ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 4, June 2012

A Morphological approach for discrimination between Glaucomatous and Non glaucomatous Eyes by Optic Disc Localization

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Abstract-**A Portion of optic nerve that is visible in the retinal fundus is called the optic disc (OD).Optic disc is one of the vital information in detecting the diseases in the retina by implementing an image processing algorithm. Algorithm focuses on the properties and the characteristics of the optic disc. Optic disc has got its own shape, color, size and intensity used to detect it in the retinal images. The optic disc is the entrance of the optic nerve and the vessels in the retina called blind spot. Blind spot in the retina has the cone cells, rod cells which captures the impulses and convert them into proper images and carry them to the brain. Detection of optic disc is useful in diagnosing the pressure within the skull that causes this disc to bulge forward. The pressure within the eye squeezes off the blood supply, and reduced blood supply starves the retina from nourishment, and ultimately the nerve cells start to die - glaucoma. A novel approach is proposed to investigate the screening performance on the glaucoma disease, and to differentiate the normal and glaucomatous eyes, this screening system is designed. With Cup to disc ratio (C/D), the classification among the normal and the glaucomatous images was found. When the cup to disc is greater than 0.3 (cup to disc> 0.3mm), it is considered as the glaucoma affected eye.**

Index Terms— **Glaucoma, cup to disc ratio, optic disc detection, interface tool, screening system.**

I. INTRODUCTION

Detection of optic disc is an indispensable step in the automatic analysis of digital color fundus images. Optic disc detection is an integral part of the screening system for glaucoma. The retina contains anatomic structures like the vasculature, optic disc, and macula, when the system has located these structures in the image then, these locations will be used as the landmarks for the detection of the symptoms for glaucoma. The optic nerve is the region of the retina where the blood vessels and nerve fibers pass through the sclera. It is sensitive to the changes associated with intraocular pressure associated with glaucoma that may occur asymptomatically and which can be diagnostic and that must be tracked to monitor the progress of treatment.

One of the symptoms of glaucoma is an increase in pressure within the eye. It is caused as a result of blockage of the flow of aqueous humour, a watery fluid produced by the ciliary body. The increase in pressure damages the optic nerve that carries the vital information from the retina to the brain. The damage can be avoided only by treatment that can reduce or prevent further damages. Visually, the damage is observed in the relative areas of the optic disc and the cup within the disc.

The normal optic disc is the site of passage from the eye of more than 1 million axons that connect their retinal ganglion cells. The diameter of the normal optic disc varies from eye to eye. As the nerve fibers die in the patients who were affected by glaucoma, the diameter of the cup within the optic disc gets enlarged. The normal cup to disc ratio is about 0.3 mm, whereas with the glaucoma injury it is increased to more than 0.7 mm. Abnormality detection in retinal fundus images is predicted to play an important role in many real life applications. A fast, accurate and reliable method for abnormality detection in images will help greatly in improving the health care screening process.

The retinal fundus photographs are widely used in the diagnosis and treatment of various eye diseases in clinics. It is also one of the main resources for mass screening of glaucoma. Being able to automatically and quickly process, a large number of fundus images can help the ophthalmologists increase the productivity and efficiency in medical field. Developing an automatic fundus [14] image analyzing and diagnosing system has been the ultimate aim to facilitate the clinical diagnosis.

Extraction of the normal and abnormal features in color fundus images is the fundamental method that is useful for automatic understanding of fundus images. It is concerned with developing automated techniques of generating quantitative descriptions of the retina that might be used in diagnosis and treatment. The automatic determination of the position of distinctive points is an important and intermittent theme in medical image analysis. A wholly automated approach involving computer analysis of fundus images could provide an immediate classification of glaucoma without the specialist opinions.

This article describes about the optic disc location and glaucoma screening system using various methods to pre-process the image to improve the quality and computer based algorithms were employed for the detection of optic disc in the retinal image, and various techniques were used to recognize the important features of glaucoma.

II. LITERATURE SURVEY

In the literature a number of different techniques have been employed to automatically detect the optic disc. In general these techniques apply preprocessing operations, followed by several image processing operations and finally the OD-localization. A preprocessing is for instance the generation of a mask image to determine which area belongs to the actual fundus and which area belongs to the background of the image. Some of the automatic OD- detection methods produce only a point that can be used as the ODcenter.

In [1] Osareh propose a template-based OD-detection. This method uses a color normalization of the fundus image. The template-based OD-detection method assumes the optic disc to be approximately circular and consisting of bright pixels. At first the color images are normalized and then the intensity components from the HSI space are used to create a template and to perform the template matching. The normalization of the color fundus images is performed by applying histogram specification on each color plane (R, G and B). Histogram specification requires one image specifying the preferred histogram of the color plane. The histogram of this image is used to approximate the new histogram of the image to normalize, this way the appearance of the normalized image approaches the appearance of the model image.

In [2], Walter proposes an OD-localization method that applies a threshold to obtain pixels with high intensity values and selects the center of the largest object as the OD-center. The detection of the optic disc is performed on the intensity component from the HSI space. In the intensity image the optic disc is assumed to be the largest brightest part of the image. A simple threshold is applied to obtain a binary image containing parts of the optic disc and perhaps other bright appearing pathologies like exudates. The largest connected object within the threshold image is expected to be a part of the optic disc. The center of this object is selected as the center of the optic disc.

In [3], Barrett proposes a method based on a Hough transform in order to locate the optic disc. The Hough transform technique is able to find geometric shapes in an image. Objects of geometric shapes may be detected by converting the equation of the object into a Hough space parameter equation.

In [4], optic disc is often a bright circular shape at the convergence of the vasculature. This method assumes that the OD -center lies close to a vessel of the vasculature. However, this time the Hough transform is only applied on and close to the vasculature. In order to determine the potential OD-locations the segmentation of the vasculature is required.

In [5] three exploratory processing techniques are described. In the first technique, commonly used in quantitative coronary analysis (QCA), the initial and end points of the vessel (sometimes also the direction and width) are entered manually. Although these algorithms are very accurate, they are unsuitable for real-time retinal image processing since they require manual input and suffer from high computational time, which are not compelling constraints in QCA. In the second technique, the algorithm starts with a manually-entered initial point and an initial direction, and recursively tracks the entire arterial tree using a breadth-first search. This would not be useful for retinal images since the vessels are not necessarily connected, especially in partial views.

III METHOD

A Overall Scheme

Our goal is to detect the blind spot of the retina called optic disc and to identify whether the retina is affected by glaucoma disease or not. Many algorithms were developed for detecting the optic disc in the retinal fundus images. Many algorithms were theoretically good and many methodologies concentrates on the optic disc detection alone. Hence the good interface for disease detection has not been proposed. The proposed system is being the interface between the optic disc detection and the screening system for the glaucoma disease. The following are the various steps involved in detecting the optic disc and identifying the disease in the retinal image. (1)Color conversion for intensity enhancement, (2) grayscale conversion, (3) fast level for multi level thresholding, (4) optic disc identification, (5) morphological operations, (6) optic disc circle measurement, (7) identification of cup to disc ratio, and (8) classification between normal and glaucomatous eyes.

B. Color Conversion for Intensity Enhancement

Color conversion process is the initial process in the image processing. This process facilitates thresholding and used to blur the noise in the image and to smooth the boundaries of the particles to be detected. Pre-processing methods use a small neighborhood of a pixel in an input image to get a new brightness value in the output image. Such pre-processing operations are called also filtration. The image generally will be highly correlated; most of the colors are muted. To overcome this drabness, it is necessary to get more pure colors. So color manipulation is very important as shown in Fig-1.

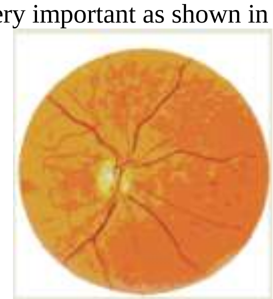

Fig 1: Color conversion for intensity enhancement

C. Grayscale Conversion

The gray scale image should visibly reflect the magnitude of the color contrast. The transformation from color to grayscale is a continuous function. Grayscale is a range of shades of gray without apparent color. The darkest possible shade is black, which is the total absence of transmitted or reflected light This constraint reduces image artifacts, such as false contours in homogeneous image regions. When a pixel in the color image is gray, it will have the same gray level in the grayscale image. This constraint assists in image interpretation by enforcing the usual relationship between gray level and luminance value. Grayscale is best because it produces the result whose brightness is the most perceptually similar to the brightness of the original color image – Fig-2.

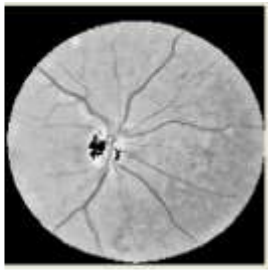

Fig 2: Gray Retinal Fundus Image

D. Fast level for multilevel thresholding

Thresholding is an important technique for image segmentation that tries to identify and extract a target from its background on the basis of the distribution of gray levels or texture in image objects. Otsu's method [7] was one of the better threshold selection methods for general real world images with regard to Uniformity and shape measures. An image is a 2D grayscale intensity function, and contains N pixels with gray levels from 1 to L. In the case of bi- level thresholding of an image, the pixels are divided into two classes, C1 with gray levels [1… t] and C2 with gray levels [t+1… L]. the gray level probability distribution for the two classes is found and the means for the two classes are also found. From the means of the two classes, the mean intensity for the entire image is found. Using discriminant analysis, Otsu defined the between-class variance of the threshold image. For bi-level thresholding, Otsu verified that the optimal threshold is chosen so that the between-class variance is maximized and the maximum variance is chosen as the optimal threshold (Fig-3a).

Optimal Thresholding Methodology: (OTM)

An image is 2Dimensional (2D) gray images and it contains N pixels with the gray levels 1 to L. The probability of gray level i in an image is

$p_i = f_i / N$. Eq.1

The gray level's probability distributions for the two classes C1 and C2 are

$C1 = p_1/w_1(t) \ldots P_t/w_1(t)$ Eq.2

$C2 = p_{t+1}/w_2(t) \ldots p_L/w_2(t)$ Eq.3

$\omega_1(t) = \sum \rho_i$ (for i=1 to t) Eq.4

$\omega_2(t) = \sum \rho_i$ (for i=1 to t+1) Eq.5

Means for the classes C1 and C2 are

$\mu_1 = \sum i \rho_i / \omega_1(t)$ (for i= 1 to t) Eq.6

$\mu_2 = \sum i \rho_i / \omega_2(t)$ (for i= t+1 to L) Eq.7

Let μ_t be the mean intensity for the entire image.

$\Omega_1 \mu_1 + \omega_2 \mu_2 = \mu_t$ Eq.8

Otsu defined the between class variance of the thresholded image

$(\sigma_B)^2 = \omega_1(\mu_1 - \mu_t)^2 + \omega_2(\mu_2 - \mu_t)^2$ Eq.9

Otsu verified that the optimal threshold t* is chosen so that the between class variance is maximized. That is

$t^* = \mathrm{Max}\{(\sigma_B)^2(t)\}$ Eq.10

E. Optic Disc Identification

Once the threshold value is identified using the fast level multi thresholding, the region of interest is identified .The region less than the threshold value is considered as the part1 and the region greater than the threshold value is considered as the part2. Part1 consist of the other region such as blood vessel, fovea, macula etc. Part 2 consist of the optic disc which is the landmark for identifying the disease called glaucoma. In the abnormal images the features of the optic disc vary from the normal retinal images. Hence the features of optic disc such as bright yellowish region, the shape, and the size of the optic disc will not help to identify the land mark region. Hence the fast level multi thresholding is adopted to identify the optic disc both in normal and abnormal images.

F. Morphological Operations

Mathematical morphology can extract important shape characteristics and also remove irrelevant information. Using grey level morphology, the operation can be applied to the intensity or lightness channel. The best method of obtaining a homogeneous OD region by performing grey level morphology. Opening and closing are the morphological operators. Opening smoothes the contour of an object, and eliminates the thin protrusions. Closing tends to smooth sections of contours but, unlike opening, it fuses narrow breaks and eliminates the small hole, and fills the gap in the contour. The closing operation is performed i.e. a dilation to first remove the blood vessels and then an erosion to restore the boundaries to their former position. This can result in some minor inaccuracies, particularly if any boundary concavities are filled by the dilation, but in the main performs very well. The other operation is opening operation is performed i.e. a erosion which is similar to dilation but opposite effect. It removes the pixels from the edges of objects within an image.

Closing Operation

Closing is an important operator from the field of mathematical morphology. Like its dual operator opening, it can be derived from the fundamental operations of erosion and dilation. Like those operators it is normally applied to binary images, although there are gray level versions. Closing is similar in some ways to dilation in that it tends to enlarge the boundaries of foreground (bright) regions in an image (and shrink background color holes in such regions), but it is less destructive of the original boundary shape. As with other morphological operators the exact operation is determined by a structuring element. The effect of the operator is to preserve background regions that have a similar shape to this structuring element, or that can completely contain the structuring element, while eliminating all other regions of background pixels. This operation uses the two functions structuring element T and the input fundus image S

$(S+T) - T$ Eq.11

Opening Operation

Opening is the dual of closing, *i.e.* opening the foreground pixels with a particular structuring element is equivalent to closing the background pixels with the same element. The effect of opening can be quite easily visualized. Imagine taking the structuring element and sliding it around *inside* each foreground region, without changing its orientation. All pixels which can be covered by the structuring element with the structuring element being entirely within the foreground region will be preserved. However, all foreground pixels which cannot be reached by the structuring element without parts of it moving out of the foreground region will be eroded away. After the opening has been carried out, the new boundaries of foreground regions will all be such that the structuring element fits inside them, and so further openings with the same element have no effect.

This operation uses the two functions structuring element T and the input fundus image S

(S - T) + T   Eq.12

G. Structuring Element

All these morphological operators take two pieces of data as input. One is the input image, which may be either binary or grayscale for most of the operators. The other is the structuring element. It is this that determines the precise details of the effect of the operator on the image. The structuring element consists of a pattern specified as the coordinates of a number of discrete points relative to some origin. More complicated elements, such as those used with thinning or grayscale morphological operations may have other pixel values. When a morphological operation is carried out, the origin of the structuring element is typically translated to each pixel position in the image in turn, and then the points within the translated structuring element are compared with the underlying image pixel values. The details of this comparison and the effect of the outcome depend on which morphological operator is being used.

H. Optic Disc Circle Measurement

Fitting circles to given points in the plane is a problem that arises in many application areas, e.g. computer graphics, medical image processing, statistics. Here the least square fitting algorithm is used since the shape of the optic disc is considered as the circle, hence to fit the circle around the optic disc region this algorithm is used. There are several algorithms such as ellipse square fitting algorithm, but it won't suite for the optic disc. Only when the shape of the optic disc is considered as the circle, the radius, diameter, and the cup to disc ratio of the optic disc can be identified and the classification among the images can be made in order to identify the normal and the glaucomatous retinal images (Fig3b).

The parameters used for fitting the circle around the optic disc are as follows;

(1) X- the x-co-ordinate of the center of the circle
(2) Y- the y-co-ordinate of the center of the circle
(3) R- the radius of the circle

Fig 3 (a) Optic disc of the Retinal Fundus Image after Morphological Operation

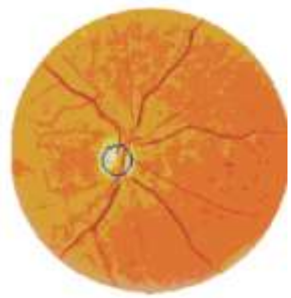

Fig 3(b) Circle fitting Operation on retinal fundus image

I. Cup to Disc Ratio (C/D Ratio)

The optic nerve carries impulses for sight from the retina in the eye to the brain. It is composed of millions of retinal nerve fibers that bundle together and exit to the brain through the optic disc located at the back of the eye. The optic disc has a center portion called the "cup" which is normally quite small in comparison to the entire optic disc. In people with glaucoma damage, because of increased pressure in the eye and/or loss of blood flow to the optic nerve, these nerve fibers begin to die. This causes the cup to become larger in comparison to the optic disc, since the support structure is not there. A cup to disc ratio greater than six- tenths is generally considered to be suspicious for glaucoma. Through periodic photographs of the optic nerve, the ratio of the cup to the disc can be monitored. Glaucoma affects the optic nerve head causing cupping and nerve cell fibers are destroyed. This destruction of healthy nerve fiber cells at the optic nerve causes loss of the peripheral visual field. This cupping is the hallmark sign of glaucoma. A cup -to-disc ratio [5] is critical when evaluating glaucoma. The cup-to-disc ratio is the amount of the entire nerve head that has been cupped out or where glaucoma has caused damage. Using these optic disc measurements, the cup to disc ratio can be calculated. The normal cup to disc ratio i.e. the diameter of the cup divided by the diameter of the whole optic disc is about 0.3 mm. If the ratio varies and if it is larger than 0.3mm then it is suspected that the cup could be getting enlarged. Glaucoma is one of the diseases which is related to the cup to disc ratio parameter. This parameter is helpful in identifying this disease because the glaucoma can

ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 4, June 2012

cause the cup to enlarge.

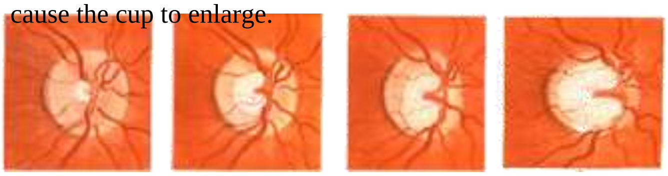

Fig 4: The retinal images affected by the disease glaucoma and the variation in the cup to disc

IV RESULT

The results of the present study lead to a resurgence of the cup-to-disc diameter ratios in the clinical diagnosis of glaucoma if the dependence of the cup-to-disc diameter ratios on the disc size is taken into account. The optic disc size was found to be useful clinically, especially to assist in identifying small glaucomatous optic discs (Fig-4).

In the affected eye, the frequency increases with larger cup/disc ratios, being greatest for C/D of 0.8 to 0.9, whereas in the control, the frequency is highest for C/D values between 0.0 and 0.3 and decreases markedly and progressively for larger C/D values so that the least frequent is 0.8 to 0.9. In the unaffected eye, the frequency distribution of C/D ratio is also different from the control group. Frequency of C/D of 0.0 to 0.1 is very small compared to the control, whereas that of values greater than 0.3 is comparatively greater. These differences in frequency are statistically significant at the 1 per cent level of confidence.

Parameters under study

The fundus images from various datasets were collected and tested against the proposed methodology. Among those images, 100 images were included and analyzed. These 100 images worked exactly against the proposed methodology under three parameters namely sensitivity, specificity, and conformity as shown in Table-1.

a) Sensitivity: It specifies the classification among the normal and glaucomatous retinal fundus images

b) Specificity: It specifies whether the region of interest i.e. the optic disc is exactly normal or affected by the disease called glaucoma

c) Conformity: It specifies the detected optic disc is correct or some other landmark other than the optic disc.

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Sensitivity

Among 100 images, 95 images were correctly sensed and the classification was among normal and the glaucoma affected images.

Specificity

Among 100 images, 89 images were perfectly specified the region of interest i.e. the optic disc. In these 13 images the optic disc were correctly detected both in normal and in the glaucoma affected images.

Conformity

Among 100 images, 92 images shown the detected optic disc is exactly the region of interest or some other land marks

Total images	Sensitivity	Specificity	Conformity
100	95	89	92

Table 1- Parameters under Study

V CONCLUSION

We have presented the method for locating the optic disc in retinal fundus images and to develop methods for separating normal from abnormal images (cases of glaucoma). These would be used in a screening clinic to identify at-risk patients. Images were collected from various sources and the data collected at a range of sites. Methods were developed to separate the normal from the abnormal images. This was done with reasonable success. Whilst the modest success could be attributed to the insensitivity of the analysis, it can also be attributed to the nature of the diagnosis. we are labeling images as being abnormal or not, without recognizing that there is a spectrum of appearances. The tests indicate that the optic disc's appearance is more uniform in the normal and becomes progressively less so as the diseases progress. The screening system acts as an interface tool for the early detection of the glaucoma disease and also could serve as one of the module in the medical diagnosing system in the medical field.

VI FUTURE ENHANCEMENT

Future work can focus on two directions: accumulating further data with respect to the variables for the optic disc as well as for detecting the various other diseases related to the optic disc and developing more robust and accurate methods of processing the screening system in the clinical environment. The modification can be done in such a way that the system should be able to recognize various images from various datasets and the screening system can be used in the clinical environment at large extent. The diabetic retinopathy is also another disease which affects the optic disc region in the retinal fundus image, hence this screening system can be widen for screening this disease and this interface tool will be one of the module in medical diagnosing field in the medical environment.

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