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# Intraretinal Fluid Detection by Means of a Densely Connected Convolutional Neural Network Using Optical Coherence Tomography Images †

**Plácido L. Vidal [1,2,*], Joaquim de Moura [1,2], Jorge Novo [1,2] and Marcos Ortega [1,2]**

1 Department of Computer Science, University of A Coruña, 15071 A Coruña, Spain
2 CITIC-Research Center of Information and Communication Technologies, University of A Coruña, 15071 A Coruña, Spain
* Correspondence: placido.francisco.lizancos.vidal@udc.es; Tel.: +34-981-16-70-00 (ext. 1330)
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**Abstract:** Hereby we present a methodology with the objective of detecting retinal fluid accumulations in between the retinal layers. The methodology uses a robust Densely Connected Neural Network to classify thousands of subsamples, extracted from a given Optical Coherence Tomography image. Posteriorly, using the detected regions, it satisfactorily generates a coherent and intuitive confidence map by means of a voting strategy.

**Keywords:** Computer-Aided Diagnosis; retinal imaging; Optical Coherence Tomography; deep learning; DenseNet; intraretinal cystoid region characterization

## 1. Introduction

A macular edema consists in a swelling of the macula caused by the accumulation of pathological fluid in between the retinal tissues. This disease corresponds to one of the main causes of blindness in developed countries, as its main triggers are related to an increasing lifespan and the lifestyle of the afflicted. To study, diagnose and treat these fluid accumulations, clinicians typically use Optical Coherence Tomography (OCT) images. This non-invasive medical imaging technique allows to generate a representation of the retina with a resolution of microns.

To date, this diagnostic is mostly done by means of a visual inspection by the expert ophthalmologist, prone to subjective factors. Thus, and given the relevance of the aforementioned pathologies, an automated methodology to facilitate the inspection is desirable.

## 2. Methodology

To solve this issue, we merged a regional analysis strategy that has proven to be resilient in the identification of fluid regions [1], a visualization technique specially designed to offer satisfactory results even when facing the most challenging conditions [2] and an artificial neural network architecture specially designed to overcome overfitting thanks to its densely connected layers, adding capabilities of self-supervision [3]. Thus, to generate the pathological confidence maps, the images are thoroughly sampled, extracting thousands of samples from them. Afterwards, using a previously trained DenseNet, these samples are classified and used as ballots to determine the confidence of the different regions in the image.

## 3. Results

The network was trained using a base dataset of 3247 samples from two different representative OCT capture devices, increased by means of data augmentation. Additionally, the training of the network was done by using an automated control of the learning rate depending on the validation results, and stopped by means of an early-stopping criteria that detects when the training quality has stagnated. To further study the capabilities of our system, the training process was repeated 50 times, randomly distributing the training and validation datasets and recalculating the data augmentation procedure. After all the repetitions, the system attained a satisfactory mean test accuracy of 97.45% $\pm$ 0.7611 and a mean area under the ROC curve (AUC) of 0.9961 $\pm$ 0.0029. Regarding maps, as shown in Figures 1 and 2, the DenseNet architecture is able to successfully represent both pathological and healthy regions in different representative devices of the domain.

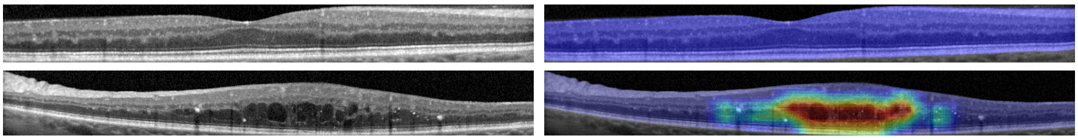

**Figure 1.** Results from a Spectralis OCT device from Heidelberg Engineering, including a healthy and a pathological example.

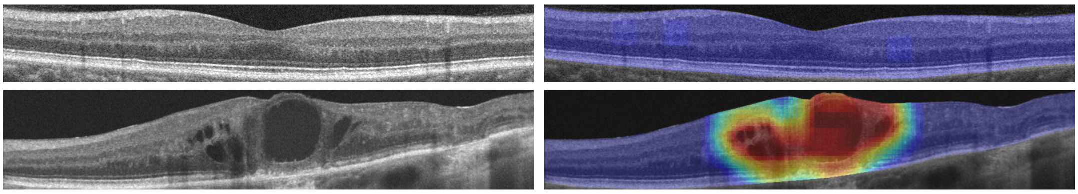

**Figure 2.** Results from a Cirrus HD-OCT OCT device from Carl Zeiss Meditec, including a healthy and a pathological example.

**Author Contributions:** P.L.V. and J.d.M. designed and performed the experiments. J.N. and M.O. contributed with their domain knowledge. All the authors helped with the analysis of the results and revision of the manuscript, written by P.L.V.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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