Automatic Glaucoma Detection
by Using Funduscopic Images

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Abstract

This paper describes an automatic system to identify glaucoma disease from funduscopic images by using digital image processing. Glaucoma caused by increase of pressure in eye and damages in optic nerve. Glaucoma tends to be grown and may not show until final stage. Through this system, doctors can easily identify patient's condition quickly and do treatment. Rural people also will get advantage through this system. Glaucoma is identified through cup to disc ratio (CDR) calculation and orientation of the blood vessels in this system. For that Optical disk's inner circle (cup) and outer circle (disc) is extracted. From that radius is calculated. The outer and inner circles are extracted by using average and maximum grey level pixels respectively with the use of histogram. Then find contours and draw circle which is best fitting the contours. The radius of cup and disc are found. After calculating CDR, the abnormal image can be found if CDR exceeds a particular threshold value. Otherwise it is normal image. The system extracts the blood vessels and through the orientation of the blood vessel glaucoma is identified.

Key Terms:

Glaucoma; Funduscopic Image, Image Processinng, Cup Disc Ratio

1. INTRODUCTION

Eyes are the organs of vision which detect light and convert it into electro-chemical impulses in neurons. World Health Organization (WHO) declares that Glaucoma is the second leading cause of blindness; which contributes to approximately 5.2 million cases of blindness [1]. Glaucoma caused by increase of pressure in eye and damages in optic nerve. Glaucoma tends to be grown and may not show until final stage. If the pressure increases over long time, the person may loss vision permanently. Glaucoma is commonly incurred in both eyes in different extent. There are two types of glaucoma such as open angle glaucoma and angle closure glaucoma.

In rural areas there are no many doctors to examine the patients. There were many mistakes happened in past years by not diagnosing the correct disease in manual diagnosing. This project was initiated with this background where there is enough technology to extract this knowledge into an automated system. Such an automated tool can be useful in health camps in rural areas in developing countries like India and Sri Lanka where a large population is suffering from these diseases goes undiagnosed.

We were keen to search for any previous attempts to automate this diagnose procedure. We searched on the possibilities and previous attempts on automating the process of diagnosing the above mentioned diseases. The system uses Funduscopic images for analysis and finding the disease. It is widely used because of high-resolution images of the retina. The information about optical disk is important to detect glaucoma disease. Optic disk is the brightest component in the image. Diameter of optic disk is usually used as a reference length for measuring distances and sizes. There are many ways to find the glaucoma disease such as assessment of raised intraocular pressure (IOP), assessment of abnormal visual field, assessment of damaged optic nerve head and calculating CDR. But we focus on CDR measurement calculation. CDR is calculated by getting radius of Disc and cup. According to the experimental values if the ratio exceeds 0.3 then the image

detected as affected. Otherwise it is detected as normal.

The rest of the paper is organized as follows. Section 2 involves the detailed description about the related research work. Section 3 presents the Research Approach. Section 4 presents Design and Implementation details of our system. Section 5 presents Results of our system and discussion about the research which is relevant to the detection of glaucoma disease, edge detection techniques and histogram features and evaluation of results. The final section contains conclusion of the study.

2. RELATED RESEARCH WORK

2.1 Automatic diagnosis of Diabetic Retinopathy and Glaucoma using fundus and OCT images

The system is used to find diseases Diabetic Retinopathy and Glaucoma. Detection of the Glaucoma is done by guessing the thickness of the Retinal Nerve Fiber Layer (RNFL) from the OCT image. This is done based on deformable snake algorithm to segment anterior and posterior boundaries. The system uses anisotropic noise suppression technique to smooth images and preserve the edges. The image is firstly smoothed by 10×10 Gaussian filter and standard deviation of 4. Then the image is filtered by 3×3 median filter. Anterior boundary estimation, posterior boundary estimation and calculating difference between the boundaries are the main task of the algorithm. It is an iterative process which identifies points with maximum gradient, that's how it identifies boundary. The system tested 31 OCT images of patients out of which 13 were found to be glaucomatous. The accuracy of finding optical disk is 97.75%[2]. In this scenario they only use 13 fundus images to check the algorithm. So we cannot say this will work for more images. They used different algorithm without calculating CDR.

2.2 An automated detection of Glaucoma using histogram features

Early detection of Glaucoma is identified using a combination of magnitude and phase features from the digital fundus image. For both magnitude and phase components, the histogram features are computed. The steps of this approach are ROI selection, Gabor filtering, LBP steps to extract the features

and Daugman's algorithm. Local binary Pattern (LBP) and Daugman's algorithm are used to accomplish the feature set extraction. Region of Interest is extracted based on some CDR measures. Here the system used only the features to detect disease, so the system doesn't calculate CDR measure. Image is transformed into an array or image of integer labels using an image operator which forms histogram features for further image analysis. To predict the glaucoma, Euclidean distance between the feature vectors are analyzed. The system results 95.45% output for sensitivity, specificity and classification [3]. Here this system only detect features and did not calculate CDR. This system uses a predefined value for all images. The value suited for their tested images. But more images the values don't suit. So the value must be a variable.

2.3 Automated location of optical disk and fovea in retinal images

Localization of the optical disk is done by means of using the morphological operations and Hough transform. The system used shade correction operator to remove slow background variations. Brightest and biggest part of the image is calculated using thresholding. ROI is calculated using morphological operation. The boundary and center of the optic disk are found by Hough transform. The proposed method is capable of localizing the optic disk correctly for 34 of these images. So success rate is 94.4%[1]. Our approach is differing from above approach because of calculating CDR is in our system. This is the value doctors calculate.

2.4 Optic Disk and Optic Cup segmentation for Glaucoma Classification

The system describes a way to automatically detect the optic nerve. This approach is based on the primary of the main retinal vessels. The steps of the approach are image acquisition, image pre-processing, optic disk identification, k-means clustering based segmentation, Gabor filter, boundary smoothing using morphological feature, optic disk segmentation, CDR calculation and Glaucoma diagnosis. Circular Hough transform is used to the disc boundary. This system uses simple linear iterative clustering algorithm (SLIC) to combine nearby pixels into super pixels in fundus image. K-means clustering algorithm is used to determine the number of cluster in the data. The system gives disc and cup segmentation methods achieve an AUC of 0.800, 0.039 lower than AUC of 0.839of the manual CDR computed from manual disc and manual cup[4]. Our approach is differing from them to calculate CDR.

2.5 Segmenting Optic Disk Cup ratio in Retinal Fundus images

In this approach Optic Disc Cup ratio is segmented using Gradient method, Adaptive threshold and connected Component. The Segmentation of Optic Disc is done by observing the vasculature network inside the retina. The system used red channel image for the image analysis. The steps of the approach are background normalization, saturation detection in red, blood vessel removal, bright region removal, brighter region removal and gradient method. The region is segmented by thresholding. The system calculated Disc area, Bright area and Blood vessel area for the images [5]. They used red

channel of image. But in that only outer circle could be found. But we used green channel image which has inner and outer circle.

2.6 Clustering based Optic disc and Cup segmentation for Glaucoma detection

Simple Linear Iterative Clustering (SLIC) algorithm and K-Means clustering for glaucoma detection are proposed in this paper. This segmentation is used to obtain accurate boundary delineation. Histograms and center frame statistics are used to classify each super pixel as disc or non-disc. Location information is also added into the feature space to boost the performance. The output of the SLIC algorithm is given as an input to the K-Means Clustering. Gabor filter is used for edge detection. After optic disc segmented, CDR measure is calculated to identify whether the image has glaucoma or not. The system used 16 images and categorized as normal images and abnormal images through CDR measure [6]. This system only uses 16 images. So we can't say this method is suitable for more images.

2.7 Segmenting the Optic Disc in Retinal images using Bi-Histogram Equalization and Thresholding the connected regions

This paper uses thresholding the morphologically connected regions and boundary extraction. The input image is enhanced using Bi-histogram equalization. By this, efficiency of the conventional thresholding method can be improved. Gray level thresholding is applied on the enhanced retinal images. For respective level only, circle fitting algorithms applied. Brightness preserving Bi histogram Equalization method divide input image into two sub images. Then the system finds pixels with maximum brightness. Then following steps has to done such as gray level thresholding, finding label connected region, morphological boundary extraction and circle. The method is tested on the 40 different optical disc images [7]. They used Histogram equalization, but in our method we did not use their approach.

2.8 Super pixel classification based optic disc and optic cup segmentation for Glaucoma screening

This paper uses super pixel classification for glaucoma screening. A self-assessment reliability score is computed to evaluate the quality of the automated optic disc segmentation. This paper mainly focuses on CDR measurement of the 2D fundus image. OD segmentation and blood vessel segmentation including the generation of super pixels. Centroid calculation, stochastic watershed and region discrimination are inside the OD segmentation. PCA is used to make better quality grey scale image. This paper is mainly based on mathematical morphology with PCA in preprocessing step. Experimental results show an average overlapping error of 9.5% and 24.1% in optic disc and optic cup segmentation, respectively [9].

3. RESEARCH APPROACH

In this application if a user uploads a Fundus retinal image to the system, then the system will calculate the CDR and give result as normal (the image without glaucoma disease) or abnormal (the image with glaucoma disease). The output of the system is with the measurement of the CDR and whether

the image is positive for the disease or not. The Procedure of identifying glaucoma is presented below. To extract the disc only the red channel of the image was taken from the RGB channels and converted to grey scale because the red channel shows only the disc. Then the image was noise filtered using median filtering to remove the noise without losing needed data. The disc's pixels lies in the range of brighter grey level so the darker grey level range which has the higher density was removed by thresholding using the average grey level value and only the needed pixels were taken; these are the pixels of disc. The cup of the image also extracted from the image after removing the disc. The green sale image was used to extract the cup because it shows the disc and cup clearly. The cup's pixels lies in the brightest grey level range so the darker grey level range which has the higher density was removed by thresholding using the average and maximum non-zero grey level values and only the needed pixels were taken; these are the pixels of cup. After the disc and cup were extracted the contours of them were identified and the best fitting circle was drawn. The cup's and disc's radius were identified from the circle and used to calculate cup to disc ratio (CDR = cup radius/ disk radius).

If the CDR is above 0.3 then the image is abnormal image according to the experimental values. Otherwise the mage is normal. Figure 1 illustrates the system design of the application used in CDR calculation.

For the blood vessel extraction we used green channel image because of its clear specification of blood vessels. Morphological operation was applied to enhance darker parts than surroundings to get the clear visibility of the blood vessels where the blood vessels are darker than the surroundings. After doing morphological operation the blood vessels were extracted using the average grey level value. Then a mask was drawn over the cup and disc and the orientation of the blood vessels around the circle was identified. If the orientation is biased to a particular range of angle then the image is abnormal. Otherwise it is normal.   The algorithms and methods used are explained clearly in the next section.

Figure.2 illustrates the system design of the application used in blood vessel segmentation.

4. DESIGN AND IMPLEMENTATION

This section describes about how the system identify the glaucoma disease when a user uploads an image of retina. There are many procedures to decide whether the image is normal or abnormal. The procedures and techniques are explained below.

4.1 Get red and green channels of the image separately

An RGB image contains three channels (RGB) within it. These channels can be extracted separately. The red channel image hides the cup and shows only the disc. But for CDR calculation disc and cup should be needed. Blue channel image is a noise because it did not give the needed information. The green channel image shows the inner and outer circles of the optical disk. According to this red channel image is used for disc extraction and green channel is used for cup extraction.
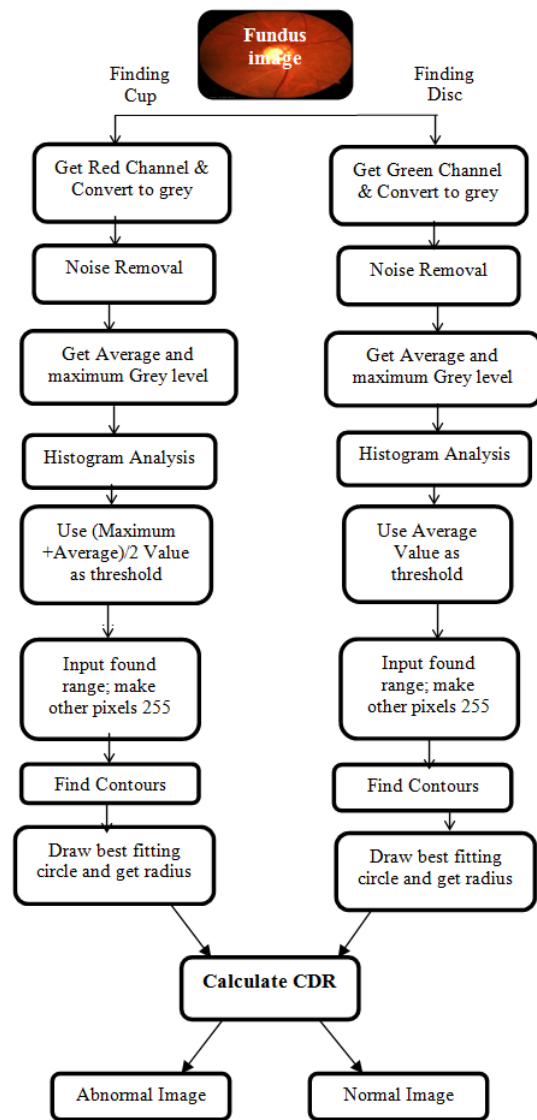

Figure 1: System design of the application used in CDR calculation

4.2 Convert to grey scale image

To view the features clearly than the red and green channel images, the image is converted into grey scale image. Red channel grey scale image shows only the disc. In the green channel grey scale image, disk and cup are brighter than the other parts of the image. Within the brighter part inner and outer circles of the optical disk is shown in different levels of intensity of brightness.Figure 3 shows the green channel and grey scale image of retina.

4.3 Noise removing using median filter

Median Filter is used to remove noise from the image to get better extraction of the feature. By trying other available filters, the median filter removes the noise better than the other filters without losing needed data. Here 7×7 kernel is used to filter the image. Median filter replaces the center value in the window with the median of all the pixel values in the window of kernel.
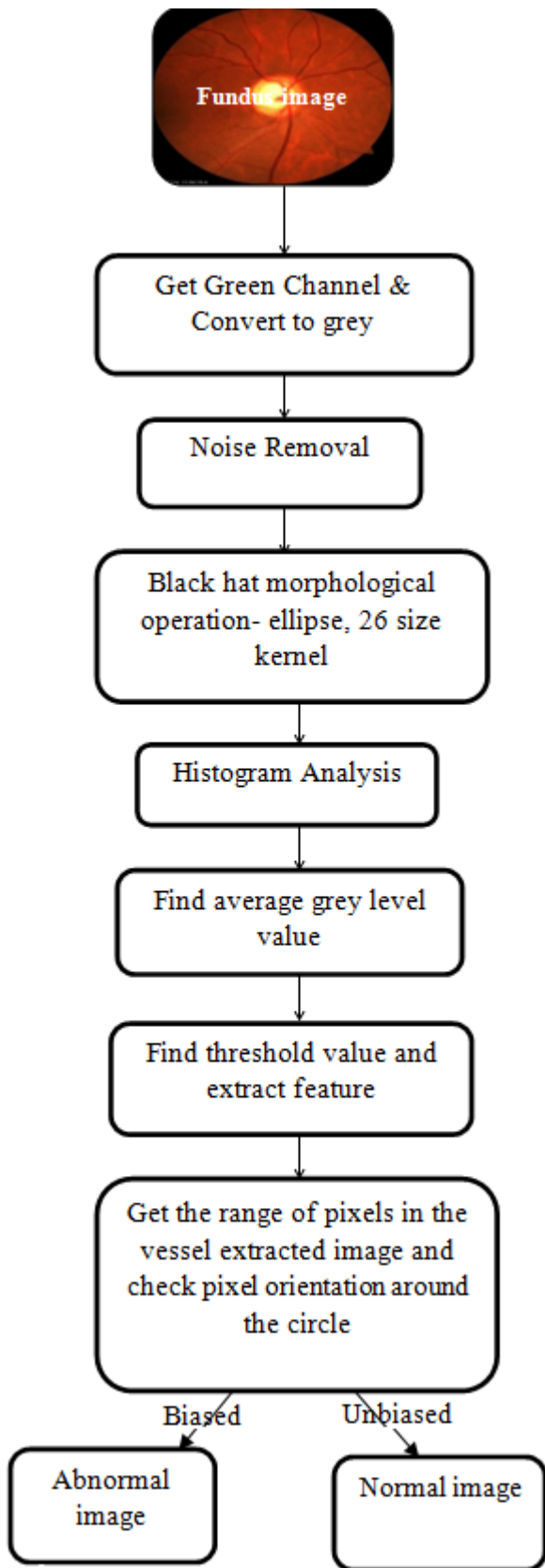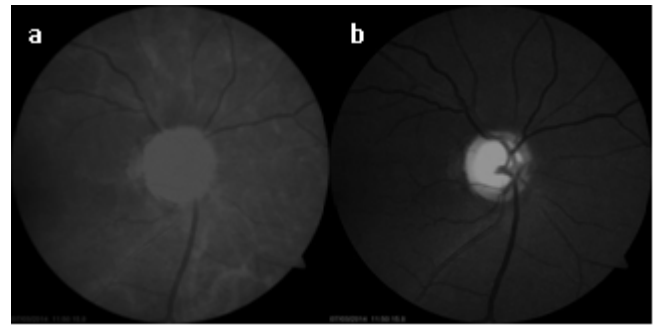
Figure 3: Red channel and green channel grey scale images of the retina (a) Red channel image, (b) green channel image

4.4 Find the average, maximum grey level values and histogram analysis of the grey image

Average and maximum grey level values are important values in this system. Average grey level value is used to extract the optical disk by getting brighter points with the use of histogram analysis. The cup was extracted by using the average and maximum grey level values. After finding the maximum grey level value the histogram is needed to be checked and if there is a peak in the density of pixels near the maximum value then the range of that peak will be taken to find the inner circle. Histogram and the pixel value of nearest maximum pixel are very important to calculate the range of values. The range of values is calculated by the below algorithm.

Algorithm 1 Identifying threshold value
---
  i = averageGreyLevel
  while i ≤ 255 **do**
    j = i
    while j < nonZeroDensityGreyLevel **do**
      if no. of pixels at i < no. of pixels at i-1 **then**
        thresholdGreyLevelValue = i
      else
        continue
      end if
      j = j +1
    end while
    i = i +1
  end while

Similar approach is used to find the outer circle also. Here average value is being used. Needed range of values is identified like above method. The range of pixels needed lies after the average value. Similar pattern is identified in histogram when different images were examined. Those similar patterns are shown in Figure 4.

By using this similar feature of the histogram the value range finding algorithm was created. For more images this algorithm was suited.

4.5 Input only the find range in the new image and make all the other pixels' value to 255.

In order to extract the needed feature only, the system will send only the found range in above step to the new image and all the other pixels' values are converted to 255. That means all other pixels are converted to white color. Through this the system extracts the features which are needed to calculate the CDR.

Figure 2: System design of the application used in blood vessel extraction
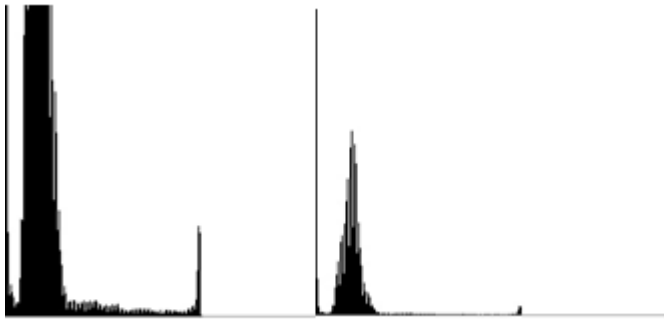
Figure 4: Two sample histogram for two different images: x-axis-grey level pixel level, y-axis-no of pixels in a particular level

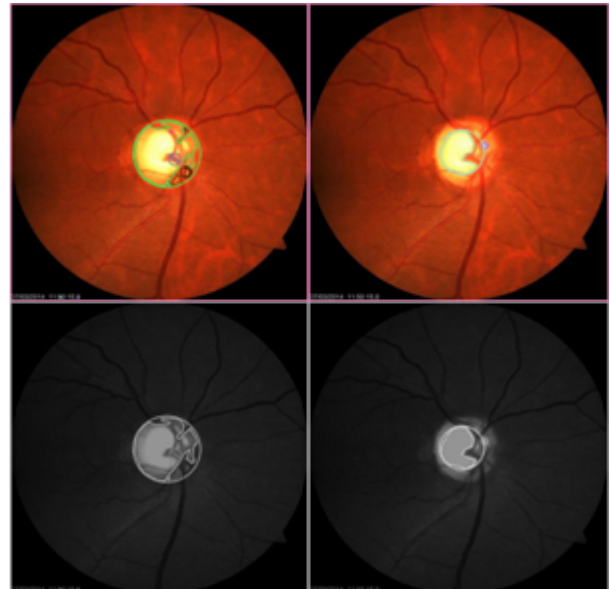Figure 5: Cup and Disc are separated individually (a) Cup image, (b) Disc image

Figure 6: Two The images with best fitting circle (a) Color image with best fitting circle in disc, (b) Color image with best fitting circle in cup, (c) Grey image with best fitting circle in disc, (d) Grey image with best fitting circle in cup

The disc and cup are separated and they will be inputted into different images. Figure 5 shows the cup and disc separately without another part of retina. Algorithm for getting only the needed pixels is given below:

Algorithm 2 Finding average grey level value

i = 0
while i < rows **do**
    j = 0
    while j = columns **do**
        read grey level value of a pixel
        if greyLevelValue > thresholdGreyLevelValue **then**
            pixelValue = pixelValue
        else
            pixelValue = 255
        end if
        j = j +1
    end while
    i = i +1
end while

4.6 Find the Contours of the newly derived image

Then the system will find the contours of the newly derived image which will be useful to find cup and disc circles.

4.7 Draw the best fitting circle and find the cup's and disc's radius

As the final step of this procedure best fitting circle is drawn by using the contours of derived image. Then the best fitting circles' (inner and outer circle) radius is calculated in pixel. The best fitting circles in images are given in Figure 6.

Then CDR is calculated and if the CDR is above 0.3, the image is glaucomatous else the image is normal. Steps to

segment the blood vessel is given below:

a) Getting green channel image
b) Convert it to grey scale
c) Use Black hat morphological operation.

Blood vessels are darker than the other pixels after converting to grey scale. So by using black hat operator converted the blood vessels into brighter pixels while surroundings converted into black. Used Black Hat Morphology operation with ellipse kernel type with the kernel size of 26.

d) Find the average of grey level value after doing morphology operation. This value is used to find out the threshold value to segment blood vessel. The algorithm to find this value is given below.

e) Find threshold value to find needed grey level value to

Algorithm 3 Extracting needed pixels

i = 0
while i < 255 **do**
    read grey level value of a pixel
    sum = sum +greyLevelValue
    i = i +1
    pixSum = sum + (i * grHistogram[i])
end while
avarageGreyLevel = pixSum/sum;

---

extract blood vessel. We used the following algorithm to find out threshold value. The threshold value has been used to extract only needed pixels which are brighter pixels than others.

f) Extract blood vessel and display. If grey level is above than the threshold value, then the value will be taken as it is. If grey level value is less than threshold value, then that value will be changed to 255. Through that we could extract only

Algorithm 4 Finding threshold value

```
i = averageGreyLevel
while i < 255 do
    while pixels density < 10000 do
        j = i
        while j < nonZeroDensityGreyLevel do
            if no. of pixels at i < no. of pixels at i-1 then
                thresholdGreyLevelValue = i
            end if
            j = j+1
        end while
    end whilei = i +1
end while
```
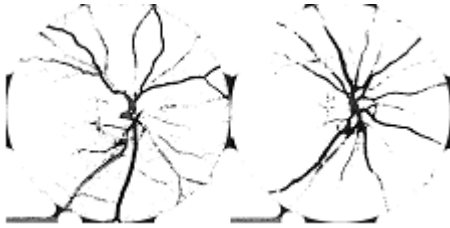
Table 1: RESULTS OF 50 IMAGES

TP	38
TN	9
FP	2
FN	1
Precision	0.95
Specificity	0.82
Sensitivity (Recall)	0.97
F-score	0.96

Figure 7: Blood vessels orientation of different images

the relevant feature. The algorithm is given below.

Algorithm 5 Extracting needed pixels

```
i = 0
while i < rows do
    j =0
    while j = columns do
        read grey level value of a pixel
        while j < nonZeroDensityGreyLevel do
            if greyLevelValue > thresholdGreyLevelValue then
                pixelValue = pixelValue;
            else
                pixelValue = 255
            end if
            j = j+1
        end while
    end whilei = i +1
end while
```

g) Get the pixels in the extracted image and check how they are oriented around the disc. A mask was drawn over the cup and disc and the orientation of the blood vessels around the circle was identified. If the orientation is biased to a particular range of angle then the image is abnormal. Otherwise it is normal.

5. RESULTS AND DISCUSSION

There are many image processing techniques that have been used to identify glaucoma disease and those techniques have advantages as well as drawbacks.

Our application is desktop application which will run in windows operating system. The application has the capable of identifying the uploaded image and gets the details of whether the image is normal or glaucomatous, Cup Disc Ratio (CDR) of the image. As discussed earlier, Glaucoma

detection is a major research area where several methods have already been formulated using different techniques and approaches. In this study we were able to find a new approach for Glaucoma detection by checking more images and using simple algorithm with better performance.

The process of the system will start at the point when the user uploads the image. The user of the system can be a doctor, lab assistant or a patient who can handle the application and computer. There should be a scanner connected to the machine or soft copy of the image could be used to upload the image.

In earlier system by using histogram features they found cup and disc by using a constant. But they tested for only 20 images but we have used 50 images when identifying the algorithm and have tested using different 50 images. If the number of images increased then the constant cannot be used for all images. So we found a variable which suits for all images which can be identified by the system automatically using the histogram features.

The things we consider to evaluate the system are given below:

True Positive (TP): Actually the image is glaucomatous and the image is detected as glaucomatous

True Negative (TN): Actually the image is normal and the system detects it as normal.

False Positive (FP): Normal image is detected as Glaucomatous image.

False Negative (FN): Actually the image is glaucomatous but the system detects as normal image.

Precision: Proportion of glaucomatous images detected as glaucomatous images from the cases that normal images and glaucomatous images that are detected as glaucomatous images.

The results of 50 images according to the above scenario are given in Table 1. The original image data set we have used for testing contains 39 glaucomatous and 11 normal images.

Precision = TP/(TP+FP)
Specificity = TN/ (TN+FP)
Sensitivity (Recall) = TP/ (TP+FN)
F-score = 2*[(Precision* Recall)/ (Precision+ Recall)]

6. CONCLUSION

Through this project, "Automatic Glaucoma Detection" will provide better solution for the difficulties and drawbacks of

current manual procedure of detecting glaucoma with naked human eyes, it is more time consuming and requires more effort and it requires more human resources who should have an expert level of knowledge and experience. Even diagnosis of this kind of eye disease by a doctor is not reliable. Even though some researches happened earlier in Sri Lanka until now they are using manual procedures. Many rural people lost their vision because of lack of eye specialist in those areas. So by introducing automatic diagnosing system will reduce barriers of diagnose even in rural area. The proposed system can detect glaucoma by calculating CDR. The system shows a higher level of precision and recall values while maintaining F-score value about 96%. However, it is required to further evaluate the method against variety of retina images with different image qualities.

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