Early Detection of Glaucoma Using Retinal Fundus Images

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Abstract: Glaucoma is the second leading cause of blindness in the world. It is difficult to detect and diagnose glaucoma in its early stages. An approach to automatically extract the features from the fundus images and detect glaucoma has been proposed in this paper. There are two features that are extracted from retinal images. i) Cup to Disc Ratio(CDR), which is the primary parameter for the diagnosis of glaucoma and ii) Ratio of neuroretinal Rim(NRR) in Inferior, Superior, Nasal, and Temporal (ISNT) quadrants to check whether it obeys the ISNT rule or not. The novel technique is implemented on 80 retinal images and an accuracy of 98.8% is achieved with average computational time of 0.6463 seconds.

Keywords: Cup to Disc Ratio(CDR), Fundus images, Glaucoma, ISNT rule, Neuroretinal Rim(NRR).

Introduction

Glaucoma is a neurodegenerative disease in which optic nerve and optic nerve cells are progressively damaged resulting in partial loss of vision. Since, this damage is irreversible thus glaucoma is said to be the primary cause of permanent blindness[1]. In normal eyes, there is a balance between the fluids i.e. produced in the eye and the one that leaves the eye. This balance keeps the Inter-ocular pressure (IOP) inside the eye constant while in glaucoma, this IOP is not constant and keeps increasing resulting in the damage of optic nerve[9]. In normal eye, this pressure is between 14 to 20 mmHg. If it is between 20 to 24 mmHg, it shows the symptoms of glaucoma. However, if it exceeds 24 mmHg, it is detected as glaucoma. The increased IOP leads to increase in cup size. As cup size increases, it increases the Cup to Disc Ratio(CDR). For normal eyes, CDR is considered to be less than 0.3 while in glaucoma affected eyes, it is considered to be 0.3 or greater than 0.3[2]. The increased cup size also affects the Neuroretinal Rim(NRR). NRR is the area located between the edge of optic cup and optic disc. The area ratio covered by NRR in nasal and temporal regions is thicker than the area ratio covered in inferior and superior regions[12]. The retinal fundus image representing the nomenclature used is shown in Figure 1.

Figure 1: Retinal fundus image

Related Work

Several studies and researches have been reported in the last few years for the detection and classification of glaucoma by extracting different features. Kevin Noronha et al.[3] extracted main features of retinal fundus images such as optic disc, fovea and blood vessels and used Hough Transform to determine optic disc and its center. Geetha Ramani et al. [4] proposed a novel methodology which utilizes image analysis and data mining strategies to classify the retinal pictures. Cheng et al. [5] proposed superpixel classification techniques to segment the optic disc and cup. Deepali A. Godse proposed [6] proposed a novel methodology for automatic localization and determination of optic disc in retinal images. Hafsah Ahmad et al. [7] proposed a system for early detection of glaucoma using CDR and ratio of NRR in ISNT quadrants. The strategy is executed on 80 pictures and 97.5% precision is accomplished in 0.8141 seconds. Sobia et al. [8] proposed a strategy in which anisotropic filtering is performed. Disk is extracted using 3 strategies i.e. edge detection method, optimal thresholding method and manual threshold analysis. Babu at el [10] has implemented Hill Climbing Algorithm for the extraction of optic disc whereas for optic Cup extraction Fuzzy C-Mean clustering. Classification of glaucoma using Open CV programming tools is proposed in [11].
Retinal Image Database

RGB retinal fundus images are obtained from different sources including FAU data library[13] and MESSIDOR[14] data set. Experiments were performed on 80 fundus images having variable size but all were in RGB color space. The images from Friedrich-Alexander University (FAU) of Erlangen-Nuremberg database library had an image size of 3504 ×2336 with JPG format and the images from MESSIDOR had an image size of 2240 ×1488 with TIFF format. The websites for datasets mention that the images were taken using fundus camera and fixed light conditions.

Proposed Methodology

To detect glaucoma, two features are required to be extracted by Mean Threshold Morphological method to evaluate CDR and NRR ratio in ISNT quadrants. For calculating CDR, optic disc and cup are required while to find NRR ratio, NRR is itself required.

Preprocessing of fundus image

In RGB retinal fundus images, Optic disc has all the earmarks of being the brightest part having pink or light orange shading and is thought to be Region of Interest (ROI). The ROI from all images (dataset) is crop down using intensity values and then resized to 256×256. The original RGB fundus image was converted to HSV plane from where V-plane was extracted. By analyzing a number of images, it was concluded that optic disc has a better contrast in V-plane but still some of its part did not have better contrast, thus green plane was extracted from RGB image (Fig.3). Also, the optic cup has a better contrast in green plane (Fig.2). Thus, for the extraction of both optic disc and cup, green plane is used.

Extraction of Optic disc and Cup

For the detection of glaucoma, one of the primary feature is the calculation of CDR For CDR evaluation, we require optic cup and disc. For the extraction of optic cup, the extracted green plane image is converted into gray scale image (Fig.2) because here we get the better contrast than the other regions of fundus image. Then, the brightest pixels value from the gray scale image is set as threshold value to get the binary image of optic cup. This threshold value varies from image to image because of the gradual transition in cup color by which the boundary of cup is not clear. The threshold value is found to be around 0.65 to 0.82. The unwanted objects obtained in resultant binary image were labeled and removed by thresholding. Due to the presence of blood vessels, there are gaps in the binary image which are removed by morphological operations such as dilation and erosion. The area of cup is calculated by counting the number of white pixels.

For the extraction of optic disc both V-plane and green plane are required because use of only V-plane does not give accurate results. Thus, by merging both the planes we get better optic disc. This is because the color optic disc is spread outside of the disc also so it is not easy to extract optic disc completely by green plane only. So first we take green plane and convert it into gray image and then invert this image. Finally, convert it into binary image. The left part of this image will be ANDed with right part of the other image. The other image is the gray image of the V-plane which is converted into the binary image. The threshold range for green plane is found to be around 0.45- to 0.75 while for V-plane 0.54-0.9. The gaps in the binary image due to blood vessels are filled by dilation and then erosion is performed to decrease the size of disc increased due to dilation. Then, the area of disc is

Fig.2. L to R: a)Original Image, b)Gray scale of Green plane, c)Binarized cup, d)Dilated cup, e)Eroded cup
calculated by counting the white pixels. The area of cup is now divided by area of disc to find CDR.

CDR = (Cup area / Disc area)

Fig.3. L to R: a)HSV plane, b)V-plane, c)Binarized disc, d)Dilated disc, e)Eroded disc, f)NRR

Extraction of Neuroretinal Rim

Another feature to detect glaucoma is the extraction of NRR. The ratio of area covered by inferior to superior is thinner as compared to the ratio of area covered by nasal to temporal region in glaucoma. The optic disc and optic cup are already extracted. Thus, to extract NRR AND operation is applied on both the images of optic disc and cup. Then, apply a mask of size 256x256 on the resultant image of NRR to find the ratio of NRR in ISNT quadrants. This mask is rotated 90 degrees each time to determine area ratio separately in ISNT quadrants. Fig.4 shows the mask and its rotated versions. Finally for ISNT ratio area covered by white pixels are counted.

Fig.4. Ratio of NRR in ISNT Quadrants

Classification

Classification has been done on the basis of above two features i.e. CDR and NRR ratio in ISNT quadrants. If the CDR is greater than 0.3 and it violates the ISNT rule, then it is glaucomatic whereas if the CDR is less than 0.3 and it obeys the ISNT rule, then it is normal. If there is a tie between both features i.e. CDR is greater than 0.3 but it obeys ISNT rule or vice-versa, disc is considered to be suspected as glaucoma.

Experimental Results

All the results that are classified can have a misclassification rate i.e. it can classify a normal eye as glaucoma or it can also classify glaucoma as normal. This misclassification rate is usually described by the parameters such as true positive, false positive, true negative and false negative. The
accuracy can be calculated by using these parameters.

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\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}
\]

The confusion matrix showing accuracy and the parameters TP, TN, FP, FN is shown in Fig.5. and the computational time for the images vary as shown in Fig.6.

**Conclusion**

In this paper, we have designed and implemented an algorithm to detect glaucoma in retinal fundus images. The proposed method uses morphological techniques to extract the important features required to detect glaucoma i.e. cup to disc ratio and ratio of neuroretinal rim in ISNT quadrants. The algorithm has been tested on two different databases FAU and Messidor. The novel method achieves an accuracy of 98.8% in the average computational time of 0.6463 seconds.

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**References**


