Cataract detection and grading based on Retinal Images using Deep Learning

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Contents

Eye Diseases

- Visual impairment, generally termed as vision loss, is described as an inability to see.
- Rectification is not possible using aids such as lens or glass adoption.
- Cataract, glaucoma, ARMD, uncorrected refractive errors, trachoma, and diabetic retinopathy are some major reasons behind it.
- Worldwide, 50% of blindness cases are contributed by cataract alone.
- Hence, the availability of knowledgeable ophthalmologists and proper treatment facilities is a must to cure the impairment timely.

Why an Automated System is required?

- Traditional methods for cataract detection are based on slit-lamp images and dependent on availability of ophthalmologists.
- It leads to less efficiency relatively.
- The system is also cost-ineffective due to the less availability of quality doctors than the growing cataract cases.
- The people dwelling in underprivileged and less developed areas find it very difficult to get their diagnosis done in a cost-efficient manner.

What is Cataract?

- Lenticular opacity or lens opacification is termed as cataract in medical terminology.
- It is characterized by a blurred and foggy vision, which leads to partial (myopia) or complete loss (blindness) of eyesight if turned severe.

Types of Cataract

There exist three types of cataract based on the location of protein denaturation or deposition in or around the lens of the eye, viz.,

- Nuclear Cataract
- Cortical Cataract
- Posterior Subcapsular Cataract

Classes of Cataract

Cataracts can be classified into four classes, viz.,

(a) Normal or Non-cataractous
(b) Mild
(c) Moderate
(d) Severe

Blood vessels (small and large), and optic disk collectively demonstrate the cataract degree, a patient is suffering from.

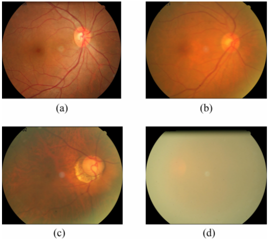

Figure 1: Fundus images for each class [1]

Cataract Detection System

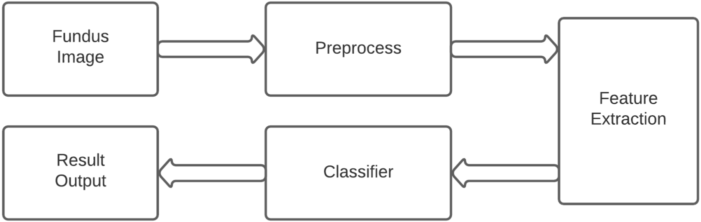

Figure 2: Cataract Classification Process Flow [2]

Clinical Cataract Detection and Grading Systems

- Involves Slit-lamp imaging and Scheimpflug imaging techniques and developed on a protocol known as the Lens Opacity Classification System (LOCS III).
- This is a very intricate procedure required to be performed by very experienced ophthalmologists; hence, it poses a challenge to be conducted in less developed regions.

- Ultrasound back-scattering signal detection method improved the assessment accuracy up to 95% but with small training data.
- The use of such techniques was soon found to be very much cost-inefficient and complicated.

- The use of fundus images has been investigated to grade nuclear cataracts, as the fundus cameras are quite easy to operate for technologists or even patients themselves.
- They were used to grade cataract severity by comparing clinical and examiner's grades and proved to be a better technique than the classical slit-lamp investigation ones.

Cataract Detection Systems based on IP and ML I

Table 1: Comparison of Cataract Detection Techniques

Reference	Preprocessing	Feature Extraction	Classification	Accuracy
[3]	Nuclear Cataract: Lens Localization Cortical Cataract: Converted to Polar Coordinate, Local Thresholding	Intensity inside lens and sulcus, color on posterior reflex, intensity ratio	SVM	Nuclear: 76%; Cortical: 73%
[4]	Convert to Green Channel, Improved Top Bottom Hat Transformation, Trilateral Filter	24 features from GLCM and 15 features from GGCM	Back Propagation	82%

Cataract Detection Systems based on IP and ML II

[5]	Resizing and Localization of Fundus Image	PCA and Spectrum from 2D DFT Fundus Image	LDA with Adaboost Algorithm	2 Class: 95.22%; 4 Class: 81.52%
[6]	Image Normalization, RGB to HSI Transformation	Small Ring Area, Big Ring Area, EPC, Object Perimeter	SVM	88%
[7]	Histogram Equalization	6 clusters are extracted by using Fuzzy Means Algorithm	Back Propagation	90%
[8]	Obtain ROI, RGB to Grayscale conversion	Contrast dissimilarity and uniformity using GLCM	KNN Method	94.5%

Result of Literature Survey

- The method having LDA with Adaboost classifier along with PCA and DFT feature extraction techniques has shown better results for detection and grading of cataract compared to others. Fundus Retinal Images are processed in this algorithm. The system demonstrates an accuracy of 95.22% for two-class and 81.52% for four-class classification.
- The technique using the KNN method for classification and GLCM for feature extraction is also reaching considerable accuracy of 94.5%.
- The conducted survey has made the fact quite clear that SVM classifier's performance can be comparatively increased to a good extent if the preprocessing techniques are improved, and more significant features like SRA, BRA, EPC, and Object Perimeter are included in the system. A steep slope in the accuracy has been observed in such cases from around 73% to 86%.
- If the classification process involves using ANN architectures, then clustering extracts better features to train rather than GGCM.

Case Study: Overview

- The most efficient algorithm observed after the conduction of Literature Survey is *LDA with Adaboost Algorithm as a Classifier*.
- Zheng et. al. in this proposed work made use of an image sample set consisting 460 fundus images belonging to four classes of cataract i.e., Normal, Mild Moderate, and Severe.

Preprocessing

- Initially, the G-channel of the fundus images were extracted because it is the best contrast measure observed so far.
- Moreover, these images are said to constitute the details of the original fundus images.
- Apart from this, patient's personal information was cropped to maintain their privacy.

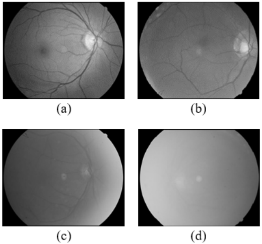

Figure 3: G-channel fundus images [5]

Feature Extraction

- The lens-opacities in cataract act as low-pass filter which absorb and scatter the light rays propagating through the eye lens.
- So, 2D DFT was applied after preprocessing to get the spectrogram which is in Fourier or frequency domain.
- For an *m*n* sized image, the 2-D DFT is represented by:

$$F(k,l) = \sum_{i=0}^{n-1} \sum_{j=0}^{m-1} f(i,j) e^{-i2\pi(\frac{ki}{n} + \frac{lj}{m})} \quad (1)$$

where, *f(i,j)* is image in spatial domain and exponential term is basis function corresponding to each point *F(k, l)* in the Fourier space.

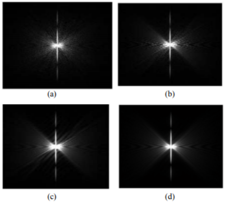

Figure 4: Results of 2-D DFT [5]

Dimension Reduction

- Dimensionality reduction using PCA was performed to reach a 300-dimensional feature space.
- PCA is a widely used dimensionality reduction method that sees a projection to best represent the data in a least square sense.
- The error observed after dimension reduction is 0.36% as observed.

Classifier Building

- All the Fourier images were divided into ten equal-sized subsets in a random permutation.
- During training, a ten-fold cross-validation technique was used, i.e., for each subset consider it as the testing set and nine others together as the training set to train the classifier.
- Firstly, dimensionality reduction was performed. Then LDA classifier was used to train for this fold.
- LDA is used to find a projection that separates the data in the best least square sense.
- 100 Adaboost iterations were adopted for each fold.
- Every two class of cataract fundus images are separable in one-dimension. Hence, one-vs-one strategy is used for four-class classification.
- It means any two-classes were adopted from the training set to train the classifier, then decide samples in the testing set into these two classes.
- Thus, 6 decisions were made for 6 combinations and voting classification was used to predict the result. The same process was repeated for the ten folds.

Evaluation of the Classifier

- The average accuracy of ten folds was considered to evaluate the classifier's performance in both two-class and four-class classification.
- This model possessed an accuracy of 95.22% for two-class classification and 81.52% for four-class classification.

Proposed Work: Overview

Two algorithms have been proposed and implemented:

1. Comparative Study of seven CNN models for two-class cataract classification.
2. An image processing process to calculate percentage of cataract in an epidemic eye.

Dataframe

- The datasets available in [9] and [10] are used together for the training purpose.
- The image in the dataset are preprocessed and a table or a dataframe is created which contains 2 columns.
- One column for the image path, and second column is the label, it is '1' for cataract and '0' otherwise.

Architectures under Study

Table 2: Comparative performance analysis of implemented models

Architecture	Optimizer	Number of Trainable Parameters	Accuracy (%)
DenseNet121	RMSProp	6,955,906	38.83%
NasNetMobile	Adam	5,584,092	76.21%
DenseNet121	Adam	8,532,354	88.83%
EfficientNetB0	Adam	4,010,110	90.29%
EfficientNetB5	Adam	28,344,882	90.77%
EfficientNetB7	Adam	63,792,082	92.23%
InceptionV3	Adam	22,334,850	93.20%

Architecture of InceptionV3 I

- InceptionV3 is a CNN architecture which is basically an improved version of Inception Family.
- Label Smoothing, Factorized 7 x 7 convolutions, and the use of an auxiliary classifier are some of the acquired improvements.
- It works on Transfer Learning methodology.

Architecture of InceptionV3 II

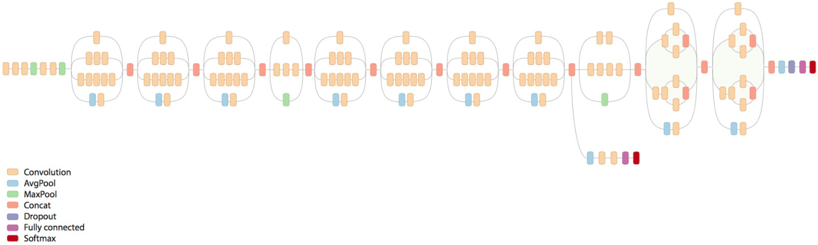

Figure 5: InceptionV3 Architecture [11]

Proposed Process

Figure 6: Proposed Classification Process Flow

Results of InceptionV3

- The InceptionV3 model was set to train for 100 epochs but early stopping was conducted at 44^{th} epoch with a validation accuracy of 93.50% and training accuracy of 99.71%.
- 93.20% testing accuracy was observed when the model was evaluated on the test set. The given two graphs demonstrate the training trends between losses and accuracies.

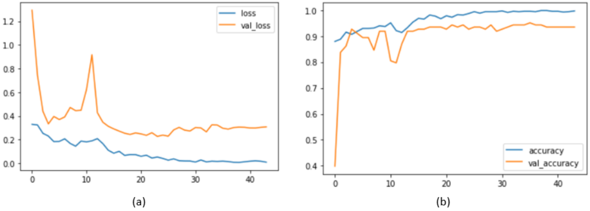

Figure 7: Training Plots

Flow of Process

An image processing technique for calculating the percentage of cataract in an epidemic eye based on geometrical and morphological transformations, contouring, and bit-wise manipulations in image vectors has been implemented.

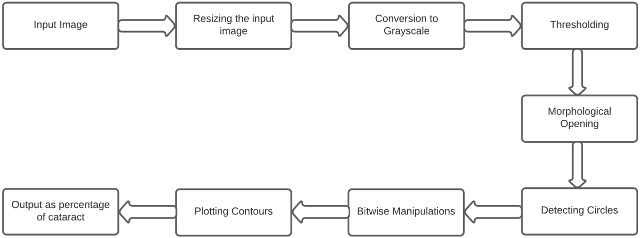

Figure 8: Flow of the process for calculating percentage of cataract

Conclusion

The study suggests that there exist various efficient automatic methods for cataract detection and grading purposes that too at no cost, it implies the scope of improvements in the concerned domain. The implementation of machine learning algorithms has made it significant to note that CNN architectures can prove to be a huge success while operating with fundus images.

Future Works

Further advancements in the project encompasses the extension of its domain by combining multiple approaches for feature extraction to the proposed algorithm as surveyed through in Literature Review.

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Thank You!!