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Mobile Aided System of Deep-Learning based Cataract Grading from Fundus Images

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Abstract.

The cataract is an ocular disease which requires early detection to avoid reaching a higher severity level. However, a worldwide deficiency of ophthalmologists and medical imaging devices is registered, which prevents early cataract detection. Our main objective is to propose a high performance method of cataract grading with a lower computational processing to be suitable for mobile devices. The main contribution consists in extracting features through a transfer-learned and fine-tuned MobileNet-V2 model, and deducing the cataract grade using a random forest classifier. The evaluation is conducted using a dataset of 590 fundus images, where 91.43% sensitivity, 89.58% specificity, 90.68% accuracy and 92.75% precision are achieved. In addition, the method implemented into a smartphone requires an average execution time of 1.41 second. The method implementation as an app into a smartphone associated to an optical lens for retina capturing, presents a mobile-aided-grading system that facilitates diagnosing the cataract disease.

Keywords: Cataract, Deep learning, MobileNet-V2, Random forest, M-health.

1 Introduction

The cataract is an ocular disease where the eye lens, initially transparent, becomes cloudy due to protein accumulation [1, 2]. This pathology is the main cause for half of the blind worldwide, where their number may achieve 40 million in 2025. It is always diagnosed using the ophthalmoscopy technique where the blurriness of the retina components is similar to the protein accumulation and hence to the cataract severity, where the mild, moderate and severe grade are respectively shown in Fig.1.

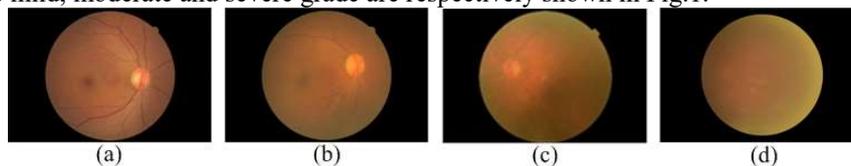


Fig. 1. Retinal images of cataract grades. (a) Non-cataract. (b) Mild. (c) Moderate. (d) Severe

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A higher difficulty has been noticed in recognizing cataract, despite that significantly affects the life quality by imposing activity limits. Therefore, it is highly recommended a periodical diagnosis to avoid achieving advanced stages [1, 2, 3]. However, worldwide deficiencies of ophthalmologists and medical imaging devices are observed. Elsewhere, the cataract affects a population that exceeds 50 years old, having a limited mobility. Consequently, a delay of early cataract diagnosis is registered.

Actually, several lenses have been recently proposed which can be snapped onto mobile devices to ensure capturing fundus images [5]. The provided fundus images are easily readable and have an acceptable quality with respect to the ones captured by classical ophthalmoscopy. For this purpose, our main idea is to suggest a novel method for cataract grading. The challenge is to perform reliable grading from fundus images using lower complexity processing to be suitable for mobile devices. For such need, we perform cataract grading through the MobileNet-V2 deep learning architecture associated to the random forest classifier. The implementation of the method into a smartphone as an app leads to a Mobile-Aided-Grading (MAG) system for the cataract disease. The paper is organized as follows. Section 2 describes the propounded method for cataract grading. The method evaluation is presented in section 3. The implementation of the MAG system is detailed in section 4, followed by a conclusion in section 5.

2 Novel method for cataract grading

2.1 Preprocessing & data augmentation

The fundus images are resized to $(224 \times 224 \times 3)$ as required for MobileNet-V2. In addition, a cataract-affected fundus image appears with a blurred region with a different contrast than the retina background. Furthermore, handheld capturing with a smartphone leads to a light leakage, and so to a randomly increased contrast in image sections. To resolve this problem, we apply the Contrast Limited Adaptive Histogram Equalization (CLAHE) approach to enhance the fundus image contrast. Thereafter, a mask is applied to encompass the retina from its background. Elsewhere, we put forward data augmentation where the fundus images are rotated, zoomed, shifted and flipped in both vertical and horizontal direction [6]. Both preprocessing and data augmentation are depicted in the black dotted squares of Fig.2.

2.2 Fine tuning and transfer learning

The preprocessed image is provided to a MobileNet-V2 architecture to generate feature map. This architecture is a convolutional neural network, which is composed of 17 bottleneck residual blocks followed by a global average pooling layer. The limited size of images, as the case of cataract-affected fundus images, avoids converging the model weight, thus not achieving higher performance grading. For this purpose, we adopt the transfer learning method where a MobileNet-V2 model, trained with the "ImageNet" dataset containing 1000 categories, is used in our method [7]. The initial classification layer is replaced by a set of three layers. The first one consists in a fully connected dense layer with the ReLU function where the feature map size is reduced to 256. The second layer applies a dropout function to initiate the classification. The last one is a

dense layer with the Softmax function which provides a vector of probability features, where the size is identified experimentally as mentioned in section 3.2. To enhance the weight convergence, we proceed to fine-tune the model, which allows updating its weights during training with a learning rate of 0.0001. In addition, the optimal weight with respect to accuracy is saved after each epoch, in order to accelerate the model convergence while avoiding overfitting [7]. Training is done into 150 epochs using the "Adam" optimizer and the "categorical-cross entropy" loss function.

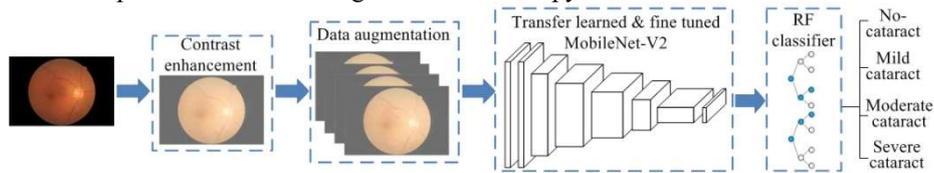


Fig. 2. Processing flowchart of the proposed cataract grading method

2.3 Classification for cataract grading with Random Forest

Our goal is to achieve a higher performant classification even with a reduced dataset size while having a lower complexity to be suitable for a mobile implementation. The classifier retrieves a feature vector from the deep learning model, which is composed of four probability values with respect to the four cataract grades. It is noticed that some grades have a higher dependency with specific features, while other grades correspond to a significant variation in a whole feature sub-set. To handle the feature correlation, the Random Forest (RF) is used to ensure the classification into cataract grading. It is considered as a set of decision trees where each one is formed by a feature subset, randomly selected [19]. The RF has two main parameters, which are the number of trees in the forest and the maximum depth of the trees. We perform an experimental study, as detailed in section 3.2, where the RF is employed with a varied depth to identify the one achieving better detection performances.

3 Experimental results

3.1 Dataset and evaluation metrics

Two public databases have recently uploaded in Kaggle which are the "Cataract Dataset" and "Ocular Disease Recognition (ODiR)" respectively containing 100 and 293 fundus images affected by different cataract stages. To guarantee a reliable evaluation, a dataset of 590 fundus images is build which are split into 220 non-cataract, 65 mild stage, 145 moderate stage and 160 severe stage fundus images. The images of each grade are randomly divided into five subsets where the three first ones are used for training, the fourth is dedicated for validation, while the last is used for testing. The experimental evaluation is conducted by referring to four metrics which are sensibility (Sens), the specificity (Spec), the accuracy (Acc) and the precision (Prec), respectively computed as indicated in equations (1-4).

$$\text{Sens} = \frac{TP}{TP+FN} \quad (1); \quad \text{Spec} = \frac{TN}{TN+FP} \quad (2); \quad \text{Acc} = \frac{TP+TN}{TP+TN+FP+FN} \quad (3); \quad \text{Prec} = \frac{TP}{TP+FP} \quad (4)$$

where TP, TN, FP and FN are respectively True Positive, True Negative, False Positive and False Negative cataract-detected images.

3.2 Cataract grading performance

A first experimentation is performed where the size of feature vector is varied. It was deduced that a vector of four feature allows achieving a better classification performance. In a second experimentation, we conduct an experimentation of four different evaluations, where the tree depth is varied from 1 to 4, which corresponds to the number of probability features taken into account. The maximal number of trees is fixed to 300 in order to guarantee achieving better feature combinations. The metrics for the four evaluations are illustrated in Table.1, where it is deduced that using a depth of 4 allows achieving the highest performances.

Table.1. Performance of cataract grading

Arch.	MobileNet-V2			MobileNet-V2 & Random Forest			
	Size of Feature vector			Tree depth			
	4	8	12	1	2	3	4
Sens (%)	87.50	85.94	83.08	93.22	92.19	91.18	91.43
Spec (%)	77.78	74.07	75.47	78.57	79.63	86.00	89.58
Acc (%)	83.05	80.51	79.66	86.09	86.44	88.98	90.68
Prec (%)	82.35	79.71	80.60	82.09	84.29	89.86	92.75

Then, we evaluate our methods with respect to the existing ones by comparing the whole accuracy and sensitivity and specificity of each grade, where the values are shown in Table 2. We notice that our method achieves the highest accuracy and realizes better sensitivity performances in the first, third and fourth grades.

Table. 2. Cataract grading performance of related methods

Methods of cataract grading	Non-cataract		Mild		Moderate		Severe		Acc
	Sen	Spec	Sen	Spec	Sen	Spec	Sen	Spec	
Yang et al. [4] (2016)	89.3	90.4	79.5	87.9	74.6	96.7	75.0	98.9	84.5
Cao et al. [2] (2020)	93.53	95.44	82.17	93.83	73.27	94.55	89.66	97.37	85.98
Song et al.[3] (2019)	--	--	--	--	--	--	--	--	88.6
Zhou et al. [1] (2019)	--	--	--	--	--	--	--	--	89.23
Our method	97.73	93.48	61.54	80.00	89.66	86.67	93.75	93.75	90.68

4 Mobile-Aided-Grading System for Cataract Disease

The whole method is coded using the python language where MobileNet-V2 is implemented using the "Keras" API. The cloud service "google Colab" is employed for training and testing the deep learning model which contains 2,257,984 parameters, where 2,223,872 are updated through fine tuning. To run the MobileNet-V2 model into a smartphone, the "TFLiteConverter" class of the public "tf.lite" API is utilized to convert the trained "TensorFlow" model into a "TensorFlowLite" model. The whole method is coded with the JAVA language and implemented as an android app. To employ the model, the "TensorFlow Lite Task" library is implemented, which contains easy-to-use methods to create apps using "TensorFlowLite" model. Then, the "TensorFlow Lite Android Support" library is used, which allows managing input data and

interpreting the provided output. Image processing and the RF classifier grading is performed using The "Open Source Computer Vision (OpenCV)" library which is compiled through Android Native Development Kit (NDK) [8].

The whole method is run as an app into a "Samsung Galaxy A31" smartphone having an octa-core processor (2 x 2GHz & 6 x 1.95GHz) and 4 Go RAM. To evaluate the execution time, three fundus images are randomly selected from each grade, where the average execution time of the whole method is about 1.41 second.

Conclusion

We have suggested a novel method for cataract grading, where the MobileNet-V2 architecture has been used for feature extraction, while the RF classifier has been performed for grading. The experimental evaluation has proved that our proposed method can achieve higher performance grading with respect to recent related work. In addition, the lower complexity has allowed performing grading under two seconds when run on a smartphone. Those grading and computational performances have resulted a MAG system for the cataract disease, where its mobility and lower cost boost the early cataract diagnosis. In our future work, we aim to enhance the grading performance by extracting other features that reflect the cataract disease. Subsequently, an ensemble learning principle can be put forward to perform accurate grading. In addition, we will be interested in extending the mobile system to detect other ocular pathologies such as the diabetic retinopathy and the glaucoma.

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