

# Towards Balancing the Complexity of Convolutional Neural Network with the Role of Optical Coherence Tomography in Retinal Conditions

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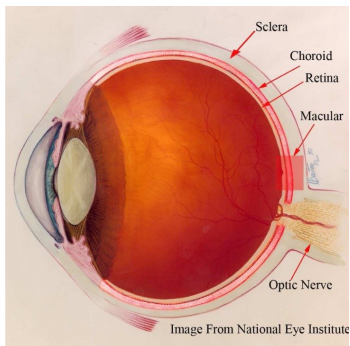
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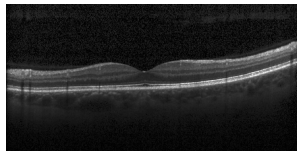
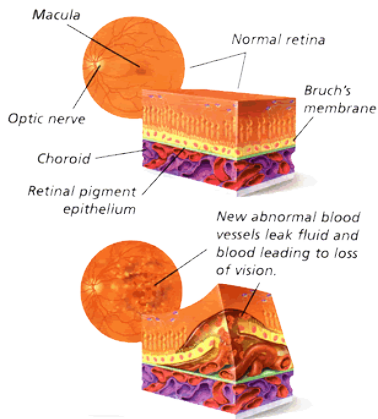
ICCP 2019

- Age-related macular degeneration (AMD) - leading cause of legal blindness and severe visual impairment in industrialized countries

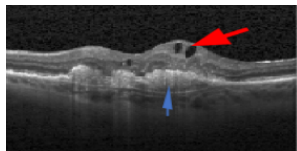


- Optical Coherence Tomography (OCT) - leading diagnostic tool in modern ophthalmology
  - a **non-invasive** imaging test
  - uses light waves to take **cross-section** pictures of the retina

# Context - Normal vs abnormal retina



Normal OCT



Abnormal OCT

- OCT biomarkers: retinal thickness, intraretinal cystoid fluid, subretinal fluid, alterations of outer retinal layers, hyperreflective foci

# Objectives

How the **pathological features** of the retinal conditions can be connected to what might be found from the **CNNs** produced by training on various data sets

- Train two different architectures
  - with transfer knowledge
  - without transfer knowledge
- Analyse the results
  - quantitative analysis
  - from the ophthalmologist perspective
  - with heatmaps built with occlusion test

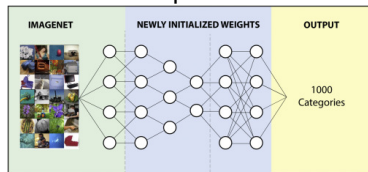
# Dataset - OCT 2017

- Train

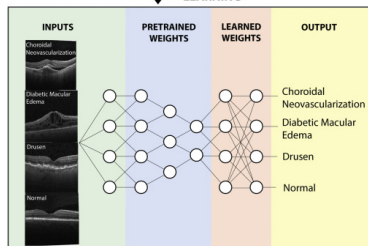
Retinal Conditions	Number of images
CNV	37,206
DME	11,349
AMD(DRUSEN)	8617
Normal	51,140

- Test: 1000 images (250 for each category)

Kermany et.al (2018)  
- Inception V3



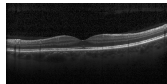
↓  
TRANSFER  
LEARNING



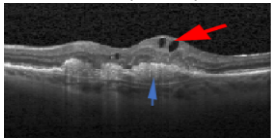
Accuracy 96.6

# Typical aspect

Normal OCT



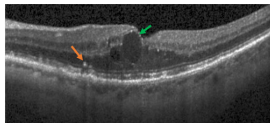
Choroidal neovascularisation (CNV)



**fibrous plaque** (typical for this class)

**cyst-like empty optical spaces** - (typical for DME, but can appear in CNV 3)

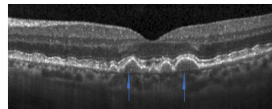
Diabetic macular edema (DME)



**the cyst-like empty optical spaces** cystoid-macular oedema

**hyperreflective dots**-hard exudates

DRUSEN



**wavelets in the RPE** with average reflectivity content with no fluid or fibrosis

# What we trained?

- With transfer knowledge: VGG-16 +
  - Conv  $1024 \times 5 \times 5$  + MaxPooling + Flatten + Dropout + Dense 64 + Dense 4
  - Total params:  $19 * 10^6$ , Trainable:  $5 * 10^6$
- Without pretrained: SqueezeNet (achieved AlexNet-level accuracy on ImageNet with 50x fewer parameters)
  - Total params: 76,059, Trainable: 76,059

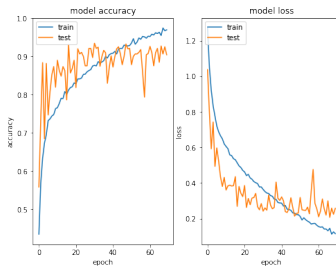
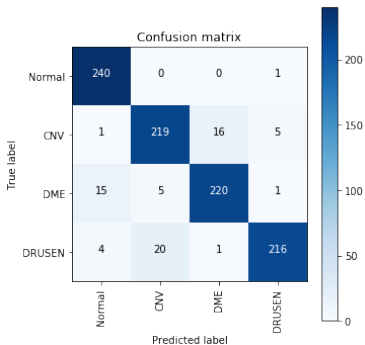
# Quantitative results

- Training on 1399 Normal images, 790 CNV, 712 DME, respectively 708 DRUSEN, meaning approximately 5% of the entire train set.
- Testing on 241 images for each category



# Quantitative results - VGG-16 based network

- learns very fast
- overfits after 50 epochs - small training set



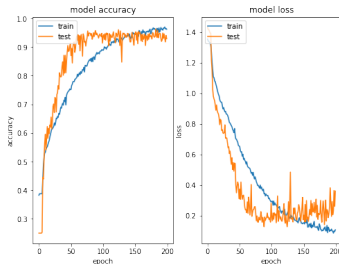
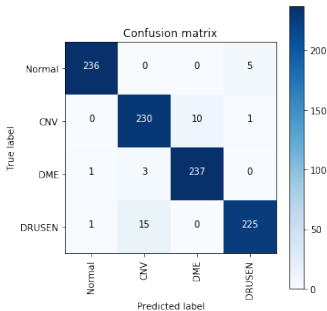
	Precision	Recall	F1-score
Support			
Normal	0.92	1.00	0.96
CNV	0.90	0.91	0.90
DME	0.93	0.91	0.92
DRUSEN	0.97	0.90	0.93
accuracy			0.93

- many abnormals included in normal

- many non-CNV included in CNV  
- very precise for DRUSEN

# Quantitative results - SqueezeNet network

- learns slowly
- the effect of overfitting appears at lower values of loss
- it reaches higher values for accuracy



	Precision	Recall	F1-score
Normal	.99	.98	.99
CNV	.93	.95	.94
DME	.96	.98	.97
DRUSEN	.97	.93	.95

accuracy

.96

- normal OCT more precise
- CNV as DME
- DRUSEN as CNV

# 1. Interpretation of the results obtained with SqueezeNet

Features which can belong to two conditions are present in the image, DL identifies both classes, but the **wrong class has higher probability**

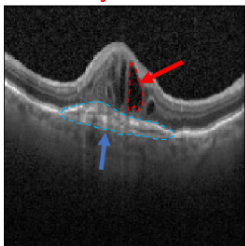


image:20  
NO: 0  
CNV: .27  
DME: .73  
DR: 0

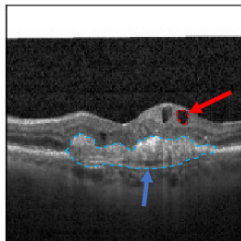


image:66  
NO: 0  
CNV: .13  
DME: .87  
DR: 0

**Subretinal fibrous plaque** is a sign of CNV, the **cyst-like empty optical spaces** are more typical for DME, but it can also appear in CNV type 3. However, seeing the fibrous plaque associated with the cysts, CNV type 3 should be the most probable diagnostic.

# 1. Interpretation of the results obtained with SqueezeNet

Features which can belong to two conditions are present in the image, DL identifies the **correct class with a probability close to 1**

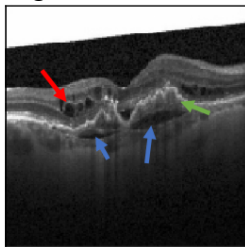


image:116  
NO: 0  
CNV: .99  
DME: .01  
DR: 0

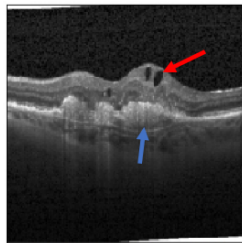


image:106  
NO: 0  
CNV: 1  
DME: 0  
DR: 0

There is **subretinal fluid** - sign of CNV and also **pigment epithelium detachment associated with CNV**. Even though there are **cyst-like empty optical spaces**, the probability for DME is 0. This comes in contrast with image 66 which is quite similar with image 106 and yet, it is classified as DME.

# 1. Interpretation of the results obtained with SqueezeNet

Features which can belong to two conditions are present in the image, DL identifies the **wrong class with probability close to 1**

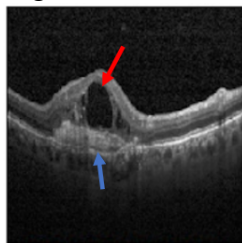


image:223  
NO: 0  
CNV: .02  
DME: .98  
DR: 0

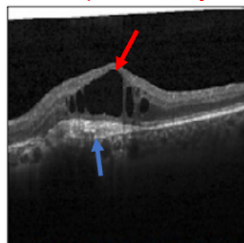
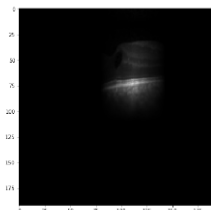
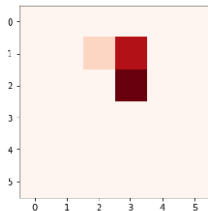
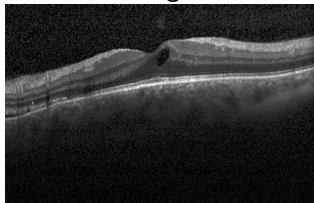


image:226  
NO: 0  
CNV: .00  
DME: 1  
DR: 0

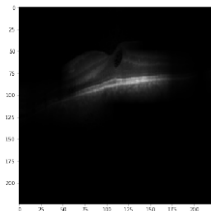
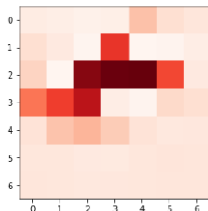
The **subretinal fibrous plaque** associated with **cyst** indicates CNV type 3. A possible explanation for the wrong classification as DME might be the size of the cysts.

## 2. Are the features of interest identified by the DL?

Occlusion test: correct  
classified image DME



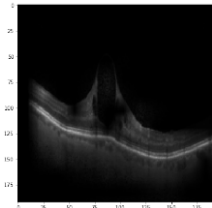
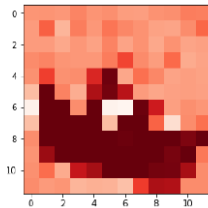
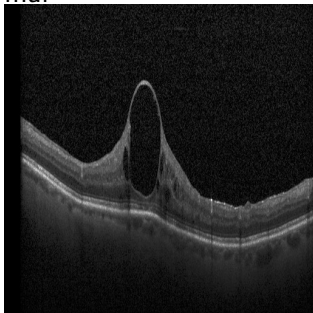
b) SqueezeNet is more specific in identifying cyst-like empty optical space DME specific feature



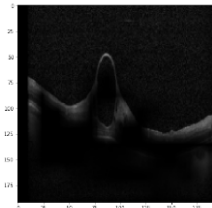
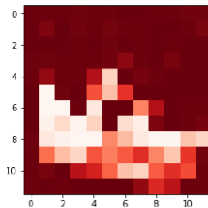
(c) VGG16 considers a larger area

## 2. Are the features of interest identified by the DL?

Occlusion test: DME  
**wrongly** classified as Normal



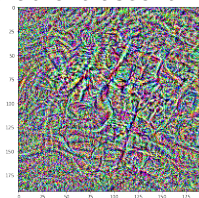
(b) Heatmap obtained for the class NORMAL (which is wrongly predicted)



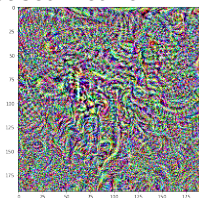
(c) Heatmap obtained for maximization of positive variance in DME and negative variance in NORMAL

### 3. Finding images that maximizes a specific class

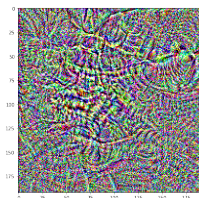
Gradient ascent for VGG-16 based network



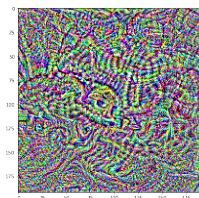
Normal



CNV



DME



DRUSEN

Classified by SqueezeNet with almost 1 in CNV



# Conclusions

- Deep Neural Network are capable of representing OCT images
  - at least for classification
    - small training set is enough in both approaches: with transfer knowledge & without transfer knowledge but with smaller network
    - the network without transfer knowledge appears to be better suited - an explanation could be the particularities of the medical domain compared to ImageNet
- Are the OCT specific features captured by the networks?  
**Current conclusion: areas containing relevant OCT features are important for the networks**

## Future work:

- continue investigation towards understanding what the network learns
- use NN representation for the analysis of evolution of AMD