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Detection of Glaucoma Using Retinal Fundus Images

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Abstract— **This paper proposes an image processing technique for the detection of glaucoma which mainly affects the optic disc by increasing the cup size. During early stages it was difficult to detect Glaucoma, which is in fact second leading cause of blindness. In this paper glaucoma is categorized through extraction of features from retinal fundus images. The features include (i) Cup to Disc Ratio (CDR), which is one of the primary physiological parameter for the diagnosis of glaucoma and (ii) Ratio of Neuroretinal Rim in inferior, superior, temporal and nasal quadrants i.e. (ISNT quadrants) for verification of the ISNT rule. The novel technique is implemented on 80 retinal images and an accuracy of 97.5% is achieved taking an average computational time of 0.8141 seconds.**

Index Terms—**Glaucoma, Cup to Disc Ratio (CDR), ISNT, Fundus Images**

I. INTRODUCTION

Glaucoma is a primary cause of permanent blindness. It is a disease in which the intraocular pressure (IOP) becomes pathologically high, sometimes rising severely to 60-70 mm Hg. Pressures greater than 25-30 mm Hg can cause vision loss when sustained for a long time. In most cases of glaucoma, the abnormally high pressure results from increased resistance to fluid outflow through eye's drainage system [1]. In normal healthy eyes there is a balance between fluids produced within eye and one that outflow. This balance keeps Inter Ocular Pressure (IOP) within the eye constant but in case of glaucoma, this balance is not maintained which in turn causes an increase in IOP, consequently damaging the optic nerve [2]. Because of increase in IOP, the cup size begins to rise which accordingly increases the CDR. For normal disc the CDR is considered to be less than 0.5 but in case of glaucoma, it is greater than 0.5 [3]. As the cup size increases it also influences the Neuroretinal Rim (NRR). NRR is the region located between the edge of the optic disc and the optic cup. In the presence of glaucoma, area ratio covered by NRR in nasal and temporal region becomes thick as compared to area covered by NRR in inferior and superior region [3]. The digital fundus image of a normal eyes and glaucomatic eyes are illustrated in Fig. 1.

Many studies have been performed to ameliorate computer based decision support algorithms for early detection of glaucoma through extraction of optic cup and disc to determine CDR. A method for ONH segmentation and its verification, based on morphological operations, Hough transform, and an anchored active contour model is proposed in [4]. A new approach to automatically segment the optic disc and exudates is suggested in [5].

Fig. 1: L to R: Normal Disc (CDR<0.5), Glaucoma tic Disc (CDR>0.5)

The techniques include use of the green component of the image followed by preprocessing and then morphological opening, minima imposition, extended maxima operator, and watershed transformation. Extraction of optic disc automatically through region of interest (ROI) and component analysis method for cup detection is proposed in [6]. Morphological techniques to extract optic disc and cup to figure out pathological process of glaucoma are used in [7]. The proposed method was applied on 61 images with a specificity of 80% and sensitivity of 100% was achieved. 95% accuracy has been achieved by implementing K-means clustering to extract the optic disc and optic cup region in [8] Hill Climbing Algorithm was used for the extraction of optic disc whereas Fuzzy C-Mean clustering for optic Cup extraction in [9] with accuracy of 90%. Open CV programming tools for Classification of glaucoma are proposed in [10]. The novel approach used K-Means Clustering for the extraction of optic disc and cup with Sensitivity of 90%.

II. RETINAL IMAGE DATABASE

RGB retinal fundus images are obtained from different sources including DMED dataset, FAU data library and MESSIDOR data set. Experiments were performed on 80 fundus images having variable size but all were in RGB color space. Websites for data sets mention that images were taken using fundus camera and fixed light conditions.

III. PROPOSED METHODOLOGY

To detect glaucoma, extractions of two features are required by Mean Threshold Morphological method in order to calculate CDR and NRR ratio in ISNT quadrants. Optic disc and cup is required for CDR evaluation and to find NRR ratio NRR itself is required.

A. Preprocessing of an image

In colored retinal fundus images, Optic disc appears to be the brightest part having light orange or pink color and is deemed to be Region of Interest (ROI). The ROI from all images (dataset) is cropped using intensity values and then resized to 256×256. The green plane is extracted from original image for extraction of optic cup, which provides enhanced contrast for optic cup (Fig. 2). The original image was then converted to HSV plane. It was concluded after analysis of a number of images, that optic disc has a better contrast in V plane extract from HSV image as shown in Fig.3

B. Extraction of Optic Disc and Cup

Evaluation of CDR is primary thing for glaucoma detection, which is calculated by extracting optic cup and optic disc. From original image green plane is extracted for extraction of optic cup and then converted to gray scale image. Optic cup having the brighter contrast with respect to others in image, the gray scale image is then converted to binary image.

Threshold value for the extraction of cup varies because there is gradual transition in cup color by which boundary of cup is not much clear. Therefore, mean of this image is calculated using software and on the basis of this mean a threshold value for linearization is defined. This mean value was around 0.4 to 0.57 for majority images in our case. Due to presence of blood vessels there are gaps in image, these gaps are filled by morphological operations such as dilation and then erosion is applied with same structuring element on image. Boundaries of optic cup in resultant image are then smoothen with help of Gaussian filter as shown in Fig.2. The area of optic cup is calculated by counting no of white pixels.

Now for optic disc Value plane is extracted from HSV image. The V plane is then converted to gray scale image. After that find mean value of gray scale image and then convert it to binary image. By setting threshold to 1500 unwanted objects are removed except optic disc in the resultant image. Now the resultant image is subjected to Gaussian filtering for smoothing the boundaries of image as illustrated in Fig.3. The area of cup is now divided by area of disc to find CDR. Edges of both optic disc and optic cup in resultant image are found by applying canny filter.

$$CDR = (Cup\ area / Disc\ area)*2$$

C. Extraction of Neuroretinal Rim

Another feature to detect glaucoma is extraction of NRR. Ratio of area covered by inferior to superior is thinner as compared to ratio of area covered by nasal to temporal region in glaucoma. The optic disc and optic cup are already extracted now in order to extract NRR AND operation is applied on both resultant images of cup and disc. On extracted NRR image a mask of size 256x256 is applied to measure the ratio of area covered by neuroretinal rim in ISNT quadrants. Mask is rotated 90 degrees each time to determine ratio separately in ISNT quadrants. Fig.5 shows the mask and its rotated versions. Finally for ISNT ratio area covered by white pixels are counted.

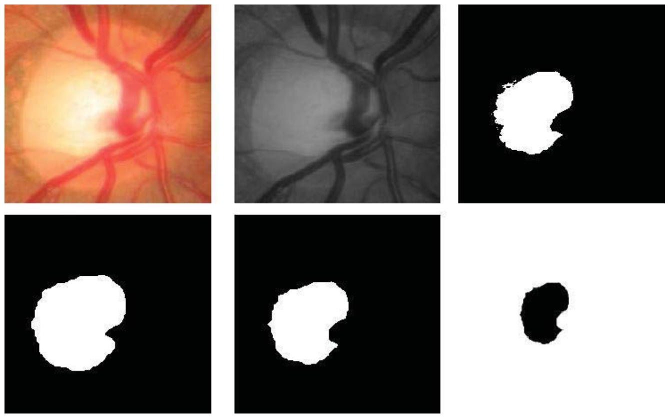

Fig 2: L to R : (a) RGB Image, (b) Gray scale of green plane, (c) Binarized image, (d) Dilate, (e) Erode, (f) Compliment of detected cup.

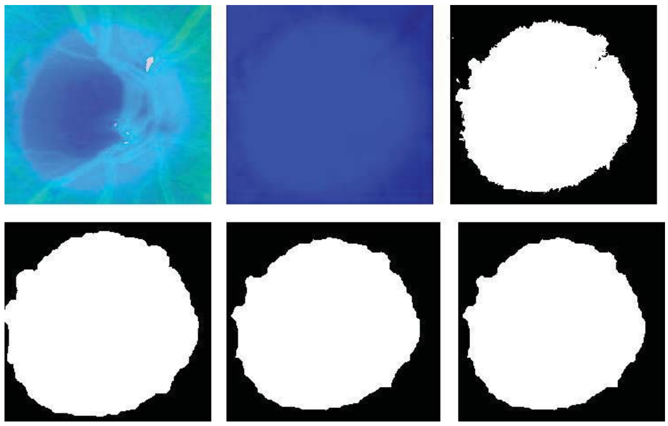

Fig 3: L to R: (a) HSV image, (b(V plane, (c) Binary image, (d) Dilate, (e) Erode, (f) Disc

D. Classification

Classification of glaucoma has been done using the above mentioned two extracted features. Retinal fundus image with presence of glaucoma have CDR greater than 0.5 and it also violates the ISNT rules. For normal healthy retinal fundus

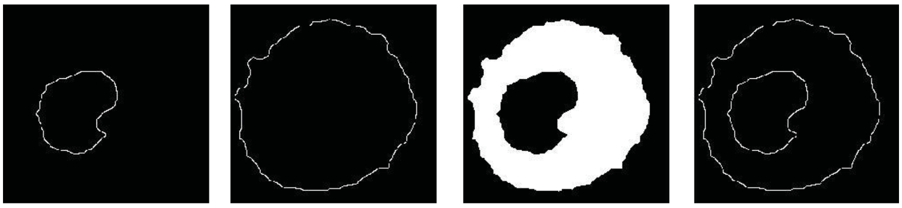

Fig 4: L to R: (a) Cup Edge, (b) Disc Edge, (c) Neuroretinal Rim (NRR), (d) NRR Edge

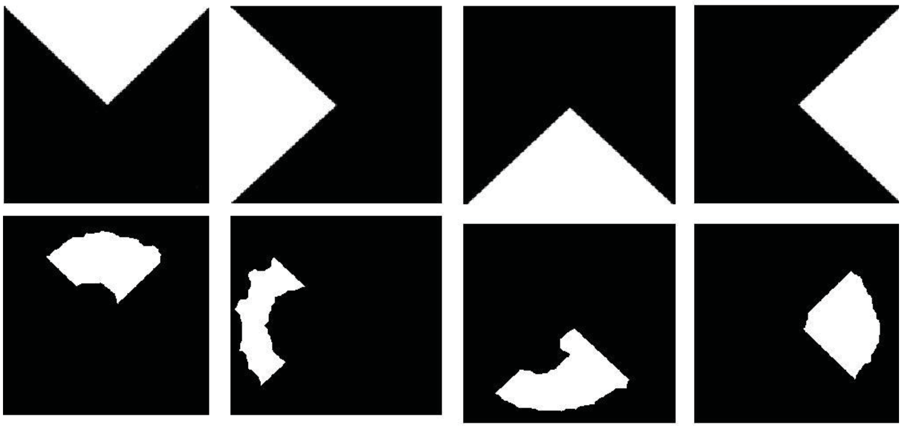

Fig 5: ISNT Quadrants
Top: Masks – (a) Superior, (b) Temporal, (c) Inferior, (d) Nasal
Bottom: ISNT masks multiplied with Neurorentinal Rim (NRR)

image has CDR less than 0.5 and obeys the above mentioned ISNT rule. If there is contradiction between both features then disc is considered to be alleged.

IV. EXPERIMENTAL RESULTS

All classification results could have a misclassification rate and on any occasion can either generate false result to identify an abnormality, or it may also classify an abnormality which is not present. Usually misclassification rate is described by the correct and false positive and correct and false negative parameters as follows:

$$Accuracy = \left(\frac{C_p + C_n}{C_p + C_n + F_p + F_n} \right) \times 100$$

Here Cp represents True Positive, Cn represents True Negative, Fp represents False Positive and Fn represents False Negative.

TABLE I. PERFORMANCE EVALUATION RESULT

	Classifier Type	True Positive	False Positive	Accuracy
Case I	Proposed Method	314	271	97.5%
	Existing Method	290	268	93%
Case II	Proposed Method	378	212	98.3%
	Existing Method	353	202	92.5%

The effectiveness of proposed system is computed by comparing the results with provisional diagnosis by Ophthalmologist. The comparison has been made with conventional method and proposed method for glaucoma identification system in Table I and shown graphically in Fig. 6. The existing model shows lower accuracy rate in than our proposed technique for classification purpose.

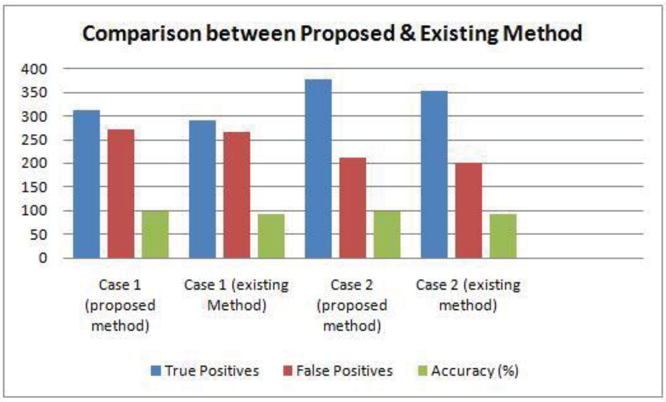

Fig. 6: Performance Evaluation Chart

V. CONCLUSION

In this paper, we designed and implemented an algorithm to identify glaucoma. The novel method uses Morphological techniques to extract two major features for detection of Glaucoma i.e. Area ratio of NRR in ISNT quadrants, Cup to Disc Ratio. The developed methods were tested on three different databases i.e., DMED, FAU and, MESSIDOR. The proposed method achieves an average accuracy of 97.5% having an average computational cost of 0.8141 seconds.

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