Glaucoma Detection Techniques: A Review

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Abstract: Glaucoma is one of the main causes of blindness today. It is basically a group of eye diseases that leads to the optic nerve damage and arises mostly due to the increases in the Intraocular Pressure (IOP) within the eyes. The early detection as well as diagnosis of this disorder is very important as at the later stages it leads to complete loss of vision. In this paper we reviewed different glaucoma detection procedures by digital image processing of fundus of eye. This paper also proposes a very simple method for the screening of glaucoma.
Keywords- Glaucoma, Optic Disk, Optic Cup, Cup-To-Disc Ratio (CDR), Intraocular Pressure (IOP), Optic Nerve Head (ONH), Retinal Nerve Fiber Layer (RNFL).

Introduction

Glaucoma is a term referring to a group of eye disorders that leads to optic nerve damage which, in most cases, is associated with an elevated fluid pressure in the eye i.e. Intra-Ocular Pressure (IOP) [1]. Most of these disorders give rise to elevated pressure within the eye. The Intra-Ocular Pressure (IOP) is measuredby a tonometer in millimeters of Hg and ranges from 10-21 mm Hg in normal subjects [1, 2]. An elevated eye pressure is one of the major risk factors for glaucoma and can be used for its screening. In glaucoma, higher eye pressure damages the delicate nerve fibers and blood vessels and finally the optic nerve as shown in Figure 1. In front of the eye there is a small space called the ‘anterior chamber’ and a clear fluid flows through it and nourishes the nearby tissues and the trabecular meshwork. This very fluid is the aqueous humor which is basically a transparent fluid consisting of low protein concentrations. It is discharged by the ciliary bodies (in the posterior chamber a space between the iris and the lens). The fluid after being secreted then flows through the pupil into the anterior chamber between the iris and the cornea and goes in episcleral vein as shown in Figure 2. From here it drains through a sponge like structure located at the base of the iris called the trabecular meshwork and finally exits from the eye. In a healthy eye, the rate of secretion is equivalent to the rate of drainage. But in people with Glaucoma this drainage channel is blocked since it does not flow out it starts accumulating in the chamber and this increase the pressure in the chamber as well as within the eye. The pressure then pushes the lens back and presses on the vitreous humor or the body which in turn compresses and damages the blood vessels and the nerve fibers running at the back of the eye and finally the optic nerve, which transmits visual information from the retina to the brain. These injured blood vessels leads to the patches of vision loss and if left untreated may lead to total blindness.
Elevated eye pressure signifies that the subject is at risk, but does not mean that she has glaucoma. A person is glaucomatous only if the optic nerve is harmed. If someone has an elevated IOP but unharmed optic nerve, she is not considered glaucomatous but is at risk.
Also not everyone with increased IOP will have glaucoma. A certain level of eye pressure may be high for one but normal for another. Glaucoma can also develop without an elevated IOP. This is another form of glaucoma called normal-tension glaucoma.

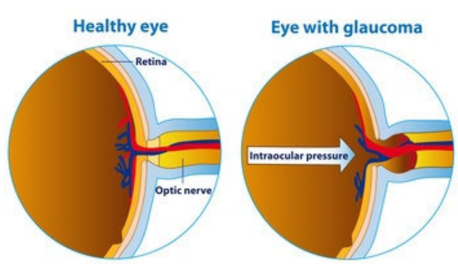

Figure 1: Normal and Damaged Optic Nerve [3]

There are different types of glaucoma namely:
Open Angle/ Chronic Glaucoma: It is caused by the partial blockage of the drainage canal. The angle between cornea and iris is open meaning the entrance to the drain is clear, but the aqueous humor flow is somewhat slow. The pressure in the eye builds up gradually over a long period of time. Also the symptoms appear gradually starting with peripheral vision loss and may go unnoticed until the central vision is

affected. The progression can be stopped with the medical treatments but the part of vision that is already lost cannot be restored, that is why the early detection of glaucoma is very important [2].

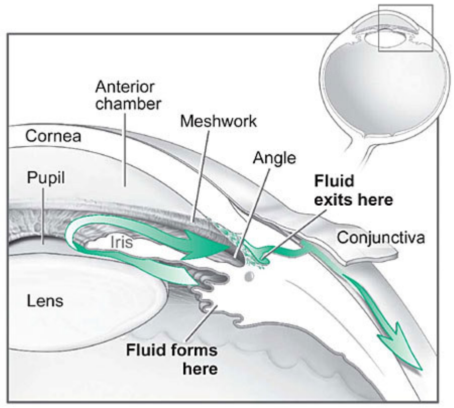

Figure 2: Aqueous Fluid Pathway [4]

Acute Angle Closure Glaucoma: It is caused by sudden and complete blockage of the aqueous humor drainage. The pressure within the eye arises rapidly and may lead to total vision loss quickly. The anatomical features of eye like narrow drainage angle, shallow anterior chamber, thin and droopy iris make it easier to develop this type of glaucoma. Typically this happens when the pupil is dilated and the lens is stuck to the back of the iris. This prevents the aqueous humor form flowing through the pupil into the anterior chamber. This results in the accumulation of the fluid in the posterior chamber which further presses the iris causing it to bulge outwards and block the drainage angle completely. This is basically a medical emergency and requires immediate attention. Usually, laser surgery and medicines can clear the blockage, lower eye pressure, and protect vision.

*Normal Tension Glaucoma:*Itis an eye disorder that shows all the features of traditional glaucoma except the elevated IOP. It is in many cases associated with issues of blood circulation. It has symptoms like increased optic nerve head (ONH) excavation and thinning of the retinal fiber layer, while the patient has an IOP that is regarded as normal.

Ocular Hypertension: It is a term signifying the presence of IOP in the absence of optic nerve damage or even visual loss. The normal range of IOP is between 10 mmHg and 21 mmHg.

Secondary Glaucoma: This glaucoma results from another eye disease. Like, if the patient had an eye injury or who is on prolonged steroid therapy or who has a tumor may flourish secondary glaucoma.

Congenital Glaucoma: It is an infrequent type of glaucoma that evolves in infants and young children and may be inherited. Conventional surgery is the suggested treatment as medicines are not effective and may cause serious side effects in infants [2].

General causes leading to Glaucoma:

- Old age - People of age above 60 are more prone to develop glaucoma
- Other illnesses and Conditions - People with diabetes have a higher chance of developing glaucoma
- Eye injuries - Eye injuries are linked to a higher glaucoma risk. Retinal detachment, eye tumors and inflammations can also lead to glaucoma
- Eye surgery – patients who underwent eye surgery have a higher risk of glaucoma
- Myopia - people with myopia also have a risk of glaucoma
- Corticosteroids – These are a class of chemical drugs that constitutes the steroid hormones. Patients on prolonged use corticosteroids have a higher risk of developing glaucoma
- Migraine and peripheral vasospasm have also been identified as risk factors for glaucomatous optic nerve damage

Glaucoma is denoted by the changes in the eye ground i.e. the region of the Optic Nerve Head (ONH). It may include:

(i) expansion of the cavity (Cup)
(ii) disc hemorrhage
(iii) thinning of the neuro-retinal rim area
(iv) unevenness of the cup between left and right eye
(v) loss of retinal nerve fibers

The image of inner eye is obtained by digital ophthalmoscope and the image so obtained is called fundus image. The fundus of a normal eye is shown in Figure 3.

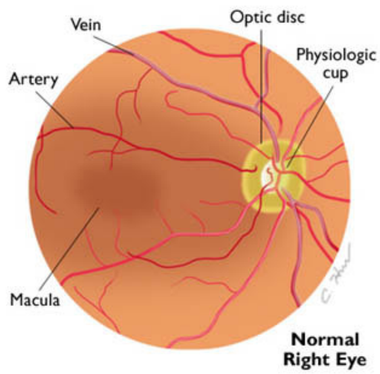

Figure 3: Normal Fundus [5]

Glaucomatous diagnosis is based on the patient's family medical and genetic history, thinner corneas, elevated Intra Ocular Pressure and manual assessment of the Optic Nerve Head from the color fundus images.

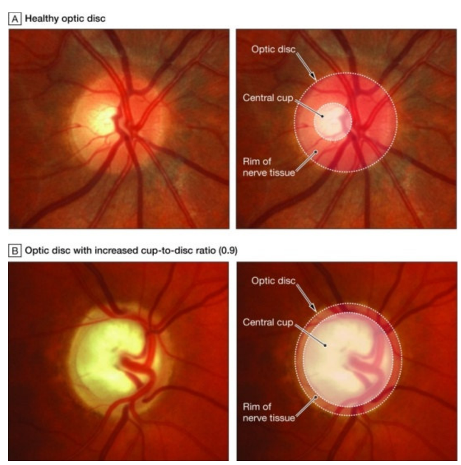

Figure 4: (a) Healthy Optic Disk (b) Unhealthy Optic Disk [6]

The glaucomatous changes observed in the color retinal fundus images are the changes in the appearance of Optic Disc (OD) i.e., enlargement of the depression called cup and diminishing of the neuro-retinal rim. these changes are shown in Figure 4.

Optic disc (OD) is the most vivid feature in a normal retinal fundus image and it has an elliptical shape. It appears as a bright orange-pink ellipse with a pale centre. Orange-pink appearance signifies a healthy neuro-retinal tissue.

Due to the pathologies, the orange-pink color moderately disappears and appears pale. Blood vessels are emerging out from the Optic Disc (OD). The pale centre is devoid of neuro-retinal tissue and is known as the cup. The vertical size of this cup can be estimated corresponding to the disc as a whole and extended as a cup-to-disc ratio (CDR). The CDR marks the proportion of the disc encompassed by the cup and is widely accepted Figure for the screening of glaucoma. For a normal eye it is acceptable from 0.3 to 0.5. As the neuro-retinal degeneration precedes the ratio increases and at the value of 0.8 the vision is completely lost.

A normal CDR thus may be used to screen glaucomatous cases.
For detecting Glaucoma we use CDR primarily for the screening purpose. The subjects with a CDR value higher than 0.5 are considered as suspicious and need further confirmatory tests. The eye with a CDR value less than 0.5 is surely not glaucomatous and this does not require any further investigation. For confirming Glaucoma, changes in Neuro-Retinal Rim (NRR) Area are studied.
Neuro-Retinal Rim (NRR) Area is the region between the boundary of the disc and the physiological Cup. The NRR is normally thickest in the inferior part; followed by the superior, nasal and the temporal. This is referred to as the "ISNT" rule, shown in Figure 5, which is observed in the normal cases. Any change in this pattern is suspicious like if the inferior rim or part is thinner as compared to the superior, it could suggest pathology. The temporal rim is thinnest for normal cases. In glaucomatous cases, the ratio of the area covered by the rim in superior and inferior region reduces and becomes thin as compared to the area covered by the rim in nasal and temporal region.

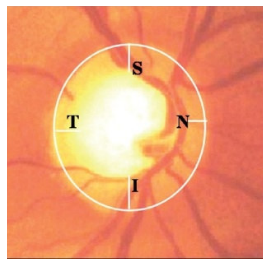

Figure 5: ISNT Quadrants [7]

Methodologies Used For Detection of Glaucoma

For the detection of Glaucoma from a retinal fundus image there are several sub-steps that are followed:

- Image Pre-processing
- Feature Extraction
- Classification

A. Image Pre-processing

The term Image preprocessing refers to the initial methods or techniques applied to the images to remove the unwanted features like bright spots or speckles introduced during image acquisition, noise, uneven contrast level or the illumination so that they don’t interfere with the extraction of the required features and not suppress their significance.
R. Chra´stek*et al.* eliminated the non uniform illumination from the fundus image by using median filtering with a large mask [8].
The blood vessels in different images vary in size, shape and location for individual cases and thereby introduce higher variations in the data that suppresses variations due to the disease. R¨udiger Bock et al segmented blood vessels to obtain a “vessel-free” image. Also images were scaled to a uniform size of 128 × 128 pixels [9].
Aliaa A. A. Youssif*et al.* proposed pre-processing techniques including Mask generation, Illumination Equalization and Color Normalization [10]. The masks were automatically generated by simple thresholding of the green channel followed by median filtering. Logical operators were used to combine the binary results of all the three channels- *opening, closing, and erosion* –to give the final Region of Interest mask. The Illumination Equalization was carried out by running a window of a particular size which calculated the mean intensity value of the pixels within the window. It can also be done by using a median filter. Another contrast enhancement method Histogram Equalization was also used.
Aliaa Abdel-Haleim*et al.* performed illumination equalization by equalizing each pixel of the image using a window and applied Adaptive Histogram Equalization (AHE) to normalize as well as enhance the contrast within the fundus images [11].

Ahmed Wasif Reza *et al.* applied an averaging filter to the original image to blend the small objects with lower intensity variations into the background itself leaving the objects of interest unchanged followed by the contrast adjustment of the extracted green channel image to make the brighter object features distinguishable from the background [12].

G.B. Kande*et al.* applied stepwise preprocessing technique by converting the image into HIS (Hue Saturation Intensity) space followed by a local contrast enhancement method and a median filter which reduces the noise level of the image [13].

Jörg Meier *et al.* used illumination correction, vessel removal and Optic Head Normalization (ONH) as a part of pre processing of the fundus image [14]. The illumination correction method subtracts the retinal background from the original image to get a uniformly illuminated fundus image. The estimation of the background was done by average intensity filtering.
The vessel structures situated in the eye ground were removed by using segmentation and in-painting of the detected vessel branch. AlsoONH template-matching, the convergence of the vessel tree or intensity assumptions were applied for ONH normalization.

M. Mishra *et al.* removed the bright small spots, distributed over the image which is acquired along with the image, by homogeneously correcting the image by subtracting the background of the image which was estimated by using morphology [15].

HaishimF.A. *et al.* generated a binary mask using Gaussian filter to define the region of interest (ROI) followed by extraction of the intensity levels from both red and green channels to obtain a modified intensity channel component [16].

B. Feature Extraction

There are different features in a retinal fundus image that can be extracted which can capture the glaucomatous structures. These are namely CDR value, textures and histogram models, blood vessel and NRR area, Optic Nerve Head (ONH) and loss of retinal nerve fibers.

Extraction of CDR
Rudiger Bock *et al.* examined different types of features (pixel intensity values, textures and parameters of a histogram model) [9]. Pixel intensity values were taken as a high dimensional feature and used principal component analysis (PCA) and linear discriminant analysis (LDA). Also the other structural changes resulted by glaucoma a set of Gabor filter banks were applied on preprocessed images. Histograms were also applied to summarize the data in the image. The change in the CDR values shows intensity shifts in the histograms models.
Ahmed W. Reza *et al.*proposed an algorithm that used green component of the image and used preprocessing steps followed by image processing techniques such as morphological operations, maxima operator, minima imposition, and the watershed transformation [12]. The methodology was evaluated using the images of STARE and DRIVE databases by using fixed and variable thresholds.
Average Filtering: In an original fundus image the intensity value variations between the optic disc and the blood vessels is correspondingly high and the vessels usually have poor contrast as compared to the background. To differentiate the optic disc from the bright parts preprocessing of the image was done. In the first phase, an averaging filter is applied to the original image.
Contrast Adjustment: Since the green channel contains a good contrast between the background and the bright retinal parts the green component was extracted from the RGB color image. The image was then enhanced to make the brighter features more remarkable.
Thresholding: A threshold value was chosen to obtain a binary image from the contrast adjusted imagethat isolates the bright parts from the background.
Morphology: It is used to determine the connected pixel components and also to smooth the contour of each pixel component obtained from thresholdedimageproducing another binary image.
Extended Maxima: Thishas been used to identify group of pixels in morphologically operated imagethat have significantly higher values compared to their immediate surroundings.
Minima Imposition: The complement of the image after applying maxima operator was obtained. This was taken as the watershed transform is applied in the next phase that identifies low points and not high points.
Watershed Transform: The watershed transform of the image is obtained and is then converted into an RGB image for getting a better view of the objects of interest.
G.B. Kande*et al.*proposed three novel approaches to extract out the main features in a retinal image [13]. The optic disk boundary detection involved the use of color morphology and geometric active contour method with variational formulation.
The exudates segmentation composed of three steps:

- The image was preprocessed to improve the contrast of the lesions
- The entropy feature was then used to eliminate the optic disk
- To extract the exudates region, a spatially weighted fuzzy c-means clustering was used

Basically, three methods were proposed:

- The method of finding the vessel branch with maximum number of vessels to localize the optic disk
- The optic disk boundary detection using geometric active contour model
- Exudates detection method based on spatially fuzzy c-means clustering

Madhusudan Mishra *et al.* used active contour method to find the CDR from the fundus images to deduce the pathological procession of glaucoma [15].
They followed different steps for the detection:
Firstly, the images were given illumination correction, after the pre-processing the blood vessels were removed from the image as they were hardly affected by the glaucoma and hence does not play any part in detecting it. And then finally the Cup and the Disk were detected by using multi thresholding and the active contour method. The cup was assigned with a higher threshold value in comparison to the disk. The method was based on the prominence of a curve around the object which is to be detected. Then the cup to disk ratio was calculated by mathematically taking the ratio of the dimensions of the cup to the disk.

S. Sekhar*et al.* described a novel method to localize the optic disk. The proposed methodology consists of two stages:

- First step, an elliptical or circular region of interest was extracted by first isolating the brightest region in the image by using of morphological processing, and
- Second step, the Hough transform was applied to detect the main circular attribute within the region of interest. Initial results on the database of fundus images showed that the proposed methodology is effective [17].

Mathematical morphology was particularly suitable for evaluating shapes in images. The two main techniques are dilation and erosion. These involve a special mechanism of integrating two sets of pixels. One set consists of the image being processed upon and the other a smaller set known as a structuring element.
Two other important processes are opening and closing. Opening generally smoothes the contour of the image and Closing proceeds to narrow smooth sections of contours by fusing narrow breaks and long thin gulfs, eliminating removing small holes and filling gaps in the contours.
The boundary of the disk and its center were extracted out by applying the Hough transform to the morphologically operated image. The total number of edge pixels and also the number of radii used were reduced by applying Hough transform only as the computational complexities of Hough transform is completely dependent on the total number of edge pixels and the number of radii to be mapped.

The method by Atef Z. Ghalwash*et al.* included normalizing luminosity and the contrast throughout the image by using illumination equalization along with adaptive histogram equalization methods [11]. The disk detection algorithm was dependent on matching the expected directional order of the retinal blood vessels. A simple matched filter was presented to roughly match or map the direction of the vessels in the Optic Disc (OD) territory. The retinal vessels were firstly segmented using a standard Gaussian matched filter. Ultimately, a vessel direction map of the segmented retinal vessels was obtained using the same segmentation algorithm. The segmented vessels were thinned and filtered using local intensity. The difference between this matched filter and the vessels' directions at the encompassing area of each of the disk center candidates were measured. The minimum difference gave an estimate of the disk center coordinates. The methodology was evaluated on a subset of the STARE dataset.
In the given methodology initially, a binary mask was constructed. Then the illumination as well as contrast throughout the image is evaluated. In the end, the retinal vasculature is extracted out, and the directions of the blood vessels were matched to the presented filter which represents the expected directions in the OD locality.
ChisakoMuramatsu*et al.* compared three different methods of active contour model (ACM), artificial neural network (ANN), and fuzzy c-mean (FCM) clustering for the detection and extraction of the optic disc [18]. The results of each of them were evaluated using different databases from different camera systems.
Disc detection by ACM: The determination of the optic disc regions was based on the active contour modeling. In this, the expected disc boundaries were searched in spiral directions from the center of the region of interest.

Disc detection by pixel classification method: Two kinds of pixel classification techniques were investigated: FCM and ANN.

In ***FCM***, the cluster center and the membership degree was updated in every iteration. The algorithm was trained to classify the pixels into 2 to 4 clusters, and a resulting cluster that comprised of the center pixel of the ROI regarded as the disc cluster. After applying the morphological opening, an isolated area in the center of the ROI was referred to as the disc region.

The ***ANN*** was trained with the input data and the clinical data determined by ophthalmologist. The count of the hidden units was varied corresponding to the number of units at the input. The count of output units was set corresponding to the probability of a pixel whether belonging to the disc and background or to the disc. Depending on the number of outputs, some number of pixels per group were randomly drawn or selected from each case and enrolled for training. If the output corresponding to the disc probability has the highest value, these pixels were then classified as a part of the disc region. After opening it morphologically, the isolated region in the center of the ROI was referred to as the final disc area.

Arturo Aquino *et al.* presented a template-based method which used morphological and edge detection techniques followed by Circular Hough Transform to detect disk boundary approximation [19]. It required a pixel located within the optic disk as the initial information. Firstly, a disk containing image was extracted from the fundus image from which an OD pixel and its neighboring area was selected. For this purpose, an Optic Disc (OD) location method was used. The Optic Disc (OD) boundary was extracted out in parallel from both the channels, red and green, of this sub-image by use of morphological and edge detection methods. Both the boundaries were estimated by using Circular Hough Transform. The better of these results were then finally selected.

The location methodology basically obtained a pixel [Optic Disc Pixel (ODP)] that exists within the Optic Disc (OD). It comprised of independent detection procedures. Each procedure carried its own ODP. The methodology used three different methods to localize the disk, namely, Maximum Difference Method, Maximum variance method and low pass filter method. Further to segment the disk firstly the blood vessels were eliminated, after that the disk boundary was zeroed in by measuring the value of gradient magnitude of the gray level variations in neighborhoods of the image, and then the final boundary of the disk was segmented by using the Circular Hough Transform.

Huiqi Li *et al.* presented a new approach to extract the main features from a color fundus image. Optic disk was first localized by the principal component analysis (PCA) and then its shape was segmented by an active shape model (ASM) [20].

Exudates were then extracted by the combined region growing and edge detection methods. A fundus coordinate system was set up to provide a better description of the fundus image features.

PCAwas proposed to localize the optic disk. The procedure was performed on the intensity image. The two steps in the localization were:

- The candidate regions were determined and PCA is employed
- A sub-image around the disk was cropped to obtain a training image
- An active shape model (ASM) was proposed to detect the disk boundary
- Mean squared Wiener filter was applied to remove noise. A combined method of region growing and edge detection has been employed here to detect the exudates

Preeti*et al.*discussed various image processing methods that have been used in the early diagnosis and evaluation of various eye diseases including Glaucoma [21]. These included Enhancement, Classification, Fusion, Segmentation, Registration, Pattern matching, Morphology, Statistical measurements, Feature extraction and Analysis.

Image Registration- It is an important method for detecting changes in fundus retinal image detection. In this, two images are mapped onto a familiar coordinate system.

Image Enhancement- It included varying illumination and the contrast of the image. It also involves histogram equalization and filtering. It is used under preprocessing steps to enhance different features of an image.

Image Fusion- it is basically a process of combining different information from the images acquired from different imaging devices. Its motive is to integrate multi-view information to a single image comprising of all the information just so that the amount of information is reduced.

Segmentation- Segmentation is a process of splitting an image into its component objects which are homogenous corresponding to some criteria. These algorithms are area-oriented rather than pixel oriented. The main objective is to extract numerous features or parts of the image which can be split in order to construct an object of interest on which any interpretation can be performed.

Feature Extraction- It is the process of pinpointing and detecting the region of interest from the image.

Morphology- It is a technique of appearance, organization and shape. It is basically a combination of non-linear processes that can be applied to an image to cut off the details smaller than a certain reference limit or shape. Different morphological operations are erosion, opening, dilation and closing.
Classification-It is a technique for image analysis used for estimating statistical parameters corresponding to the gray level intensity values of the pixels. It involves labeling of a group of pixels depending upon the grey level values and other statistical parameters.
JagadishNayak*et al.*presented a novel method for glaucoma detection using digital fundus images [22]. The RGB components of the images were analyzed and RED and GREEN image components were extracted out for disk and cup respectively.
First morphological operations were applied on both the red and green components of the image.
Second, The standard deviation as well as the threshold values for separating out the disc and the cup from the red and green images was evaluated.
Third, Using the evaluated threshold values the red and green images were converted to binary images to obtain the disk and cup.

S. Kavitha*et al.* proposed a computer aided system for automated detection of glaucoma from fundus images [23]. Detection of Glaucoma involved the measurement of the size and the shape of the Optic cup as well as Neuroretinal rim. The cup and disc areas differ in color, known as pallor. The technique was based on this pallor using K means clustering proposed to differentiate between the cup- to- disc boundary. Along with the shape based features, textural features were also extracted.
The set of features selected by the Genetic algorithm were fed as input to the Adaptive Neuro Fuzzy Inference System (ANFIS) for classification.
The methodology proceeds in following steps:

- Preprocessing: images were pre-processed using the anisotropic diffusion filter in order to eliminate noise
- Detection of Cup and Disk: Optic disc was detected by segmentation methods. The proposed method proceeded by optic cup region detection followed by the erasure of blood vessels.. The method used the difference in pallor to differ the cup-disc boundary
- ANFIS used a learning algorithm to determine the membership function parameters of the fuzzy inference system. It consisted of five layers and a certain number of nodes connected via directional links

Fauzia Khan *et al.* proposed image processing techniques for the early detection and diagnosis of glaucoma [24]. The Optic Disc and Cup were detected by first extracting the V plane from HSV image and then converted to gray scale image. The mean value of the gray scale image was calculated and set as threshold for binary image. For the cup, green plane was taken up and converted to gray scale image. Threshold value for the cup varies as there are gradual changes in the cup color due to which boundary of cup is not clear.

To extract the optic disc from a retinal fundus image J. Liu *et al.* used a variational-level-set method [25]. In case of the optic cup, two methods of color intensity with threshold level set were applied. The results signified potential applicability of these methods for automated screening for early recognition of glaucoma.
There have been previously reported investigations on the segmentation of the disc and cup that determine CD Ratio. The main challenge in the detection of the cup is the high density of vascular architecture across the cup lining as well as the diminished visibility of the cup border compared to the disks'.
The performance of a threshold based level set method and a color-intensity based method were compared for the extraction of the optic cup.
Variational level-set proceeded to extract the optic disc. The extracted contours were smoothened by using direct ellipse fitting to remove the noise in the extracted boundary. The CDRwas then calculated by using the extracted cup and disc dimensions.
Two approaches were evaluated for the segmentation of the optic cup, first using a thresholding approach based on color intensity, and the second one employing level-set approach based on thresholding.
Also in order to extract the disc and cup, a region of interest (ROI) around the disc was first delineated.
Extraction of Neuro Retinal Rim (NRR) area and the Blood Vessels
Physicians look for other features like the shifting of blood vessels towards any of the four sides or the four quadrants of a fundus image. The upper and the lower quadrants are Superior (S) and Inferior (I) respectively. Nasal (N) is the one which is close to the nose and the one towards the temple side is the temporal (T) one. Collectively they are known as ISNT quadrants.

JagadishNayak*et al.*extracted the blood vessels and the Optic Nerve Head (ONH) by using the binary image of the optic disk as a mask on the green component image [22]. The output obtained was the green component with only the optic disk area. Bottom-hat filtering was then used. The resulting image makes the optic nerves prominent within the disk. From the cropped green component image the disk centre was detected by identifying the brightest intensity area. The optic nerve head coordinates were detected by finding the area of brightest intensity.

Fauzia Khan *et al.* extracted the NRR area for the detection of glaucoma [24]. If the ratio of the blood vessel area in the nasal and temporal side is more than the ratio of blood vessel area in the superior and inferior quadrant, then it is Glaucomatous. The optic disc and the cup were extracted separately. NRR was extracted by just applying an AND operation to the binary images of both disc and cup. A mask image of a particular size was applied on extracted NRR image in order to measure the ratio of areas covered by NRR in the ISNT quadrants. The area covered by the white pixels was counted for the evaluating the ISNT Ratio (i.e. the ratio of the blood vessel area in the inferior and superior side to the area in the nasal and temporal side).

Extraction Nerve Fiber Area

RadimKolář*et al.* described a method for glaucoma detection based on fractal dimensions followed by its classification [26]. Two methods for estimating fractal dimensions, which give a different image or tissue description, were proposed. The retinal images were used in which the areas comprising of retinal nerve fibers are examined. The proposed method showed that fractal dimensions can be employed as features for nerve fibers loss detection, which indicates a glaucomatous eye. They proposed new features for Retinal Nerve Fiber (RNF) identification applied to the texture generated by RNF layer.

The first method was an enhancement for fractal dimension evaluation based on 1-D spectrum model. At the origin level, the spectrum of the image sample was 2-D.

The other method used a direct model in 2-D.

These methods gave an estimation of the two features: fractal dimension $FD1$ and $FD2$, dependent upon the spectral parameters that described a selected image sample from two different aspects: the first one as a 1-D process and the second one as a 2-D process.

Extraction of Textural Features

E. A. Essock*et al.* used wavelet transforms in image processing to extract the textural features from the fundus images [27]. In Wavelet Transform, the image is depicted in terms of a frequency of the type of any local region over a specific range of scales. This type of representation helps in the analysis of the features of an image that are independent in size and are distinguished by their own frequency-domain properties. Two types of WT are used, continuous wavelet transforms and discrete wavelet transforms (DWT) in image processing. In this method, DWTwas used to extract features and evaluate discontinuities and abrupt changes held in signals.

In DWT each level of the alteration provides an evaluation of the image at a different resolution, proceeding in its independent rough computation.

In the WFA the fast Fourier transform (FFT) was applied to the discrete coefficients. The resulting Fourier amplitudes were clubbed with the normalized approximated coefficients of the DWT to create a deck of features.

C. Classification

After the preprocessing and the feature extraction the next requisite step that is followed is classifying the subjects or the images as Glaucomatous or normal. Glaucoma classifiers employ input vectors that have contrasting features like Cup-To-Disc Ratio, ISNT Ratio, Nuero-Retinal Rim area.

Most popularly used classifiers for the detection of Glaucoma are:

Naive Bayes Classifier: It directly applies the Baye's rule to determine the probability of a sample belonging to a class [9].

k-Nearest Neighbor Classifier (k-NN): The k-NN does not assume a specific distribution of the data [9].

Support Vector Machine: It determines a maximum-margin that best separates the considered classes [11]. Jorg Meier et al used a probabilistic SVM classifier [14]. ZviaBurgansky*et al.* used five classifiers: linear discriminant analysis, recursive partitioning and regression tree, the generalized additive model including support vector machine generalized linear model [28].

Adaptive Neuro Fuzzy Inference System (ANFIS): S. Kavitha*et al.*used an Adaptive Neuro Fuzzy Inference System for the classification of the subjects or the retinal images into normal and glaucomatous categories. Also the results of this system were compared with the neural network and Support Vector Machine (SVM) Classifier [23].

Proposed Methodology

The proposed method classifies the retinal images as normal or glaucoma suspicious i.e. screens for Glaucoma. It involves:

- Extraction of the Optic Disk and measuring its dimensions
- Extraction of the Optic Cup and measuring its dimensions
- Calculating the ratio of the Cup to Disk dimensions formulated as the CDR value
- ThresholdingCDR which determine whether the subject is normal or suspicious for Glaucomatous.

The methodology provides a simple algorithm for extracting the cup and the disk out from the fundus retinal image by using image processing. The CDR values are used for the screening of the Glaucoma.

Conclusion

This paper presents a review of the digital image processing techniques for the extraction of various features of a Fundus image. A simple methodology for the screening of Glaucoma on the basis ofCDR value has also been proposed. The extraction methods for Optic Disc, Optic Cup, Neuro-Retinal Rim Area and ISNT Quadrants have been reviewed.

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