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Retinal Image Analysis for Diagnosis of Glaucoma Using Arm Processor

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ABSTRACT: *Glaucoma is the disease which effect on the human eye which may cause blindness if not treated properly. Glaucoma occurs due to increased pressure call Intra Ocular Pressure. The glaucoma detection will be carried out using Image Processing Methods like NFL(Nerve Fibre Layer) defects detection and texture analysis, Neuro Retina Optic Cup Detection and Image Segmentation.*

For the development of the system, ARM based processor and high resolution with night vision camera is used. Using camera module will capture fundus images. Image Processing algorithm will processes this images further with edge detection and apply various techniques for detection and correction of medical images.

This research work will detect glaucoma at preliminary stages. It is helpful for medical practitioner and researchers as well as patients. This proposed method is automated, portable, cheapest and more accurate and efficient device.

KEYWORDS: *Optic Cup, Optic Disc, image segmentation, blood vessels, CDR, retinal image, arm processor.*

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I. INTRODUCTION

Glaucoma is the ocular disease which damages the optic nerve of the eye which leads to blindness.This happens due to the enourmous increase in the fluids on the front part of the eye. Normally, the pressure of the fluid is 21mm Hg. When this pressure increases to the high level, it damages the optic nerves.When Glaucoma develops there are no symptoms occur in the beginning and it starts progressing inside. The main problem of these disease is that it is not detected at preliminary ages and when detected lately it is incurable which leads to blindness in the future.

Human eye is composed of layers. Outer layer is the cornea which is a transparent layer. Light is focused by cornea. The amount of light entering the human eye by contracting and relaxing the muscles of the pupil is controlled by Iris which is the cenral part of cornea. Internal crystalline lens helps in focussing the light to fall on retina. Retina is the internal layer composed of photoreceptors called rods and cons which helps in image formation by creating a neural signal which is transmitted to brain. Optic nerve is responsible for transmitting the neural signals generated by rods and cones and is also called blind spot. Light enters the human eye through pupil and is focused to fall on retina forming an image which is intercepted by brain as an image. Figure 1 shows the internal eye structure [1][2].

Aqueous Humor is the fluid generated by the Ciliary body which is used for maintaining Intra Ocular Pressure (IOP) in the eye. This flow of aqueous humar gets affected leading to increase in IOP resulting in the destruction of the optic nerve which is the source of sending information signal to brain. Glaucoma progression is preceded by some structural changes in the internal retina. Analyzing these structural changes helps ophthamologists in the diagnosis of glaucoma and its progression can be stopped. Fundoscopy and Optical Coherence Tomography(OCT) are some of the biomedical equipments used for analysing the internal retinal structure of human eye [4][5].

Different techniques have been used for optic disc (OD), optic cup (OC), or optic disc with optic cup segmentation. In diagnosis of glaucoma, ophthamologists are concerned with optic disc and optic cup. Optic disc region is a palor circular region located in densely populated vessels. Optic disc region is centered by a yellowish intense region called optic cup. Region between Optic disc boundary and optic cup boundary creates a circular rim called neuroretinal rim (NRR). Ratio of Cup size to disc size is called Cup to disc ratio (CDR). CDR is a vital factor in analysing the pressure of glaucoma in human eye [1].

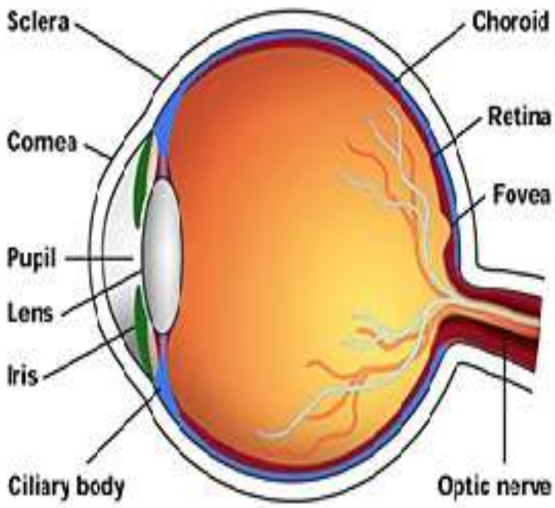

Figure 1: Internal Structure of Human Eye[3]

Determining the cup-to-disc ratio is a very expensive and time consuming task currently performed only by professionals. Therefore, automated image detection and assessment of glaucoma will be very useful. There are two different approaches for automatic image detection of the optic nerve head [6]. The first approach is based on the very challenging process of image feature extraction for binary classification of normal and abnormal conditions. The second and more common approach however is based on clinical indicators such as cup-to-disc ratio as well as inferior, superior, nasal, and temporal (ISNT) zones rule in the optic disc area [6].CDR value ≤ 0.5 indicates a healthy eye [7]. Morever, increase in CDR value decreases the neuroretinal rim. Figure 2 shows the optic disc and optic cup image with Neuroretinal Image.

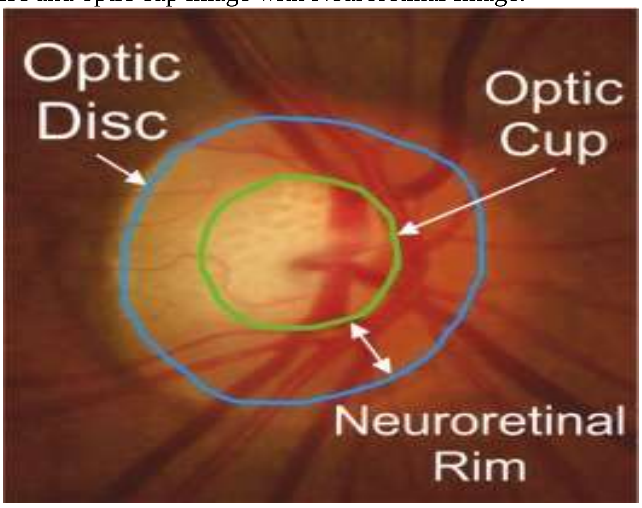

Figure 2: Optic Disc and Optic Cup with NeuroretinalRim[4]

Proposed research paper provides the image processing techniques for the detection of glaucoma using retinal images that will help to detect glaucoma at earlier stages. The measurement of the accuracy of proposed algorithms individually and comparing them with the already existing algorithm and selecting the optimal algorithm for analysis.

II. MATERIALS AND METHODS

In this section, the proposed method for the detection of glaucoma using image processing techniques is described. Figure 3 shows the block diagram for image processing techniques.

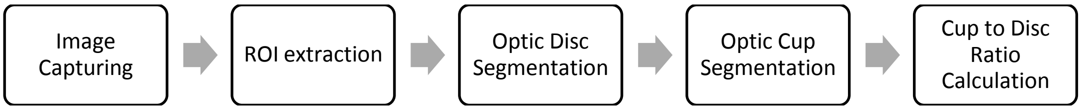

Figure 3: Block Diagram of Image Processing Techniques

The preprocessing steps consists of capturing the retinal images and then the optic disc and optic cup region is located or extracted. This extracted region is then followed by segmentation where high pixel optic disc region is segmented. The optic cup segmentation is carried out after the optic disc is segmented. Then vertical cup diameter and vertical disc diameter ratio is calculated which is called the CDR. This calculated CDR is then compared with the threshold. If the value is greater than the 0.5, the person is affected with glaucoma.

2.1 Preprocessing

The most important part of preprocessing is the Region Of Interest (ROI) as it plays a vital role in detection of optic disc and optic cup. First threshold using gray level histogram and average number of pixels occupied by OD are estimated. Applying this threshold, all bright regions within image called clusters are detected. Then morphological operations are applied to remove unwanted areas.

Algorithm for finding region of interest is as follows[8].
Step 1: Estimate Threshold.
Step 2: Apply Threshold and identify bright regions.
Step3: Apply morphological operations (closing, opening, areaopen).
Step 4: Stop

1.Threshold Estimation
First all bright regions within retinal images are detected. Gray level thresholding is used. Threshold considering gray level is estimated. Optimal thresholding method divides the pixels of the image in two groups: group A and group B such that group A contains pixels at least equal to the number of pixels occupied by the OD. OD size varies from person to person. It is a vertical oval, with average dimensions of 1.76mm horizontally by 1.92mm vertically. Its width and height are 1/8 and 1/7.33 of retinal image diameter, respectively. Thus, it is possible to determine the number of pixels occupied by the OD as:

$$\text{Pcount} = \text{estimated OD pixel count} = \frac{\pi*(D/2)^2}{7\cdot 33*8}(1)[8]$$

where D is the diameter of the retinal image in pixels. To obtain an optimal threshold, the histogram derived from the source image is scanned from highest intensity value to the lowest intensity value. The scanning stops at intensity level T when scanned pixels are greater than the estimated OD pixels and there is a 10% rise in pixel count between two consecutive intensity levels.
Optimal threshold calculation is done as follows.
Step1 : Initialize i = 255 and sum = 0
Step2: sum = sum + H[i]
Step3: i = i-1
Step4: if sum ≤ Pcount or (H[i-1]-H [i])/ H [i] 1 < 0.1 repeat steps 2 through 4
Step5: Threshold, T = i

2.Morphological Operations

To eliminate unwanted bright areas, morphological operations [9] are used. After applying threshold, the disc obtained gives some discontinuities due to veins present in retina. Thus closing operation is applied which fills black portion in white area with white pixels. To eliminate unnecessary clusters, opening operation is used. This function works exactly opposite of closing operation. Structuring element used in both operations is disk shaped of size 10. After this, if there are still clusters present other than disc then areaopen operation is used. Centre of disc plays important role in cup detection for analysis of glaucoma. Disc centre can be find by using properties of region of interest. Centroid of the region of interest is found out which is disc centre.

2.2 Optic Disc Segmentation

Optic Disc segmentation [6] method is used to segment the disc. First, superpixels are generated using simple linear iterative clustering algorithm [10] (SLIC) to group nearby pixels into superpixels in retinal images. In this, pixels are grouped depending on color and spatial proximity. In SLIC, initial cluster centres Ck are sampled by S=√ (N/k) pixels apart from the image with N pixels. The centres are first decided at the lowest gradient position in a 3* 3 neighbourhood. Then clustering is applied. For each cluster centre, this algorithm iteratively searches for the pixel which matches accurately from the (2S*2S) neighbourhood around centre based on color and spatial closeness and then the new cluster centre is computed based on the pixel which is found matched. The process iterates till the distance between the new centres and previous centres ones is small. Then feature extraction is proposed. In this centre surround statistics is used.

2.3 Feature Extraction

Some region surround disc looks similar to the disc in terms of brightness in glaucoma. It is called as PPA (parapapillary atrophy) region. It differs from disc in terms of texture. Hence centre surrounding statistics is used to detect the disc correctly. To compute this, nine spatial scale dyadic Gaussian pyramids [9] are generated. It is a sequence of low-pass filtered versions of an image. This is achieved by convolving a linearly separable Gaussian filter followed by decimation. Decimation is done by a factor of two. Then centre surround operation between centre levels and surround levels is applied and six maps are obtained at levels of 2–5, 2–6, 3–6, 3–7, 4–7, and 4–8 Maps are computed only for red channel. Hence feature size is 6*2=12. The CSS features are then computed as the first and second moments of these maps within superpixels. Where Mi, i=1,2,……18 as the ith map, the feature CSSj consists of the mean μj and variance varj of maps within the superpixels that is CSSj = [μjvarj], where μj and varj from superpixelSPj with nj pixels are computed by

$$\mu j(i) = (1/nj) * \sum_{(x,y)\in SPj} Mi(x,y) \quad (2)[6]$$

$$varj = \left(\frac{1}{nj}\right) * \ (x,y)\epsilon SPj \ (M_i \, x,y \ - \ \mu j \ i\ )^2 \quad (3)[6]$$

In this, mean and variance of the superpixels is calculated. Finally, artificial neural network is used as classifier to classify superpixels as disc or non disc. Ellipse fitting is applied to get disc boundary.

2.4 Optic Cup Segmentation

Superpixel generation is used in the same way as disc. After obtaining the disc, the minimum bounding box of the disc is used for cup segmentation. Center surround statistic is used as feature. For cup only sixth map is taken into consideration as it gives necessary information for cup detection. This reduces feature size. As a result, evaluation time also reduces. Disc centre and superpixel centre are taken into consideration and distance between them is calculated. This gives the location of the cup inside the disc. Classification of the superpixels is done using artificial neural network. Ellipse fitting is applied to get boundary of cup.

2.5 Classification

An artificial neural network[11] is an information processing system that has certain performance characteristics in common with biological neural networks. A neural network is characterized by its pattern of connections between the neurons, its method of determining the weights on the connections and its activation function. A neural net consists of elements called nodes. Neurons are connected to each other with weights. A neuron sends its activation as a signal to several other neurons. Artificial neural networks consist of many nodes, processing units analogous to neurons in the brain. The neural net can be a single layer or multilayer net. In a single layer net there is a single layer of weighted interconnections. A multi-layer artificial neural network comprises an input layer, output layer and hidden layer of neurons. The activity of neurons in the input layer is represents the raw information that is fed into the network. In back propagation network input vectors and the corresponding target vectors are used to train a network until it can approximate a function. Standard back propagation is a gradient descent algorithm in which the network weights are moved along the negative of the gradient of the performance function.

2.6 Cup to Disc Ratio

Vertical cup diameter to vertical disc diameter ratio is calculated.
CDR = VCD/VDD
When CDR is greater than threshold then it is glaucomatous otherwise healthy.

III. EXPERIMENTAL RESULTS

A. Preprocessing

Localization of optic disc is the preprocessing step in this project. Thresholdingmethod is used for locating optic disc. Value of threshold is based on pixel count and histogram. First color image isconverted to red channel image. Then diameter of retina is found out. For this purpose, first red channel image isconverted to binary image. Then number of pixels occupied by disc is calculated using formula. Then threshold isfound out using steps given in methodology. This threshold value is applied to red channel image. There are some discontinuities in the cluster and some unwanted clusters are present in image. Hence, morphological operations are used.

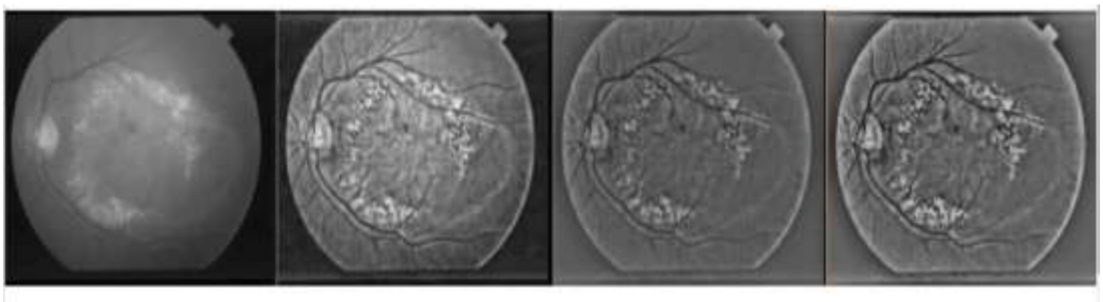

Figure 4: Localization of Optic Disc

In this project, first closing operation is used which fills discontinuities present inside the cluster. Then opening
operation is used for removing unwanted clusters outside main cluster. Size of structuring element used for both operations is 10. After this, if there are still clusters present other than disc then areaopen operation is used. Thus onlymain cluster is remained in the image. This is region of interest and it is extracted from color image.

B. Segmentation And Classification Of Optic Disc

Segmentation is done on the region of interest to get disc boundary. Superpixel segmentation is used here. This usessimple linear iterative clustering algorithm. The only parameter in this is K(the number of superpixels). As K valueincreases, accuracy increases but time required for evaluation also increases. If K value is very small then time requiredis less but results are poor. Hence tradeoff between those two is achieved and K=100 is used in project. It is iterativeprocess. 10 iterations are used here.Segmentation result is shown in figure 5.

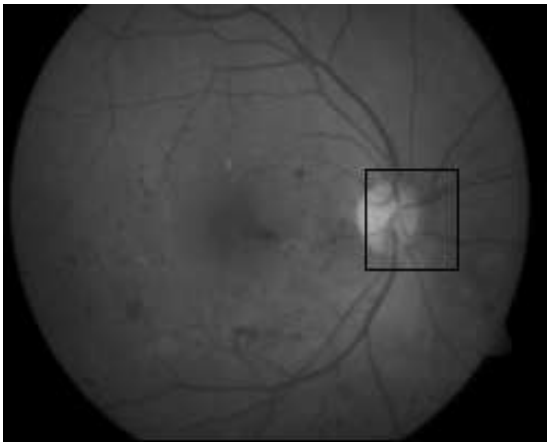

Figure 5: Optic Disc Segmentation

C. Segmentation And Classification Of Optic Cup

Segmentation is done on the disc to get cup boundary. Here also superpixel segmentation is used. Parameter values aresame as disc segmentation.Segmentation result is shown in figure 6.

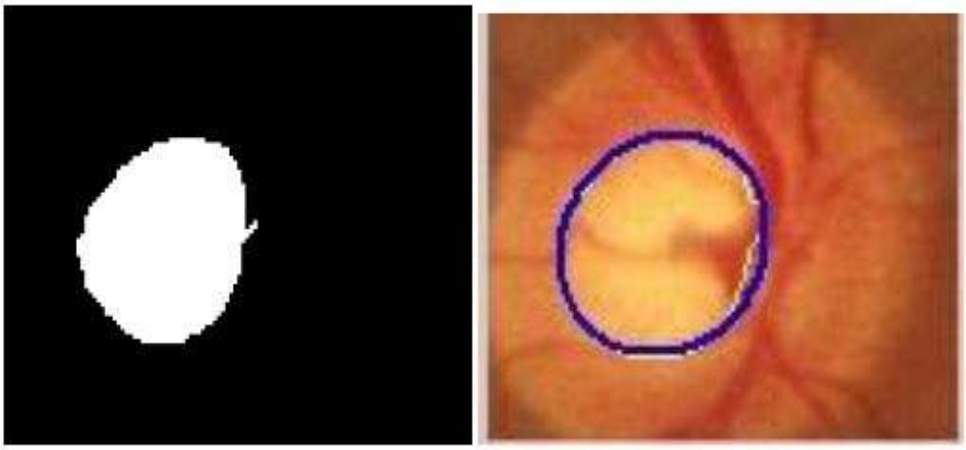

Figure 6: Segmentation of Optic Cup

IV. CONCLUSIONS

Proposed method detects whether patient is healthy or is at risk of glaucoma. This imaging technique does not requirepatient at the time of testing as only retinal image is sufficient. Cup to Disc ratio calculation method for glaucomadetection is superior to earlier methods. This uses superpixel segmentation method to detect disc and cup. This usessimple linear iterative clustering algorithm. Superpixel segmentation has less complexity than pixel based methods. Theonly parameter of segmentation is number of superpixels. Increasing this number increases accuracy of correctboundary but time required is more. Hence tradeoff between accuracy and time is achieved. 10 images are used forevaluation. Sensitivity and accuracy achieved are 82.00% and 89.90% respectively.

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