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AUTOMATED GLAUCOMA DETECTION USING FUNDUS IMAGES

Nikita Patil
BE Computer Engineering Datta
Meghe College of Engineering
Airoli, Navi Mumbai, India

Siddhesh Patil
BE Computer Engineering
Meghe College of Engineering
Navi Mumbai, India

Prajakta Patki
BE Computer EngineeringDatta
Datta Meghe College of EngineeringAiroli,
Airoli, Navi Mumbai, India

Prof. Saumya Salian
Assistant Professor Department of
Computer Engineering
Datta Meghe College of Engineering
Airoli, Navi Mumbai, India

ABSTRACT: **Retinal fundus photographs has always remained the gold standard for evaluating the changes in retina. Here, a novel method for automatic glaucoma detection from digital retinal fundus images is proposed. The methodology makes use of optic disc and cup segmentation. The optic disc is segmented from the red channel and optic cup from the green channel respectively. The threshold is determined from the smoothed histogram of the preprocessed image. Parameterssuch as cup-to-disc ratio (CDR) is calculated and used for glaucoma detection. A CDR value greater than 0.3 and indicates the presence of glaucoma. Mean error as low as 0.021 is obtained by the method. With the help of this method the optic disc and cup are segmented to an accuracyof 86.3%. The algorithm is computationally fast and produces the segmentation of both disc andcup in approx. 3 seconds. The proposed algorithm is an efficient framework and it can be used for automatic diagnosis of glaucoma in screening programs.**

INTRODUCTION

Glaucoma is an eye condition where the optic nerve (nerve that carries information from our eyes to brain) gets damaged usually due to the raised pressure inside the eye. Glaucoma turns out to be dreadful among the other diseases is due to its covertness. What exactly happens is the fluid is built up in the front part of the eye and this extra fluid creates imbalance which in turn increases the pressure in the eye known as Intra-Ocular Pressure (IOP). The increase in the IOP leads to the damage of Optic nerve. This increased IOP also causes enlargement deepening of optic cup which indirectly leads to increase in CDR i.e. Cup-Disc Ratio.

The most common types of glaucoma are “Primary open-angle glaucoma” and “acute/angle closure glaucoma”. In “Primary open-angle glaucoma” the fluid circulates freely in the eye with a slow rise in intraocular pressure over-time. “Acute angle glaucoma” is a less common form of glaucoma. It develops suddenly, causing eye-pain and redness.

What causes Glaucoma?

The exact causes for optic nerve damage from glaucoma are unknown; it involves mechanical compression and/or decreased blood flow of the optic nerve. Although high eye pressure sometimes leads to glaucoma, many people can develop glaucoma with "normal" eye pressure. The cause of secondary glaucoma is unknown. However, both "open-angle glaucoma" and "closed-angle glaucoma" can be a secondary cause due to:

- Medications such as corticosteroids
- Eye drops that dilate the eye
- Diabetes
- Eye injuries
- Uveitis which is an infection of the middle layer of the eye

Some of the symptoms of glaucoma includes: severe loss in vision, tunnel vision in advanced stages, sudden severe pain in one eye, decreased or cloudy vision, nausea and vomiting, rainbow- like halos around lights, red eye, swelling sensations in eye etc.
Open angle glaucoma is un-preventable as most of the people do not show any signs/symptoms. However, vision loss can be prevented by (i) eating healthy diet, (ii) Limited use of caffeine, (iii) Sufficient intake of fluids, (iv) Regular exercise.

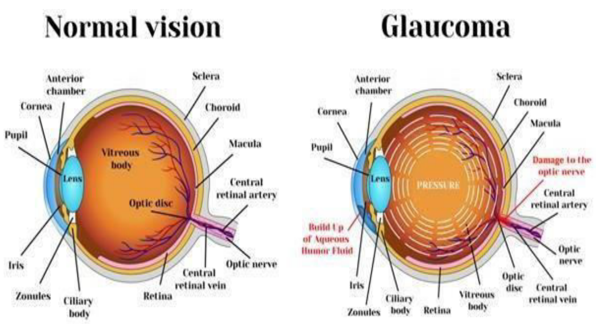

Fig: Normal Eye VS Glaucoma Eye

Glaucoma can be treated with medications, eye drops, laser surgery, drainage implants or filtering surgery (trabeculectomy). Prognosis is dependent on the type of glaucoma, and the goal of any treatment is to prevent loss of vision, as vision loss due to glaucoma is irreversible.

Need of Automated Glaucoma Detection System?

Treatment of glaucoma involves certain after-effects and financial expenses. In Medical diagnosis, the ophthalmologist looks for the images of the optic nerves and spots for the changes in the size, color, shape, blood vessels in the optic nerve. They require a number of visits to spot the changes and hence diagnose the disease and due to this longer time required for detection it may lead to increase in the severity of the disease. So with this automated Glaucoma detection system it will need only a few seconds to detect the disease using fundus images. It will definitely minimize cost than that of the medical diagnosis.

I. PREVIOUS WORKS

Glaucoma detection automated system can be modeled using variety of different approaches by making use of fundus images. Since there are a variety of methods right from the pre-processing to the classification. According to the study glaucoma detection makes use of different machine learning algorithms for classification purpose. The segmentation is also possible by extracting various features to segment the optic cup (OC) and optic disc (OD).

The paper titled **Early Stage detection of Glaucoma & its levels using fundus images of eye** makes use of an ideal framework which aims at developing a smart solution that helps in identification of Glaucoma using MATLAB software tools. Different fundus images were used from MESSIDOR dataset. The Pre-processing of the fundus images was done followed by the segmentation and classification. Pre-processing was done with the use of Gaussian filter & Guided image filter. The system provided fast, accurate & efficient with an accuracy of 83.57 %.[1]

The paper titled **Glaucoma Diagnosis with Machine Learning Based on Optical Coherence Tomography & color Fundus Images** made use of fundus images & extracted quantified images from OCT data, either alone or in combination, as the basis for automated, objective, machine learning method for Glaucoma diagnosis. This combination method

Sr No.	Title	Methods used	Dataset used	Findings	Drawbacks
1.	Early Stage detection of Glaucoma & its levels using fundus images of eye	•Gaussian filter •KNN classifier	•MESSIDOR	•Classification with 88% accuracy	•It suggested that CNN can provide better results even with larger dataset than KNN
2.	Glaucoma Diagnosis with Machine Learning Based on Optical Coherence Tomography & Color Fundus Images	•CNN (Convolutional Neural Network) •Random Forest Algorithm for decision making	•Real images of 208 OAG patients.	•Combinational method achieved results with 96.3% accuracy •Has more potential to be more sensitive to detect glaucoma in early stages.	The Glaucoma group included more cases with myopia and its difficult to classify myopia & glaucoma.
3.	CNNs for automatic glaucoma assessment using fundus images: an extensive validation	•CNN (Convolutional Neural Network)	•ACRIMA	Accuracy was 95%	Different labelling criteria is an issue faced when developing the system.
4.	Joint Optic Disc & Cup Segmentation Based on Multi-label Deep Network & Polar Transformation	•M-Net •Polar transformation	•ORIGA •SCES	•Successful glaucoma screening system with 83% & 89% accuracy on ORIGA & SCES dataset resp.	•Fails to achieve results with high accuracy in small sized datasets.
5.	Computer aided Diagnosis of Glaucoma using discrete & Empirical Wavelet Transform from Fundus Images	•Empirical Wavelet Transform (EWT) •Least Square- Support Vector Machine (LS-SVM)	•Medical Image Analysis Group(MIAG)	•Fast, accurate & efficient system is obtained with performance parameters accuracy, sensibility & specificity of 83.57,86.40 & 80.80 respectively.	•Fails to predict the level of disease. •Use large no. of features for OC OD segmentation.

achieved an accuracy of 96% & also has the potential to be more sensitive to detect Glaucoma in early stages.[2]

The paper titled **Computer aided Diagnosis of Glaucoma using discrete & Empirical Wavelet Transform from Fundus images** presents a novel hybrid & concatenation approach for CAD of Glaucoma using DWT & EWT from fundus images. Almost Seventy-seven features were extracted & fed to SVD. LS-SVM classifier with RBF Kernel is used as a classifier. The proposed method turned out to be more accurate, fast & efficient. Performance obtained using parameter like accuracy , sensitivity & specificity 83.57 , 86.40 , 80.80 respectively.[3]

The paper titled **Joint Optic Disc & Cup Segmentation Based on Multilabel Deep Network & Polar Transformation** proposed a deep learning approach that is M-net which solves the problem of OD & OC segmentation together on a single system.[4]

The paper titled **CNNs for automatic glaucoma assessment using fundus images : an extensive validation** five different ImageNet-trained CNN architectures (VGG16, VGG19, InceptionV3, ResNet50 and Xception) were analyzed and used as glaucoma classifiers. Using only publicly available databases, the Xception architecture shows the best performance for glaucoma classification, which was evaluated as the trade-off between the AUC and the number of parameters of the CNN. Based on the 1707 images and data augmentation technique, an average AUC of *0.9605* with a 95% confidence interval of 95.92–97.07%, an average specificity of *0.8580* an average sensitivity of *0.9346* were obtained after fine-tuned the Xception architecture, significantly improving other state-of-the-art works.[5]

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II. PROPOSED METHODOLOGY

The process flow consists of four main stages image pre-processing, optic cup segmentation, optic disc segmentation and lastly the classification of the fundus image intoglaucoma infected eye or a normal eye based upon the CDR value.

- **Input Fundus Images**

We define fundus imaging as the process whereby reflected light is used to obtain a two-dimensional (2D) representation of the 3D, semitransparent, retinal tissues projected on to the imaging plane. Such Images will be the input for this project.

Dataset Source

To develop the algorithm for automatic detection of glaucoma, the first essential step was to obtain the effective database. **Drishti-GS** is a dataset meant for validation of segmenting OD, cup and detecting notching. The images in the Drishti-GS dataset have been collected and annotated by Aravind Eye hospital, Madurai, India. This dataset is of a single population as all subjects whose eye images are part of this dataset are Indians. The dataset is divided into two: a training set and a testing set of images. Training images (50) are provided with groundtruths for OD and Cup segmentation and notching information.

- **Image Pre-processing**

Fundus images is an RGB color image, in general RGB images consist of three channels: red, green and blue. This can be accomplished by separating the retina image to three channels and using the channels with provide us with more information. The blue channel is characterized by low contrast and does not contain much information. The vessels are visible more clearly in the red and green channel. In this method the retinal image is taken as the input image. Then the input retinal image is pre-processed. In pre-processing stage, the input image is resized and the red or green channel image is separated as the blood vessel appear brighter in the red or green channel image.

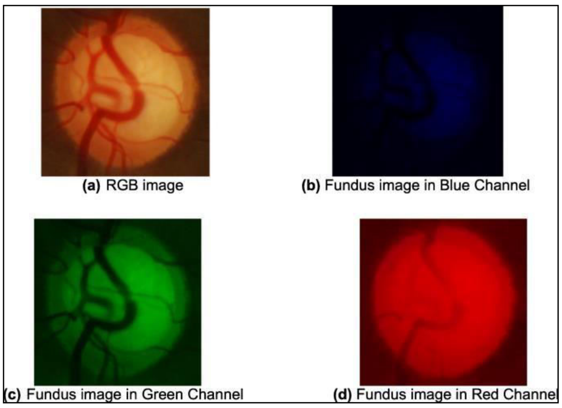

Fig: An RGB Fundus Image and it's split into red, green and blue channels.

- **Optic Disc Segmentation**

The preprocessed red channel is used for segmenting the optic disc. The histogram of the preprocessed red channel is plotted and smoothed using a Gaussian window. It removes the noise .This noise reduction is a typical pre-processing step to improve the results for further processing. A threshold value for segmentation of optic disc is then formulated using this smoothed histogram.

The threshold to segment the optic disc is given as:

$$\mathbf{T1 = (0.5*m) - (2*\imath G) - (\imath RI)} \quad (3)$$

Where,

T1 = threshold for segmentation of optic disc
m = size of Gaussian window
ıG = standard deviation of Gaussian window
ıRI = standard deviation of the preprocessed red channel

The image after applying this threshold T1 on the red channel gives a binary image which contains segmented optic disc.

- **Optic Cup Segmentation**

Similar to the Optic disc segmentation, the preprocessed green channel is used to segment the optic cup. The histogram of the preprocessed green channel is plotted and smoothed using the same Gaussian window of size m×1 used above to smooth the histogram of preprocessed red channel. A threshold value is then formulated from this smoothed histogram of preprocessed green channel for segmentation of optic cup.

The threshold is given as:

T2 = (0.5*m) + (2*ıG) + (2*ıGI) + (—GI) (4)

Where,

T2 = threshold for segmentation of optic cup

m = size of Gaussian window

ıG = standard deviation of Gaussian window

ıGI = standard deviation of the preprocessed green channel

GI = mean of the preprocessed green channel

The image after applying this threshold T2 on the green channel gives a binary image which contains segmented optic cup.

This gives us the segmented optic disc and segmented optic cup. This cup and disc are to be used for calculating the CDR ratio.

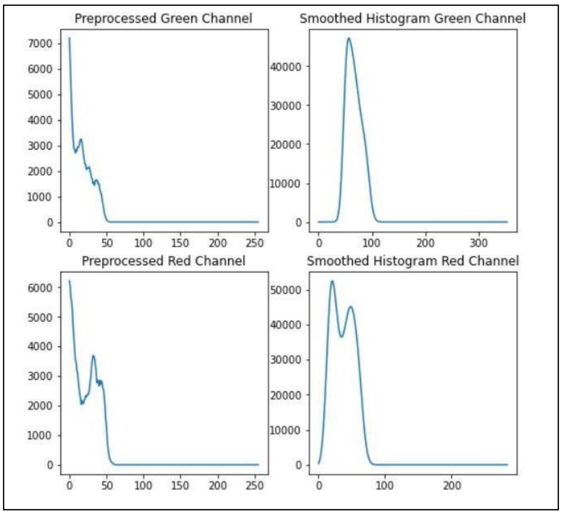

Fig: Preprocessed and Smoothed Histogram of Red and Green Channels.

- **Glaucoma Detection**

Several parameters used for glaucoma detection such as cup-to disc ratio (CDR), cup-to-disc area ratio, neuro-retinal rim thickness etc. can be found out using this approach.

The segmented cup and disc are further used for CDR calculation. CDR refers to the Cup-to-Disc Ratio. Cup-to-disc ratio is a significant parameter indicating the expansion of the cup region. Glaucoma tends to affect the superior and inferior regions of the optic nerve first, thereby producing visual field defects. The number of pixels from the segmented cup and disc will be calculated.

For CDR calculation:

$$\text{CDR} = \frac{\text{Number of pixels in segmented cup}}{\text{Number of pixels in segmented disc}}$$

This CDR value is used for classifying the image into glaucoma affected eye or normal eye.

CDR for normal human eye is considered to be less than 0.3, whereas for glaucoma infected eye it is greater than 0.3.

III. Results

The performance of the proposed method for glaucoma screening was tested using images from a real dataset named "DRISHTI-GS dataset". The results were cross-validated with that of experts in the area of glaucoma and were found to be satisfactory. Table I. shows the Cup-to-Disc ratios (CDR) obtained from the proposed methodology. The assessments deduced from these values are compared with that of an expert.

	File Code	Expert1	Expert2	Expert3	Expert4	predicted cdr
0	_001	0.85	0.82	0.80	0.82	0.674107
1	_003	0.83	0.79	0.72	0.79	0.832386
2	_005	0.86	0.87	0.81	0.80	0.757225
3	_006	0.64	0.77	0.65	0.53	0.342391
4	_007	0.86	0.83	0.70	0.62	0.624079
5	_009	0.54	0.56	0.39	0.53	0.967164
6	_011	0.81	0.81	0.77	0.83	0.981884
7	_013	0.80	0.66	0.65	0.62	0.500000
8	_014	0.86	0.87	0.84	0.82	0.800570
9	_019	0.86	0.91	0.84	0.78	0.787368
10	_020	0.88	0.90	0.80	0.78	0.756691

Fig: Table of Expert Values and Predicted CDR

The methodology used here is found to achieve better results in terms of accurate CDR values. The CDR determined by clinicians using stereographic viewers is used as ground truth against which the performance of our automated CDR method is compared. Mean error as low as **0.021** is obtained by the method.

IV. Conclusion

The proposed methodology to detect the glaucoma using fundus image is accurate and efficient. The common challenge in glaucoma detection is the accurate segmentation of optic disc and optic cup which can be affected due to presence of peri-papillary atrophy (PPA).

However, in the proposed work, this shortcoming is overcome as only the brighter pixels will be threshold.

However, when applied on the images from the DRISHTI-GS dataset, it was observed that the algorithm failed on only few images out of the vast dataset.

The proposed algorithm uses the features obtained from the image, such as mean and standard deviation, to remove information from the red and green channel of a fundus image and obtain an image which contains only the optic nerve head region in both the channels. The optic disc is segmented from the red channel and optic cup from the green channel respectively. The threshold is determined from the smoothed histogram of the preprocessed image.

The results of the proposed algorithm are compared with the images that are marked by doctors. It segmented the optic disc and cup to an accuracy of 84.3%. The algorithm is computationally fast and produces the segmentation of both disc and cup in approx. 3 seconds.

The proposed algorithm is an efficient framework and it can be used for automatic diagnosis of glaucoma in screening programs.

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