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

Amed Mvoulana, *Rostom Kachouri, Mohamed Akil*

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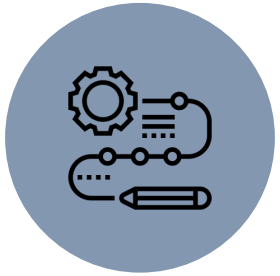
Outline

Introduction



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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)

Healthy vision

Glaucomatous vision

- 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)

↓

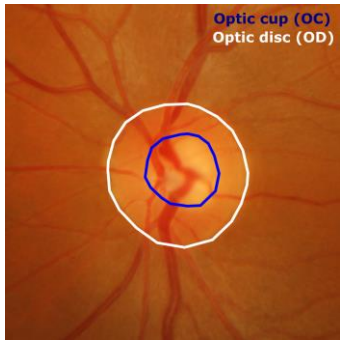
accurate, allows early screening of glaucoma for efficient treatment

Glaucoma: retinal structures' damages

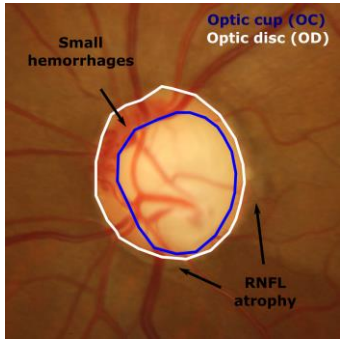
- Retina is the region responsible for capting the light entering inside the eye, for visual perception

- Glaucoma causes structural changes within and around the optic nerve head (ONH), the region in the retina where light information converges to the brain

Healthy case



Glaucomatous case



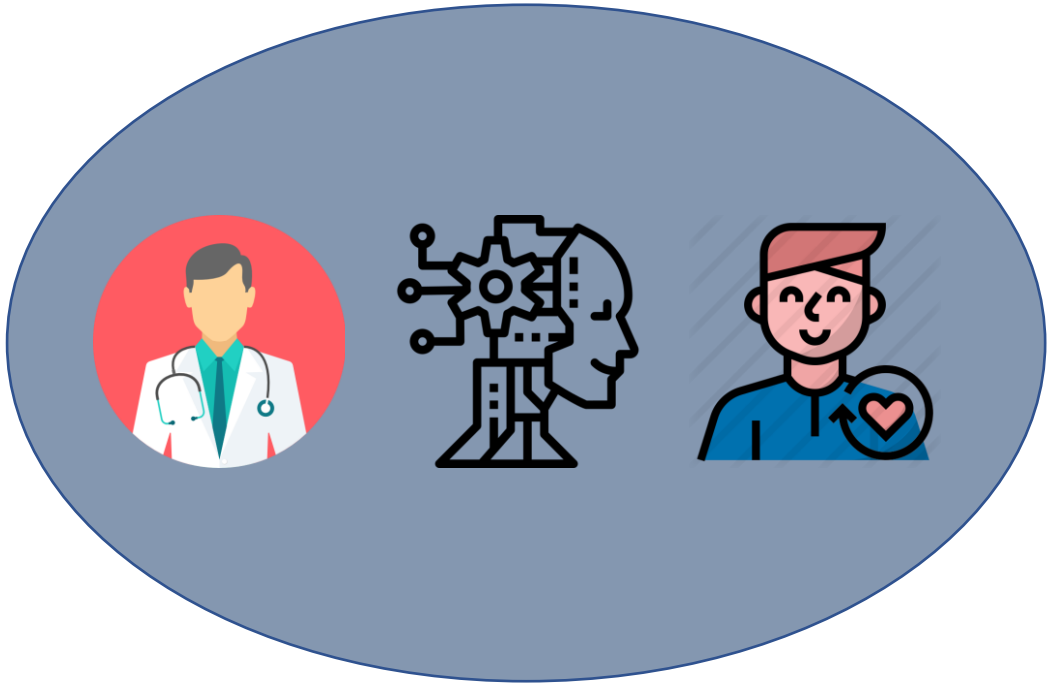
Mvoulana, A., Kachouri, R., & Akil, M. (2020). Novel approach for early glaucoma screening and diagnosis using in-depth clinical analysis of the optic nerve head from retinal fundus images.

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 widespreading 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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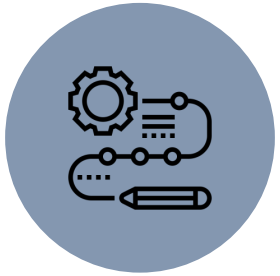

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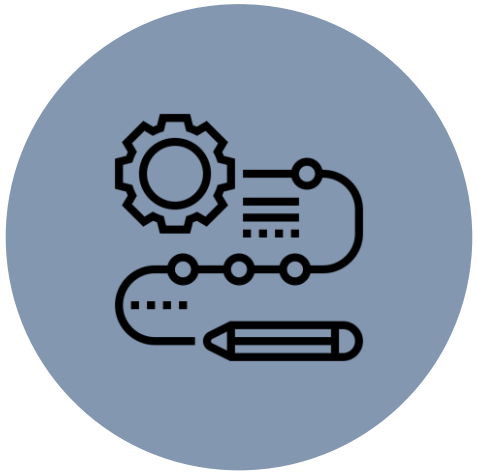
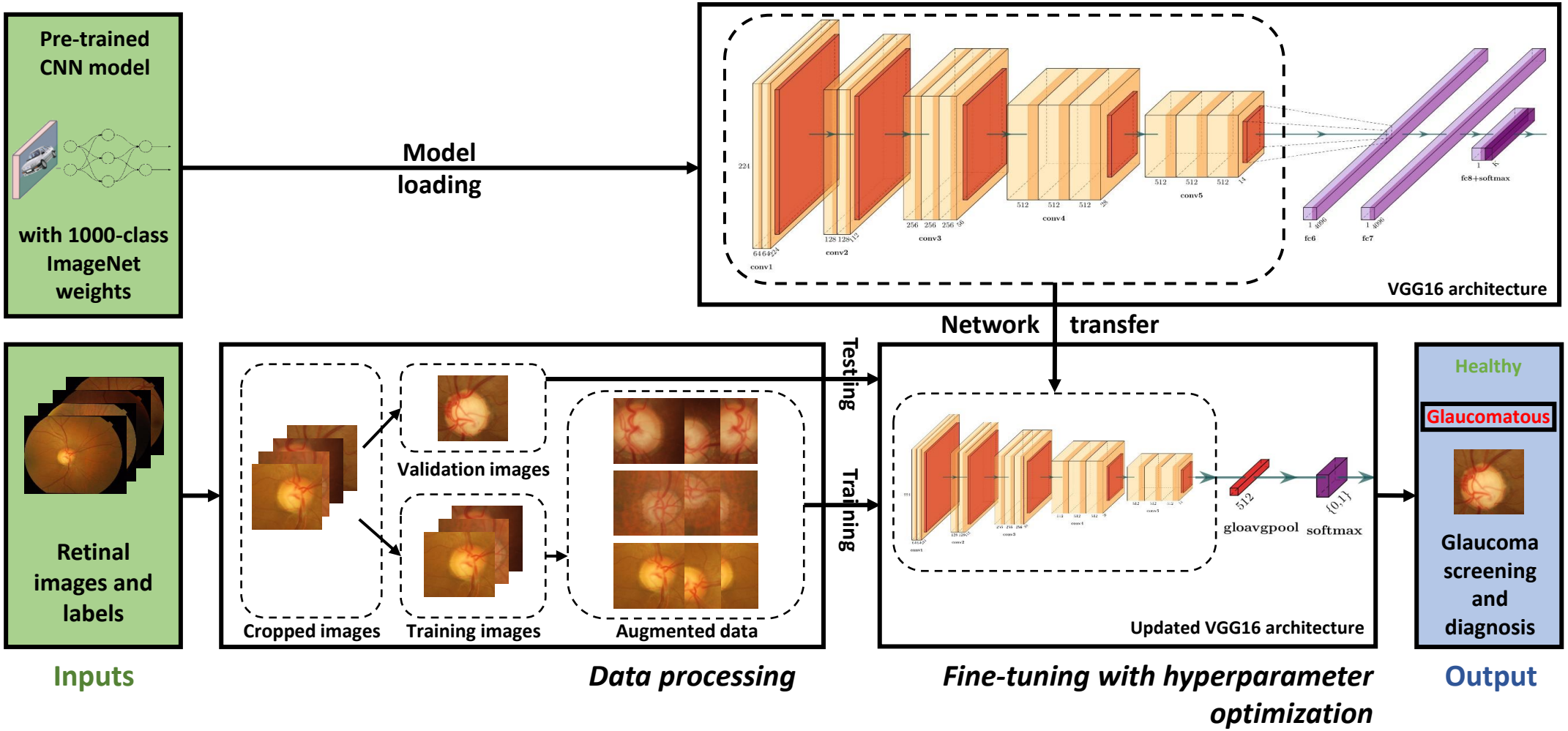


Methods

Proposed method for glaucoma screening



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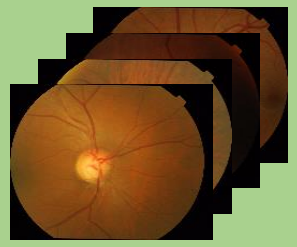
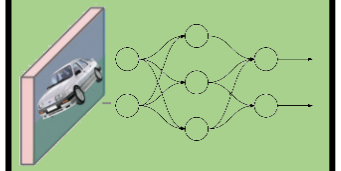


Retinal images and labels

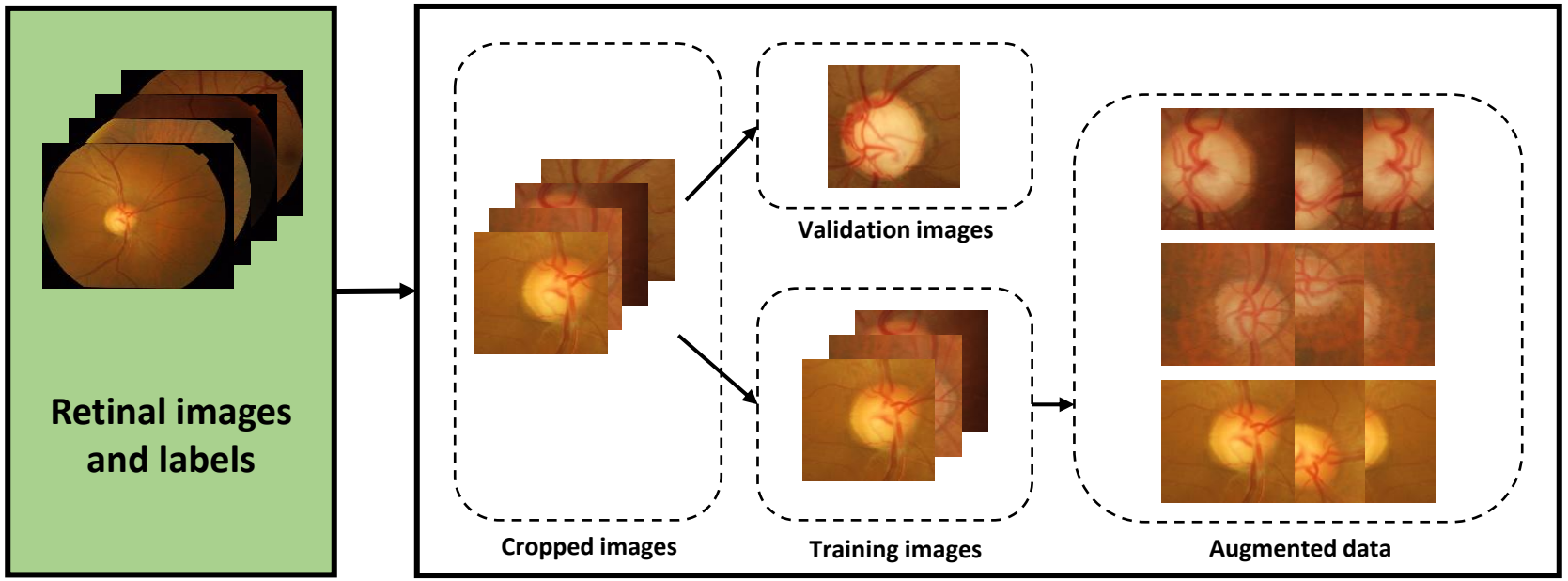
Pre-trained CNN model



with 1000-class ImageNet weights

Inputs

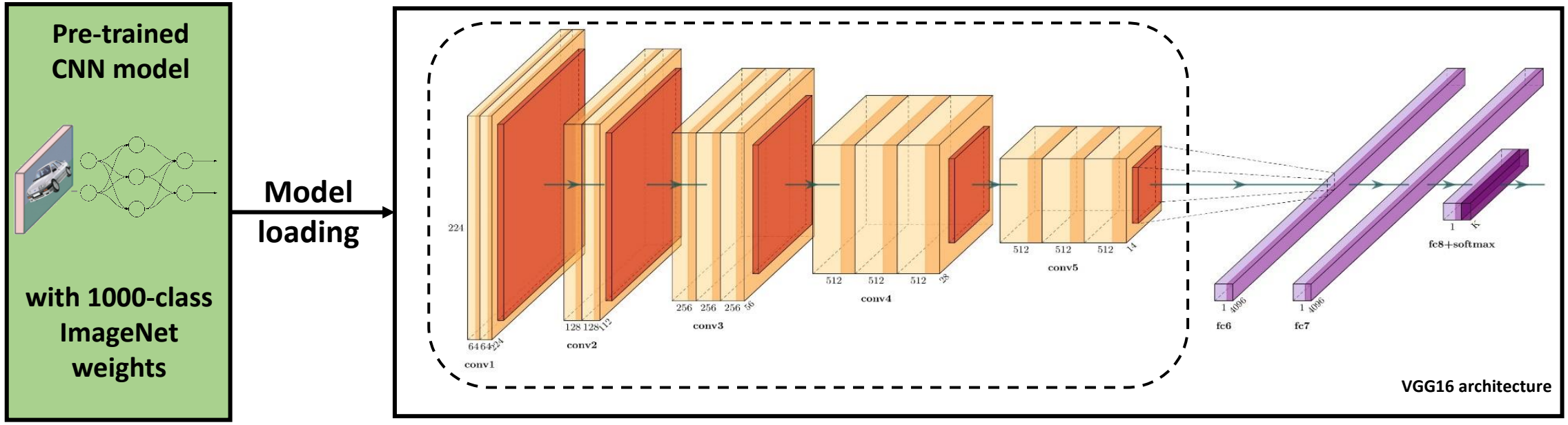
Proposed method for glaucoma screening



Data processing

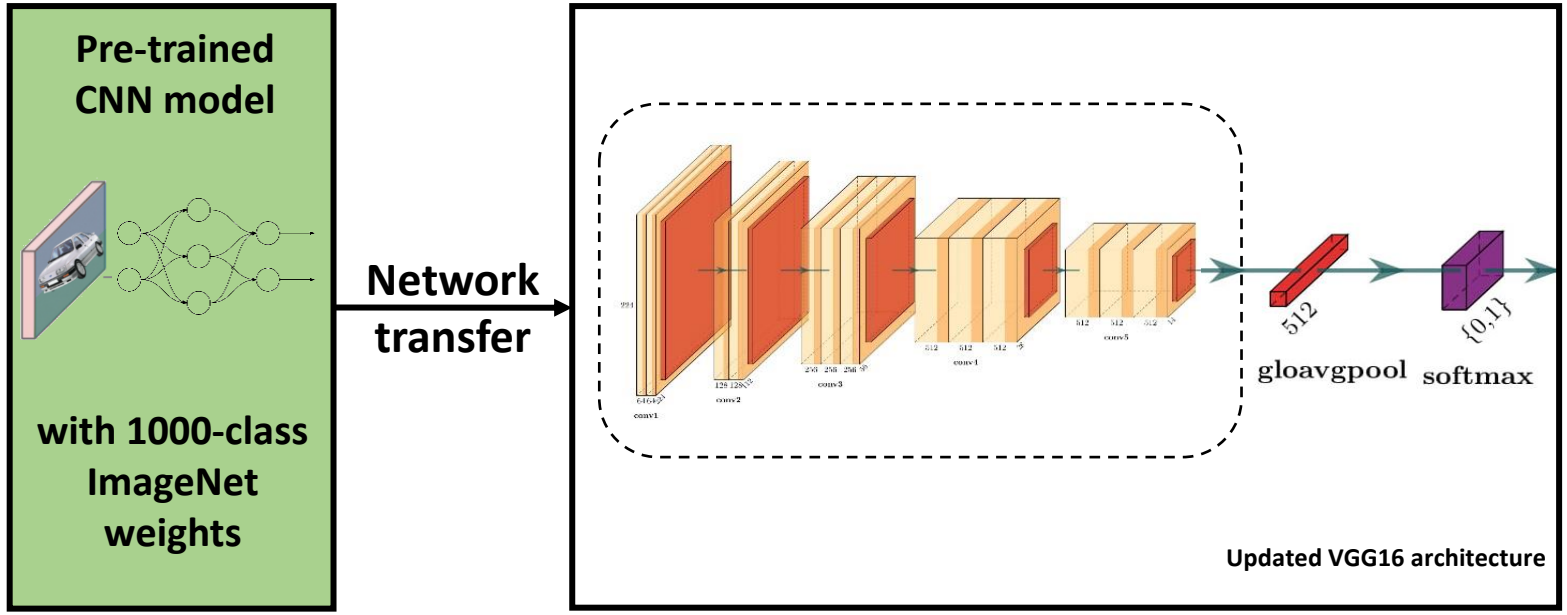
- Retinal image dataset: KIM-EYE
- Preprocessing step: crop around the optic nerve head (ONH)
- Train/validation splitting (80/20 ratio)
- Data augmentation: rotation, vertical and horizontal flipping, zooming, etc.

Proposed method for glaucoma screening



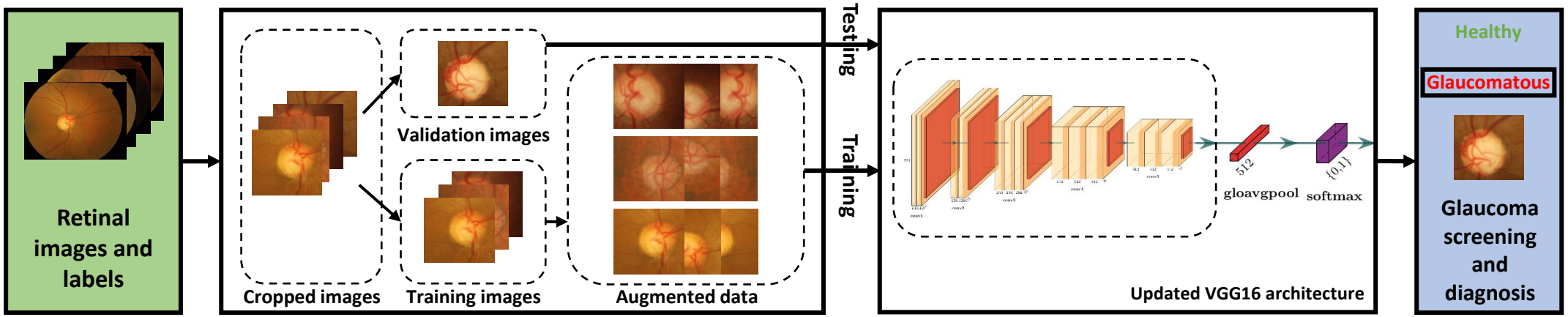
- Five networks: VGG16, ResNet50, Inception-v3, DenseNet121 and MobileNet
- Each network is loaded with its pre-trained weights from ImageNet

Proposed method for glaucoma screening



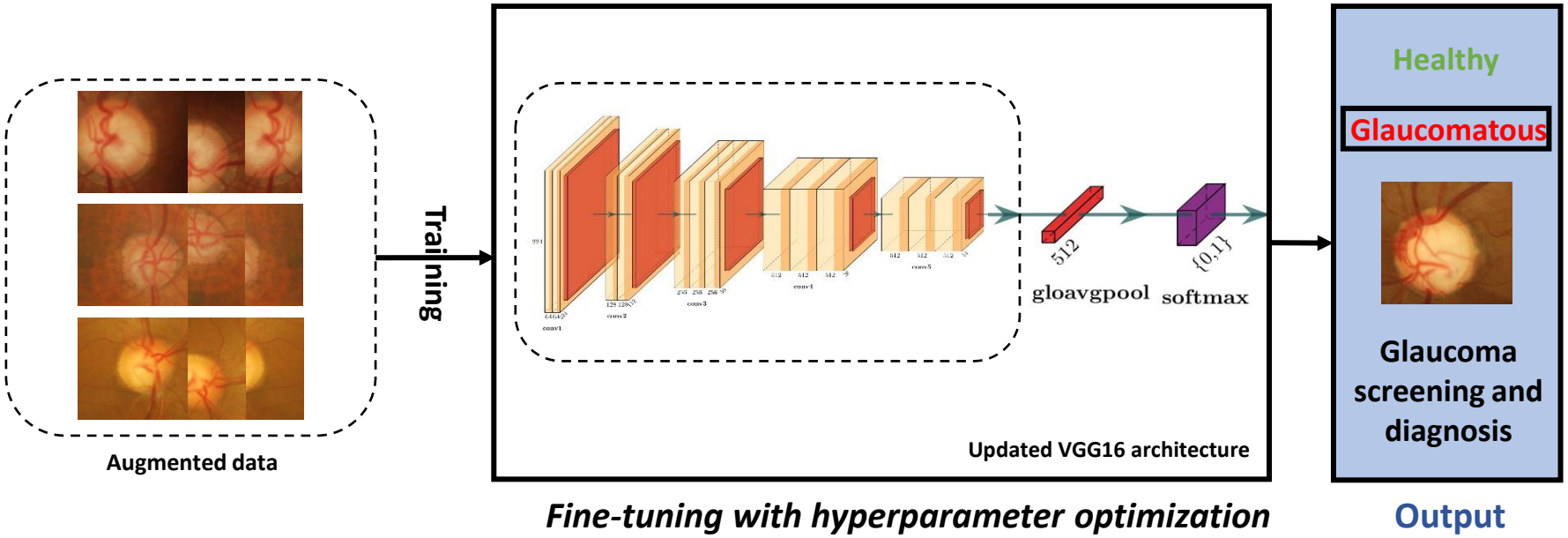
- Five networks: VGG16, ResNet50, Inception-v3, DenseNet121 and MobileNet
- Each network is loaded with its pre-trained weights from ImageNet
- Removal of the last fully-connected layer for binary classification

Proposed method for glaucoma screening



Inputs | ***Data processing*** | ***Fine-tuning with hyperparameter optimization*** | **Output**

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; 1^{e}-5} and batch size = {8; 12}
- Early stopping for each step on validation loss

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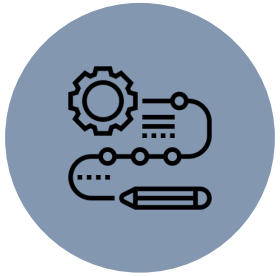

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Glaucoma screening performance

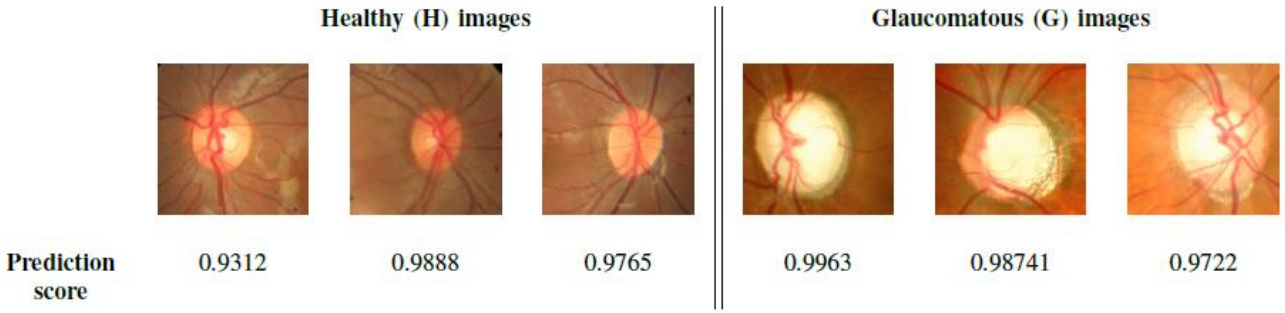


Fig: Qualitative results with output prediction on healthy and glaucomatous images.

Model	AUROC	Acc	Sen	Spe	PPV	NPV	F1-score
VGG16	**0.9772**	**0.9290**	0.9130	**0.9419**	**0.9265**	0.9310	**0.9197**
ResNet50	**0.9703**	0.9161	0.9275	0.9070	0.8889	0.9398	0.9078
Inception-v3	0.9658	0.9189	0.9275	0.8837	0.8649	0.9383	0.8951
DenseNet121	0.9681	0.9161	0.9275	0.9070	0.8889	0.9398	0.9078
MobileNet	0.9626	0.9032	**0.9565**	0.8605	0.8462	**0.9610**	0.898

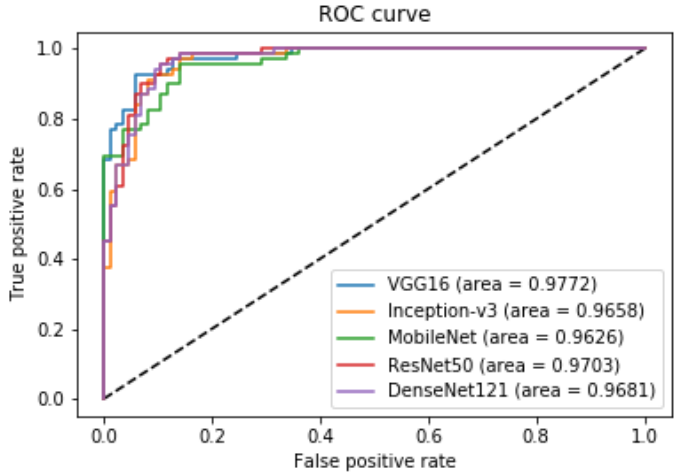
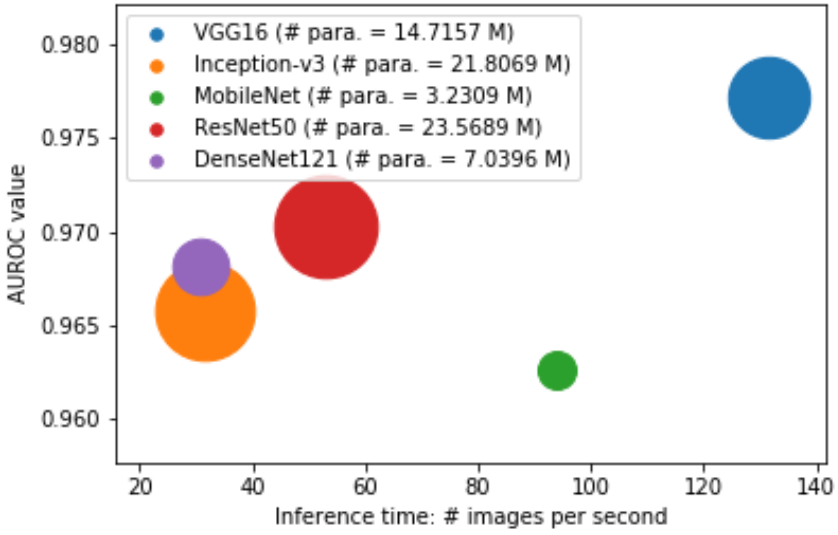


Table and Fig: Quantitative results with the evaluation of DL models for glaucoma screening.

Benchmark analysis

Model	Model depth	Model complexity (M)	Memory size (Mb)	AUROC density	Inference time (ms)
VGG16	21	14.72	118	0.0664	**7.60**
ResNet50	192	23.57	189	0.0412	18.86
Inception-v3	313	21.81	175	0.0443	31.88
DenseNet121	429	**7.04**	57.3	0.1375	32.58
MobileNet	89	**3.23**	**26**	**0.2979**	**10.64**



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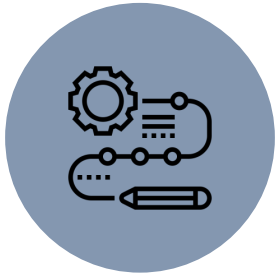

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• The proposed methods for fine-tuning CNNs for glaucoma screening allows to accurately detect glaucomatous patterns from retinal fundus images
• The benchmark analysis has highlighted the strength of CNNs trained on other computer vision tasks, including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

Thank you!

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