan location (**Fig. 1**).

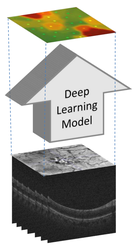


Fig 1: Schematic view of the proposed appraoch. A two-dimensional retinal sensitivity map is predicted from a three-dimensional OCT volume.

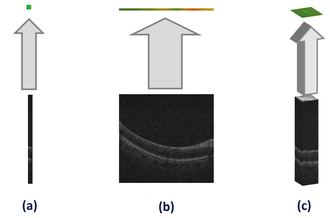


Fig. 2 Illustration of the three deep learning architectures. *DL-1* maps an A-Scan to a scalar (a), *DL-2* transforms a B-Scan into an one-dimensional vector (b), and *DL-3* predicts a two-dimensional sensitivity map from a three-dimensional patch (c).

Results: Quantitative

We compare three different deep learning approaches, using
- ❑ A-scans (*DL-1*)
- ❑ B-scans (*DL-2*) or
- ❑ 3D patches (*DL-3*)

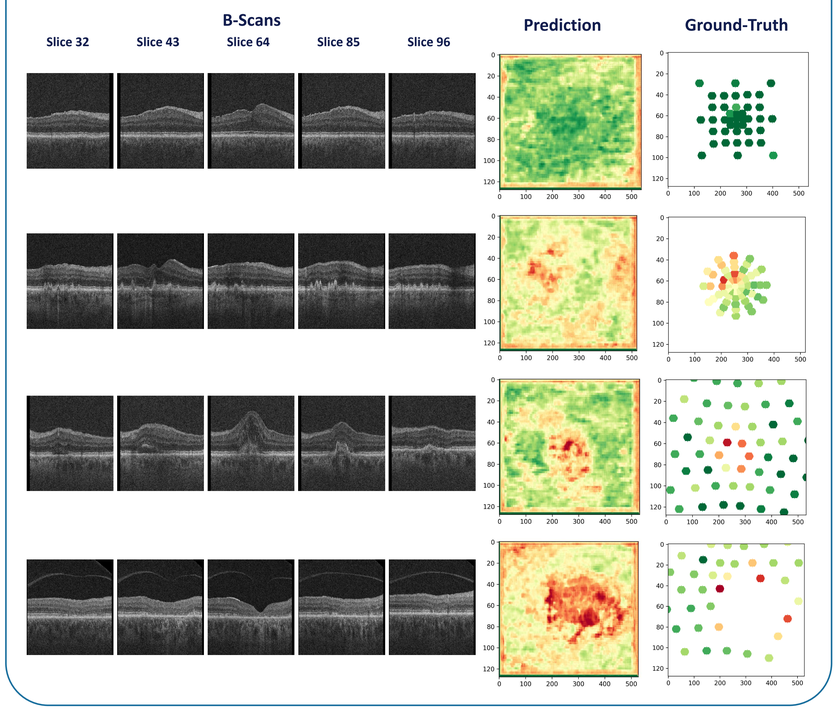
as input for prediction. In contrast to the predictions based on A- and B-Scans, the *DL-3* is able to use context information of all three dimensions. As seen in **Tab. 2**, the *DL-3* model based on the 3D input achieves the best performance (MAE) on the test set both in terms of point-wise and mean sensitivity.

	Healthy		Early/Inter-mediate		CNV		GA		Total	
	PWS	MS	PWS	MS	PWS	MS	PWS	MS	PWS	MS
DL-1	2.85 (±2.41)	2.14 (±0.52)	2.87 (±2.24)	1.13 (±0.61)	3.11 (±2.44)	1.80 (±1.09)	3.70 (±2.97)	2.02 (±1.10)	3.07 (±2.49)	1.75 (±0.95)
DL-2	2.47 (±1.98)	1.61 (±0.88)	2.99 (±2.22)	2.09 (±0.97)	3.30 (±2.52)	2.16 (±1.31)	3.15 (±2.70)	1.20 (±1.41)	2.96 (±2.36)	1.80 (±1.21)
DL-3	2.00 (±1.49)	1.55 (±0.39)	2.28 (±1.65)	1.43 (±0.77)	2.51 (±1.99)	1.63 (±0.87)	2.45 (±2.00)	0.93 (±0.35)	**2.30 (±1.79)**	**1.40 (±0.70)**

Tab. 2: The mean absolute error (MAE) on the test set in dezibel (dB) for point-wise sensitivity (PWS) and mean sensitivity per volume (MS).

Results: Qualitative

The qualitative results illustrate exemplary healthy (top row) to severely diseased (bottom row) cases.



Conclusion

The proposed deep learning method allows to **predict retinal sensitivity from OCT volumes**. Using a model based on three-dimensional input improves the prediction performance, indicating the importance of context information. The results of this study are a promising step in exploring the linkage between image-based information and function, in particular in the context of novel biomarker candidate detection.

Acknowledgements

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