Fine-tuning Convolutional Neural Networks: a comprehensive guide and benchmark analysis for glaucoma screening

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Outline

Introduction

Methods

Results

Discussion
Introduction
Context: Glaucoma

Chronic eye disease causing gradual loss of vision field, and leading to complete blindness

Number of people affected by glaucoma worldwide:
76.0 million (2020), 111.8 million (by 2040)

• Concern all age groups, all ethnicities
• Asymptomatic at the earlier stage, with silent progression until visual disturbance occurs
• Difficult to slow down disease spreading at the advanced stages

Early glaucoma screening and diagnosis is CRUCIAL

World Health Organization, « Blindness and vision impairment »
YC Tham et al., « Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis »
Glaucoma: how to screen the disease?

Assessment of the visual field

- alteration of the visual field occurs at a too-late stage

Assessment of the intra-ocular pressure (IOP)

- neither necessary nor sufficient criterion to detect the presence of glaucoma

Assessment of the eye fundus (retina)

- accurate, allows early screening of glaucoma for efficient treatment
Glaucoma: retinal structures’ damages

- Retina is the region responsible for capturing the light entering inside the eye, for visual perception.
- Glaucoma causes structural changes within and around the optic nerve head (ONH), the region in the retina where light information converges to the brain.


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**Healthy case**

**Glaucomatous case**
Glaucoma: AI for better screening

• Assist the specialists in glaucoma screening, for more accurate diagnosis

• Enhance patient-centered care, and provide better treatment delivery, prognosis and follow-up

• Integrate eye health services to the traditional health pathway

• Deploy intelligent mobile platforms for widespread eye care facilities universally.

Li et al., “Efficacy of a deep learning system for detecting glaucomatous optic neuropathy based on color fundus photographs”
Goal of our work

- To exploit powerful deep learning (DL) algorithms, and implement transfer learning strategy to provide effective glaucoma assessment from retinal fundus images.

- To give an extensive benchmark analysis of such state-of-the-art CNNs networks in terms of accuracy, computational efficiency and inference time.
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- Discussion
Methods
Proposed method for glaucoma screening

Methods

Retinal images and labels

Pre-trained CNN model with 1000-class ImageNet weights

Data processing

Model loading

Inputs

Output

Fine-tuning with hyperparameter optimization

Network transfer

Healthy

Glaucomatous

Glaucoma screening and diagnosis

VGG16 architecture

Pre-trained CNN model

Fine-tuning with hyperparameter optimization

VGG16 architecture

Updated VGG16 architecture

International Conference in Pattern Recognition (ICPR)

4-8 Jan, 2021 - Milan, Italy
Proposed method for glaucoma screening

Inputs

Retinal images and labels

Pre-trained CNN model with 1000-class ImageNet weights
Proposed method for glaucoma screening

• Retinal image dataset: KIM-EYE
• Preprocessing step: crop around the optic nerve head (ONH)

Data processing

• Train/validation splitting (80/20 ratio)
• Data augmentation: rotation, vertical and horizontal flipping, zooming, etc.

Methods

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Proposed method for glaucoma screening

- Five networks: VGG16, ResNet50, Inception-v3, DenseNet121 and MobileNet
- Each network is loaded with its pre-trained weights from ImageNet
Proposed method for glaucoma screening

- Five networks: VGG16, ResNet50, Inception-v3, DenseNet121 and MobileNet
- Each network is loaded with its pre-trained weights from ImageNet
- Removal of the last fully-connected layer for binary classification
Proposed method for glaucoma screening

Methods

Retinal images and labels

Data processing

Fine-tuning with hyperparameter optimization

Outputs

Updated VGG16 architecture

Healthy

Glaucomatous

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Proposed method for glaucoma screening

- Two-stage transfer learning method: warm-up phase (freezing all layers) and fine-tuning phase (incrementally defreezing the last layers)
- Automated grid-search of hyperparameters: learning rate = \{1e-4; 5e-5; 1e-5\} and batch size = \{8; 12\}
- Early stopping for each step on validation loss

Methods

**Healthy**

**Glaucmatous**

Glaucoma screening and diagnosis

- Augmented data
- Updated VGG16 architecture
- Fine-tuning with hyperparameter optimization

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Introduction  Methods  Results  Discussion
Results
Glaucoma screening performance

Fig: Qualitative results with output prediction on healthy and glaucomatous images.

Table and Fig: Quantitative results with the evaluation of DL models for glaucoma screening.
Benchmark analysis

<table>
<thead>
<tr>
<th>Model</th>
<th>Model depth</th>
<th>Model complexity (M)</th>
<th>Memory size (Mb)</th>
<th>AUROC density</th>
<th>Inference time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGG16</td>
<td>21</td>
<td>14.72</td>
<td>118</td>
<td>0.0664</td>
<td>7.60</td>
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<tr>
<td>ResNet50</td>
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<td>23.57</td>
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<td>18.86</td>
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<td>Inception-v3</td>
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<td>21.81</td>
<td>175</td>
<td>0.0443</td>
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<td>DenseNet121</td>
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<td>7.04</td>
<td>57.3</td>
<td>0.1375</td>
<td>32.58</td>
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<tr>
<td>MobileNet</td>
<td>89</td>
<td>3.23</td>
<td>26</td>
<td>0.2979</td>
<td>10.64</td>
</tr>
</tbody>
</table>

![Inference time vs AUROC value graph]

- VGG16 (# para. = 14.7157 M)
- Inception-v3 (# para. = 21.8069 M)
- MobileNet (# para. = 3.2309 M)
- ResNet50 (# para. = 23.5669 M)
- DenseNet121 (# para. = 7.0396 M)
Outline

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Discussion

• The proposed methods for fine-tuning CNNs for glaucoma screening allows to accurately detect glaucomatous patterns from retinal fundus images
• The benchmark analysis has highlighted the strength of CNNs trained on other computer vision tasks, including MobileNet and VGG16

• Difficult to generalize the screening process with the most suspicious cases, or other real-world retinal image with different image capturing settings

• Study novel algorithms for providing interpretability and explainability on the model result (saliency maps, GRAD-CAM, integrated gradients, etc.)
• Explore image domain adaptation algorithms for enhancing generalization ability of the models
• Build other ensemble methods combining the strenghts of ML/DL algorithms for even better diagnosis (SVMs, AdaBoost, etc.)
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Thank you!

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