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Glaucoma Detection Using Fuzzy-C Means Clustering Algorithm and Thresholding

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Abstract— Glaucoma is a non-curable eye disease hence early detection is required to prevent the further progression of it. This disease leads to total blindness. To deal with the disease various automated systems have been designed. In this paper we are giving explanation for Cup to Disc ratio (CDR) measurement using fuzzy algorithm. The Cup to Disc ratio (CDR) is one of the important factor in glaucoma detection. In the proposed method, the optic disc and optic cup is segmented using fuzzy c-means clustering and thresholding. The Cup to Disc Ratio (CDR) of the color retinal fundus camera image is the primary identifier to confirm glaucoma for a patient. It classifies the given input image as normal or diseased and if it is recognized as diseased then classify the stage of glaucoma affected patient whether Moderate, Severe or normal based on the CDR ratio. In this paper we are giving a number of screenshots which shows results of different image processing techniques applied on input images.

Keywords— Fundus image, Optic disc, Optic cup, Cup-to-disc ratio, Fuzzy c-means clustering.

I. Introduction

Glaucoma is an irreversible chronic eye disease that leads to vision loss. It damages the optic nerve and occurs basically due to the increase in pressure within the eye which is known as Intra Ocular pressure (IOP). It eventually leads to blindness if left untreated. Drainage system of human eye is able to function properly for normal eyes. The intraocular fluid present in our eyes has normal flow and it prevents building up of high pressure inside eyes. When a person is affected by glaucoma normal drainage system become blocked and intraocular fluid faces blockage and can not come out. This phenomenon raises the IOP level which in tern damages the optic nerve fibres. With time the optic disk forms a hollow structure and extends to a cup shape. This newly formed structure is named as Optic Cup. Slowly the disease moves ahead and causes peripheral vision block. The disease glaucoma basically can not be recognized in early stage, but its early detection is necessary to avoid further development. Manual detection of glaucoma used by ophthalmologists is a time consuming process and we need an automatic detection process. Among various tools used for image processing, the fundus photography is the easiest and efficient way of early detection of glaucoma. Many experiments are going on in this research field, yet more accuracy is needed for early detection of glaucoma in human eye which is curable if detected at early stage.

The paper is organized as follows, section 1 contains Introduction to the disease Glaucoma, section II contains the Related Work already done on the disease identification, section III contains some measures of description about the Methodology used in the proposed glaucoma detection, section IV contains the architecture and essential steps of Results and Discussion with the help of some snapshots. Section V concludes research work with future directions.

II. Related Work

This section provides a previous study on various journals and conference papers related to our proposed work. In this section how glaucoma can be detected by the different methods has been mentioned. The main features used for the detection of glaucoma are CDR, ISNT rule, NRR, PPA etc.

In the paper Kavitha et.al proposed a method which used erosion and dilation as morphological operations for optic cup and optic disc segmentation [1]. It extracted the region of interest (ROI) and used labelling plot method on contour of the image.

Cheng et al. proposed a super-pixel classification-based approach by including features from super-pixel level, which significantly improves the disc and cup detection [2]. However, it has a bias of underestimating large cups and over estimating small cups due to the dominance of medium sized cups used to train the model.

Noor Elaiza Abdul Khalid et.al proposed a method where pre-processing was used for extraction of region of interest, used color channel analysis and other morphological operations [3]. Then for segmentation of optic cup and optic disc fuzzy c mean clustering (FCM) algorithm was used. Finally, CDR value was calculated and compared the method with others by calculating Receiver Operating Characteristics (ROC).

K. Padmanaban et.al proposed a method which used median filtering in green plane for pre-processing, for segmentation they used fuzzy c mean clustering on extracted region of interest and morphological operations for post processing [4]. Hafsah et al. proposed a method where blood vessels were removed by using morphological operations and median filter[5]. The Canny algorithm was used for edge detection, K-means and a Variational Level-Set were used to segment the OD.

Survey on above mentioned papers were carried out thoroughly to make an in-depth analysis of the work done previously. From all those papers in the literature it is seen that CDR is one of the main indicator in case of glaucoma diagnosis. For CDR calculation OD and OC segmentation are mainly done. Several methods have been observed in the above papers for segmentation of OD and OC.

III. METHODOLOGY

This section covers the brief description of the CDR method that we have used for the diagnosis of glaucoma. Figure 1 shows the block diagram of our proposed work. Input images are taken from different sources (mentioned later), automatic cropping is done to achieve ROI with OD[6]. For a low cost glaucoma screening, automated optic nerve head evaluation is a better option for two dimensional retinal fundus image, we have used it. The input retinal image is then enhanced using histogram equalization technique.

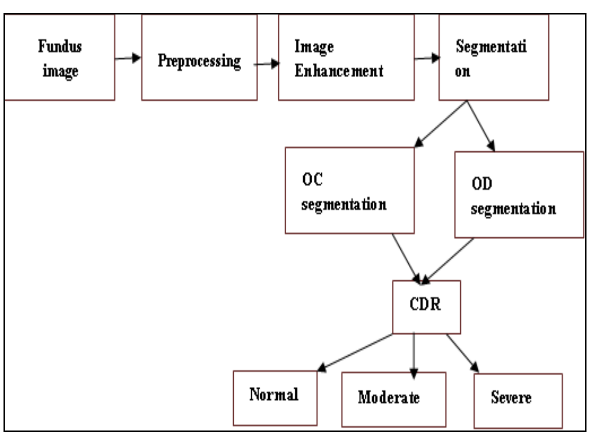

Figure 1. Block diagram of the proposed method

Fuzzy C-means (FCM) clustering algorithm is used to segment the optic disk region. Image morphological operations erosion, dilation, opening and closing are further applied to remove unwanted objects and to get accurate segment of the disc area. Moreover thresholding is applied for optic cup region segmentation. After Optic disc and Optic cup segmentation, pixels occupied area of the image is measured. The Cup to Disc Ratio (CDR) is measured from the optic disk and optic cup segmented image. Correct value of CDR is important for proper evaluation of glaucoma. Now the retinal image is ready to classify as moderate or severe depending on value of CDR ratio. In this way a precise diagnosis of glaucoma can be achieved. Figure 2 shows the OC and OD of a fundus eye image.

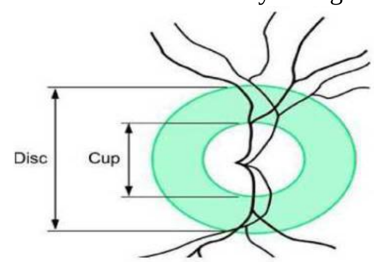

Figure 2. Evaluation of CDR from OD and OC

According to study when IOP increases then cup area also increases slowly, this phenomenon happens due to existence of glaucoma. The CDR value is used to examine the raise of cup area. Different ways are there to measure the CDR. CDR can be defined in terms of area, perpendicular and horizontal lengths of both OD and OC. Clinically, the CDR is the ratio of the Vertical Cup Diameter (VCD) to Vertical Disc Diameter (VDD).

CDR with a value less than 0.5 gives the normal image, whereas CDR with value greater than 0.5 gives the glaucomatous images [7].

A. Pre-processing

Pre-processing phase performs two tasks, these are evaluation of Region of Interest (ROI) and color channel analysis. ROI involves cropping the fundus image before processing.

1) Region of Interest (ROI)

A simple but vigorous method is proposed for the segmentation of OD. The pre-processing step is very essential for correct segmentation. Since the fundus image is high in resolution as well as large in size, the image should be cropped before it is processed. The ROI is seen as sprint in the optic cup and disc area as shown in the figure 3. The proposed way uses fuzzy c-means clustering method for OD segmentation.

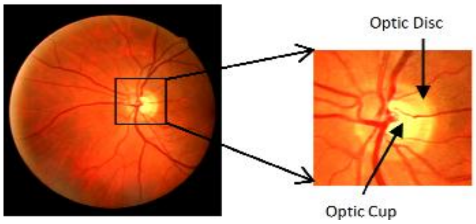

Figure 3. Cropped Region of Interest (optic cup and disk) From the original image

2) RGB to channel conversion (Colour Channel Analysis)

Colour channel analysis is necessary for next image processing phases. After ROI extraction retinal colour image is set as input for channel analysis where outputs are red, green and blue channel images. After thorough study on the channels as mentioned in the literature review, we have chosen green channel to use for CDR computation as it is more prominent and usable than other two channels.

B. Image Enhancement

In digital image also noise presents and noise removal is done by image enhancement. Histogram equalization is used to enhance the image. Figure 6 and figure 7 show images after histogram equalization and noise removal respectively. After enhancement disk normalization is completed which helps to find average value from the calculated mean values. In disk normalization range of pixel intensity is changed then mean subtraction is done from the given input image.

C. Application of Image Morphological Operations

Next morphological operations like dilation, erosion, opening and closing are applied on the image to remove unwanted blood vessels inside the optic disk. The centre optic disk is our main concern, so intensity contours are smoothen applying different morphological operations. Dilation replaces gray scale images with maximum intensity values. When erosion is performed on a gray scale image and it replaces some of the gray values with minimum intensity values. Opening operation is used for flattening the contour and removes objects which are too small. Closing operation is used to fill up gaps and small holes on the image.

D. Fuzzy c-means

A fuzzy set is a set in which whole elements have degree of membership i.e. an element of set can be full member or a partial member [8]. Fuzzy c- means (FCM) clustering algorithm is generally used when number of clusters are predefined. The Fuzzy operations are used to change the pixel intensity [9]. According to this method each data point is assigned to one of the clusters. This algorithm ensures fuzzy partitioning where a point may be member of all the clusters with different membership grades starting from 0 to 1[10]. The algorithm works iteratively. This algorithm tries to find cluster centres which minimizes a dissimilarity function. A point nearer to a cluster centre means it is more likely to be a member of that cluster. Total summation of membership of a data point should be equal to one. Appropriate tolerance values are put depending upon accuracy of the clustering.

E. OD and OC Segmentation

Human eye accepts lights and transmits them to brain through the optic nerves. OD is considered as one of the main part for detection of glaucoma. In case of fundus images OD looks brighter than the surroundings. Segmentation is necessary to identify optic disk’s features like macula, optic cup, fovea etc. Recognizing changes in shape, size and colour produced in OD, glaucoma can be detected. Figure 4 shows the block diagram for Optic Disk segmentation.

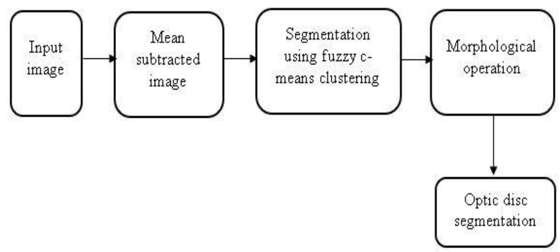

Figure 4. Block diagram for OD segmentation

1) Segmentation Methods

For optic disk segmentation a simple but robust method is adopted. We have calculated mean subtracted image of the input for normalization. Next area covered by OD and OC is calculated which helps to crop the necessary ROI. Next fuzzy - c means clustering and thresholding are applied to the ROI to segment the optic disk. Here we have to calculate the thresholding level based on which the gray scale retinal image will be converted to black and white image. The central part is optic disk, it is in white and whole background is in black color. Noises are removed by applying image morphological operations like open, close, dilation, erosion. This whole process retains only the optic disk and optic curve portions. Dilation expands the pixel areas and erosion erodes. The resulted image is shown in Figure 8.

Optic cup looks like a cup white in colour and centred in optic disk. The OD is divided into two regions, one is cup which is central bright region and other is peripheral region called neuroretinal rim. Expansion detected in the cup region generally signifies presence of glaucoma. OC segmentation becomes difficult because of numerous blood vessels present in this area. Moreover the boundary between OD and OC is not so distinct, which makes segmentation of OC from OD more difficult. Optic cup is also segmented in the same way that of optic disk. The optic cup is inside the optic disk and ROI extraction, thresholding and different morphological operations are performed to get the clear and focused image of optic cup.

F. Thresholding

Thresholding is used as a segmentation technique and converts gray scale image and gives black and white image. In general thresholding is the simplest way for converting gray scale image to binary image. It is based on a threshold level and replaces all pixels greater than this value with white and replaces all lesser value pixels with black. In this way the whole image can be converted to binary image. In binary image each pixel can hold only 0 or 1. Mean value of all the pixels of the image is evaluated then depending on this mean value other pixels can be assigned zero or one value. This process simply converts a gray valued image to binary image. In this work we have used this method with the aim for making vessels region white and background with black colour.

G. CDR(Cup to Disk Ratio)

CDR is the fundamental factor for glaucoma detection. OD and OC are segmented using the above said methods. Then CDR is computed. Based on the area occupied by segmented cup and segmented disk CDR is calculated as

CDR = area of cup / area of disc

Larger value of CDR gives more risk of glaucoma. CDR with value lesser than .5 is a normal eye without glaucoma, more than .5 gives a glaucoma affected eye. Depending on the CDR range patient's condition can be identified as Normal, Moderate or Severe.

IV. RESULTS AND DISCUSSION

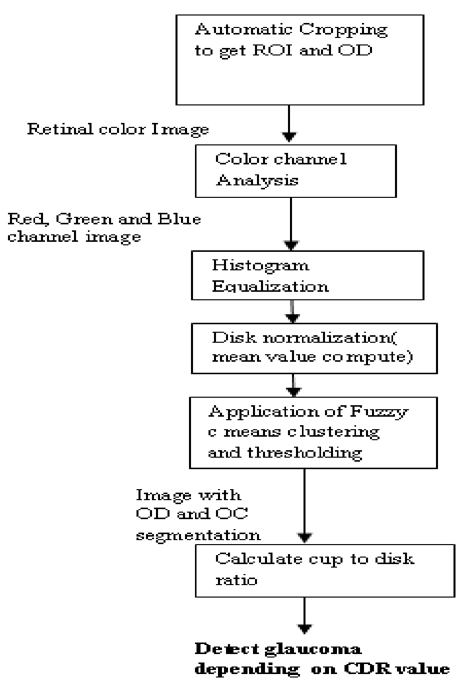

Figure 5. Activities of proposed System

The fundus images used here are taken from freely available databases DRION -DB, MESSIDOR, DIARATDB0 and from our local eye hospital. The DRION-DB database has 110 colour digital retinal images. We have selected randomly from fundus image base, belonging to the ophthalmology Service at Miguel Servet Hospital, Saragossa (Spain). The MESSIDOR database contains more than one hundred eye fundus images, it has been publicly disseminated since 2008. It was created by the Messidor project. The DIARETDB0 Database images. out of the 130 images of the DIARETDB0 database, 20 have normal construction and 110 have different types of pathology. Figure 5 is a block diagram which shows the flow of activities of our proposed system.

According to this block diagram the input images go through several stages and at last glaucoma is detected. As shown in the block diagram the input images taken from the various sources are cropped automatically in order to get the ROI. After cropping the ROI, we have performed the colour channel analysis, where the input is the retinal colour image and output are the red, green, blue channel images. After that we have performed the histogram equalization technique to remove the noise, disk normalization for mean value computation. After that OC and OD is segmented by using fuzzy c-means clustering and thresholding. After that the Cup-to-Disc ratio of each image is calculated. And based on this CDR value the Glaucoma can be detected. Table1 shows the CDR range for detection of glaucoma. In this work we have concentrated more on image enhancing and noise removal part. It is because accurate detection of optic cup is possible only if the fundus image is very clear and noise free.

Table 1. CDR Range and Glaucoma Condition

Condition	CDR Range
GRADE 1(Normal)	$0 \le CDR \le 0.4$
GRADE 2(Moderate)	$0.4 < CDR < 0.55$
GRADE 3(Severe)	$CDR \ge 0.55$

From Table 1, we understood that if the CDR value is greater than or equal to 0 and less than or equal to 0.4 then the patient is considered as normal. If the CDR value is greater than 0.4 and less than 0.55 then the patient condition is moderate and if the CDR value is greater than or equal to 0.55the patient condition is severe. We have done several experiments with most of the prominent images with us and found results correctly which were also carried out manually by the physician. The output result of our experiment after testing upon the above-mentioned dataset are shown below. Figure 9 shows severe glaucoma and Figure 10 shows moderate glaucoma respectively. The images are output of our implemented work and shown for only one experiment.

Figure 6. Histogram Equalized Image

Figure 7. Contrast Enhanced Image

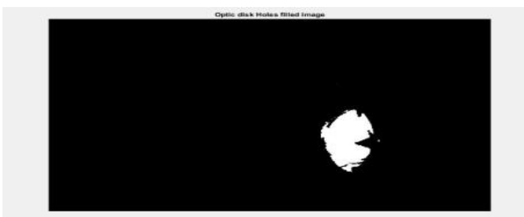

Figure 8. Optic disk hole filled image

Figure 9. Severe stage

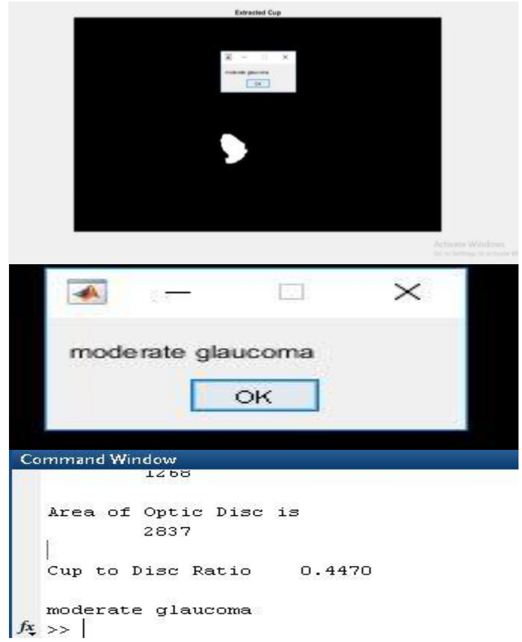

Figure 10. Moderate stage

As already discussed Fig 5 shows the major activity flows of the proposed work. Fig 6 shows snapshot of histogram equalized image of a sample taken from our database. Fig 7 is a contrast enhanced snapshot which was performed after histogram equalization. Fig 8 shows the snapshot of optic disk after filling up the holes on it. Fig 9 and fig 10 are two snapshots, first one shows program output of severe glaucoma detection with cup to disk ratio value .639. Fig 10 shows moderate glaucoma detection with .447 cup to disk ratio.

V. Conclusion and Future Scope

Glaucoma is one of the major cause for blindness but it is challenging to diagnose in early stage. We have used various image processing techniques in this work for early detection of glaucoma. Our approach is based on classification of condition's of glaucoma affected patients using cup to disc ratio (CDR) in 2-D retinal fundus images. We were able to classify almost 400 retinal fundus images correctly which were almost verified manually.

In future the proposed system can be further improved by using machine learning techniques like CNN by collecting more robust dataset. We were unable to implement this project using CNN because of lesser data available. Yet the classification we have shown here of different stages of a patient such as severe, moderate helps the patients to the reduction of cost in diagnosis and results in a prevention of better health.

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