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Detection of Optical nerve head by using Gabor and Mean filter

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Abstract

The fundus images is manually graded by the specialized clinicians which is very time consuming resource intensive process, so the motivation behind the work is to provide immediate detection and characterization of retinal feature before the specialist inspection. Optical nerve head provide an important anatomical landmark in analysis of retinal disease such as Glaucoma detection, measurement of vessel tortuosity and exudates region and for the screening programs for diabetic retinopathy of prematurity in fundus image of eyes. It is also important landmark to identify the other anatomical parts such as fovea, blood vessels (as it provides the starting point) and other task. The ONH is the entry point for the optical nerves and blood vessel supplying the retina so the center is the point of convergence of main blood vessels .It is present on the nasal side of fundus image .In normal eye it is the brightest, slightly oval disk measuring about 2mm in diameter. The approach used here is based on the detection of vascular tree as a source of reference to locate the ONH. Here after doing the basic preprocessing, in order to detect the vascular tree the resultant is fed to the gabor wavelet. Gabor functions are sinusoidally modulated Gaussian functions that provide optimal localization in both the frequency and space domains. The resultant is then applied to local mean filter of size 30X30. The pixel returning highest intensity value is considered as ONH. This method gave 100% result when applied to DRIVE database and 61.7% when applied to STARE database.

Keywords

Optical Nerve Head, Diabetic retinopathy, Gabor filter, STARE, DRIVE, CLAHE, and YIQ.

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1. Introduction

Optical nerve head (ONH) provide an important anatomical landmark in analysis of retinal disease such as Glaucoma detection, measurement of vessel tortuosity and exudates region and for the screening programs for diabetic retinopathy of prematurity in fundus image of eyes (R. A. Hitchings et al[15]). It is also important landmark to identify the other anatomical parts such as fovea, blood vessels (as it provides the starting point) and other task. Glaucoma is the next leading cause of blindness after cataract. As the vision impairment happen slowly glaucoma is known as "silent thief of sight". In glaucoma the shape of Optical nerve head changes due to the loss of retinal nerve fibers. At the age of 50 and younger one person out of 200 gets affected and at the age of 80 one person out of 10 suffers from glaucoma. Only early detection can save the vision (Hitchings et al [16]). Diabetic retinopathy (DR) is another type of eye disease which diabetic patient suffers as complication of diabetes mellitus, it can cause blindness. The blood vessel present in retina swells and the fluid get leaked to the surface of retina or abnormal blood vessel grow on the retina surface .Mostly about 80% people suffering from diabetes for about 10 years have DR . DR can affect both the eyes (Hunter et al[18]).

All the approaches for the existing work in detection of optical nerve head can be divided into three basic blocks

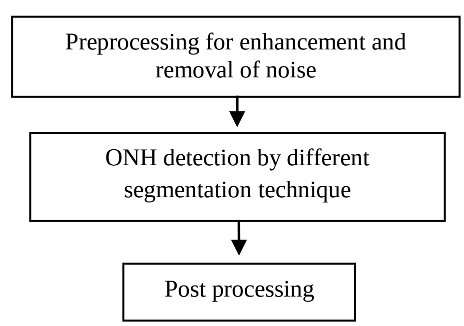

Figure 1: Flow chart of steps for detection of ONH

1.1. Preprocessing

The given RGB color space image is converted into grayscale image; this is done mainly in four ways
(i) Converting the color image directly to grayscale image (Santhi et al [22]).

(ii)Dividing the color image into three grayscale plane corresponding the red green blue colors .The red plane found to be highly saturated and blue plane contain less information so these two plane appear noisy and not useless .Among them the green channel provide highest contrast so many use the green channels as the grayscale input (Sekhar et al [11] , Shivram et al [24], Abdel-Haleim et al [4] , Trucco et al [21] , Miri et al [7] , Welfer et al [8]).

(iii)The blue and red plane may contain some useful information so, instead of considering only green plane so [RGB] color space is converted to YIQ color model and the luminance component is considered(Rangayyan et al [1][2][3] , Hoover et al [5] .

(iv)The [R.GB] color space is converted into HIS color space and the intensity plane is considered in Foracchia et al [10].

It is found in few papers that redplane is considered along with greenplane (Sekhar et al [11]), The lightness component of LAB color space is used in some paper(Lu et al [9]) .

The effective region of interest is calculated by global thresholding in order to reduce the computational overheads(Rangayyan et al [1][2][3] , Abdel-Haleim et al [4] , Miri et al[7] Foracchia et al [10].Sekhar et al [11]) used shade correction to remove slow background variations. The image is processed in order to remove the noise, provide better contrast and equalize the uneven illumination of image . The median filter is used in some case to remove the speckle noise without image blurring (Rangayyan et al [1] , Shivram et al[24] , Trucco et al [21]) . The uneven illumination of background can be compensated by illumination equalization (Abdel-Haleim et al[4] , Hoover at al[5] , Esmaeili et al [19]) .The contrast is enhanced locally by using Contrast Limited Adaptive Histogram Equalization(CLAHE) as done by Esmaeili et al [19] and Shivram et al[24] or some other technique Abdel-Haleim et al [4] . The image is inverted for making the dark blood vessel lighter (Rangayyan et al [1][2][3] , Abdel-Haleim et al [4]). Morphology can be also utilize to preprocess the image in order to remove the artifacts present on the edges as done by Rangayyan et al [1][2][3] . Trucco et al [21] used closing operator followed by opening to remove the blood vessels.

1.2. Segmentation technique

There are three basic approaches basing on which different segmentation technique has been used to detect ONH .They are as follows
Approach by taking into consideration that ONH is the entry point for the optical nerves and blood vessel supplying the retina so the center is the point of convergence of main blood vessels (directional pattern of blood vessels). The blood vessel in the retina is 50-200 µm thick (Welfer et al [8]) .In many paper PCA is used to locate the ONH (Li et al [23]) . Fuzzy convergence image is calculated by Hoover for vascular structure and a hypothesis is calculated and then hypothesis is applied to illumination equalized image and the combined method is used to detection the ONH [5]. Rangayyan et al [2][3] has used gabor filter to trace the blood vessel . Esmaeili et al [19] , Miri et al [7] used curvelet for the detection of blood vessels . Chaudhuri et al [6] used matched filter to detect the blood vessel and directional matched filter is used by Abdel-Haleim et al [4].

Approach by taking into consideration that ONH is the brightest segment in the entire fundus image .In some papers the pixel having the highest 1% grayscale value is considered followed by clustering mechanism (assembling connected neighbors having centroid within a given range) .The cluster is considered only when the number of pixels present is greater than 100 .The eigenvectors of ONH is calculated then projecting the new retinal image to eigenvectors specified space .The distance between them is calculated the point with minimum distance is detected as ONH (Li et al [23]). Trucco et al [21] found the brightest region based on mean region intensity to locate the ONH.

Approach by taking into consideration that ONH is circular in shape with specific round shape measuring about 2mm in diameter .Hough transform is used in many cases to detect the ONH canny or sobel edge detector is used before applying Hough transform as done by Rangayyan et al [1].

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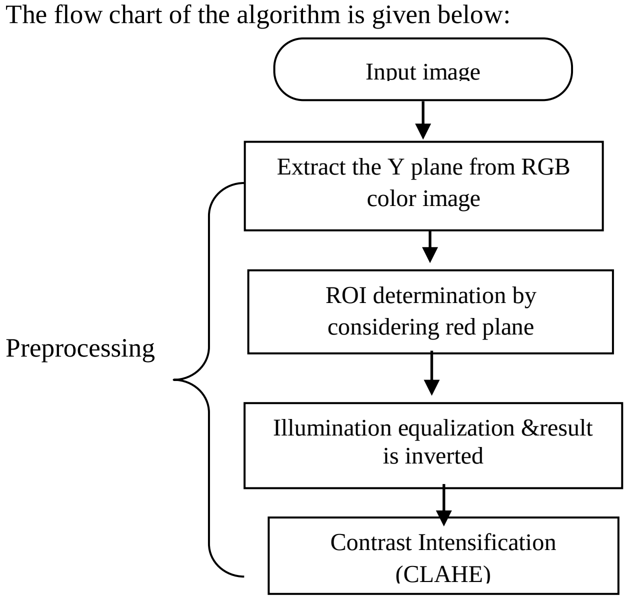
Sometime both the characteristics brightest segment and circular in shape are considered. Morphology can be also utilize to preprocess the image to find the brightest area then Hough transform is applied as done by Sekhar et al[11]. In some paper the result obtained after image morphology is followed by circle fitting method to detect ONH (Santhi et al[22]) , In Lu et al [9] line operator is constructed to detect the circular bright structure , based on minimum/maximum variation.

1.3. Postpreprocessing technique used

In some paper after getting the brightest region in order to exclude the exudates a mean filter of size [NXN] is used and the pixel having the highest mean value is considered (Shivram et al [24]). Esmaeili et al [19]) on getting of strongest edge map, a window of size M XN is appliedon it, with M=5 and N=10. The values of M and N are chosen because of structure of vessels around OD. Rangayyan et al [2] used phase portrait to find the centroid of optical nerve head.

2. My Work

This paper was highly motivated by the two methods Rangayyan et al [2] and Abdel-Haleim et al [4]. The paper is divided into two parts, first part describes the pre-processing part and second part is the segmentation technique used. The characteristic of ONH used here is that all the blood vessel to ONH and the thickness of blood is more in ONH and gradually become thinner as it goes away from ONH. The flow chart of the algorithm is given below:



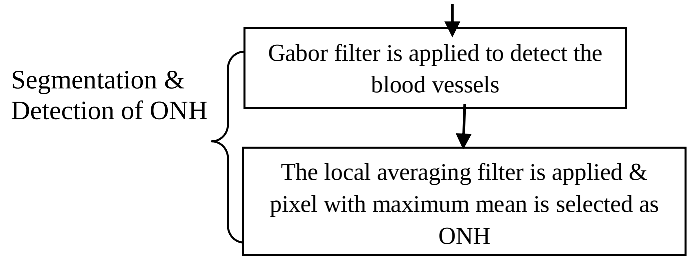


Figure 2: Flow chart of steps for detection of ONH in my work

2.1. Preprocessing

The image is converted from [RGB] color space to YIQ color space and then the luminance component is considered , instead of green component as the blue and red plane may contain some useful information .Each (red, green, blue) image was normalized to the range[0, 1] .

$$Y=0.299R+0.587G+0.114B \quad (1)$$

Mask generation is required so that the computational overhead can be reduced. Effective region of each image obtained by global thresholding (found experimentally) the red plane of the input image by 25/255 for DRIVE database and 31/255 for STARE database. And then the morphological operators (opening, closing, and erosion) were applied respectively (to the result of the preceding step to remove small object that may leave inside) using a 3X3 square kernel to give the final ROI mask. The illumination in retinal images is non-uniform due to the variation of the retina response or the non-uniformity of the imaging system. Uneven illumination negatively affects the OD detection .So, illumination Equalization is done by given equation as done by

$$Ieq(r,c) = I(r,c) + m - \bar{I}_w(r,c) \quad (2)$$

$I(r,c)$ is intensity value at point (r,c), m is the average intensity desired, $\bar{I}_w(r,c)$is mean intensity (the local average intensity) of pixels with in a window of 40x40 . It is then inverted in order to provide better contrast to blood vessel. Contrast Intensification is done by applying CLAHE.

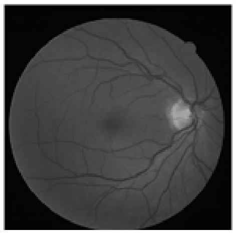


Figure 3: Y plane obtain from 02_test.tif (DRIVE)

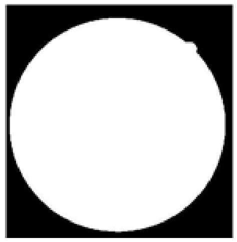


Figure 4: ROI obtain from 02_test.tif (DRIVE)

Figure 5: Illumination equalized 02_test.tif(DRIVE)

Figure 6: Contrast intensification 02_test.tif(DRIVE)

2.2. Segmentation & Detection of ONH

Then ONH is detected and the approach used here is based on the detection of vascular tree as a source of reference to locate the ONH (J.J. Staal et al [20]). This characteristic is chosen as the blood vessel tend to not be affected by the diabetic signs and can be detected even such sign exist in the image. Gabor filters to detect the blood vessel. Gabor functions are sinusoidal modulated Gaussian functions that provide optimal localization in both the frequency and space domains; a significant amount of research has been conducted on the use of Gabor functions or filters for segmentation, analysis, and discrimination of various types of texture (JVB Soares et al [14]). The most important properties are related to invariance to illumination, rotation, scale, and translation. Gabor is a efficient low-level oriented edge and texture discriminators along with been sensitive to different frequencies and scale information. The real Gabor filter kernel oriented at the angle θ = -π may be formulated as done by Chang et al [17] and Rangayyan et al [2].

$$g(x,y) = \frac{1}{2\pi\sigma_x}\exp[-\frac{1}{2}(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2})]\cos(2\pi f_o x)$$
(3)

σ_x and σ_y are the standard deviation values in the x and y directions, and f_o is the frequency of the modulating sinusoid. Kernels at other angles are obtained by rotating the mother wavelet. We use a set of 180 kernels, with angles spaced evenly over the range [-π/2,π/2].

Gabor filters may be used as line detectors. The parameters namely σ_x, σ_y, and f_o, need to be specified by taking into account the size of the lines or curvilinear structures to be detected. Let τ be the thickness of the line detector. This parameter is related to σ_x and f_o as follows

- The amplitude of the exponential (Gaussian) term in Equation is reduced to one half of its maximum at x = τ /2 and y = 0; therefore, σ_x = τ /(2√2 ln 2) = τ /2.35.
- The cosine term has a period of τ; hence, f_o = 1/ τ.
- The value of σ_y could be defined as $\sigma_y = l\sigma_x$, where l determines the elongation of the Gabor filter in the orientation direction, with respect to its thickness. In the parameters for Gabor filters were specified as τ = 8 pixels and l = 2.9 in the present work (Rangayyan etal [2]).

For each image, by selecting the orientation strength for each pixel the magnitude response was composed. The parameters listed above were determined by experimentation with a number of images from the DRIVE and STARE datasets ([12] [13]), and by taking into consideration the average thickness of the blood vessels in the retina.

The blood vessel can be detected if the maximum response is considered as the magnitude and then the resultant is threshold by considering the pixel with 50% highest intensity. The Gabor filter introduce edge artifacts so in order to remove these noise ,the output obtained from Gabor filter is multiplied with the eroded mask generated before. The structuring element used is disk shape of size 20.

A window of size NXN is applied and where the mean is maxed that point is detected as centroid of the optical nerve head (Shivram et al [24] , Esmaeili et al [19]). This filter performs spatial filtering on each individual pixel in an image using the grey level values in a square or rectangular window surrounding each pixel. The average filter computes the sum of all pixels in the filter window and then divides the sum by the number of pixels in the filter window .As can seen from the output of Gabor filter the entire output image is dark but only the blood vessels is having high intensity and the area of optical nerve head has highest intensity. Thus a running window of size 30×30 is applied on the image .The pixel bearing the maximum mean value is considered as the center point of Optical nerve head .The window size is taken 30 considering the optical cup diameter which is 40 pixels.

Figure 7: Maximum Response of 02_test.tif (DRIVE)

Figure 8: Blood vessels of 02_test.tif

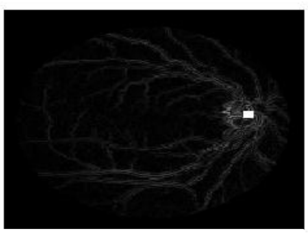


Figure 9: Detected ONH of 02_test.tif (DRIVE)

3. Result

The result is considered successful if the detected ONH center is positioned within 60 pixels of manually identified center. The Euclidean distance between the detected center and the corresponding center marked manually was computed in pixels.

For DRIVE database the ONH was detected correctly in all of the 40 DRIVE dataset images (a 100% success rate) using the proposed method .The average distance between the estimated and the manually identified ONH centers was 22 pixels .

For STARE database the ONH was detected correctly in 50 image of the 81 images dataset images (a 61.7% success rate) using the proposed method .The average distance between the estimated and the manually identified ONH centers was 32 pixels. This is mention in table.1.

The execution time obtained on Intel Pentium Dual-core, 2-GHz, 1.96GB RAM, Matlab version R2011b. Software package used here is MATLAB a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation, was the primary tool utilized to develop the algorithms.

4. Discussion

The above method had given very good result when applied on DRIVE database but failed badly on STARE database due to the following reason. The appearance of the ONH in the images in the STARE dataset varies significantly due to various types of retinal pathology. Contrast at the centre of retinal images tended to be of good quality but diminished towards the periphery and Preprocessing of the fundus data either removes or flags the aforementioned interferences. So if the ONH is present in the periphery it could not be detected .Inadequate illumination can cause a significant proportion of images to be of such poor quality as to interfere with analysis.

The ONH detection procedure is based on the fact that all the blood vessel convergence to ONH and the thickness of blood vessel is more at ONH as compare to the periphery but in some images of STARE database the converging point is not visible and in some image the blood appears thicker in other area as compared to ONH.

More over as (Shivram et al[24]) in diabetic retinopathy, the fine vessels on the surface of the retina become damaged, a condition that can be treated by laser surgery. The blood vessels have lower reflectance compared to other retinal surfaces.

5. Conclusion and Future scope

The proposed method perform very well when applied to DRIVE database but fail poorly on STARE due to the factors that STARE-images with many different pathologies, magnifications and uneven illumination, results are not very good. Several images in the STARE database do not contain the full region of the ONH.

Further studies are required to incorporate additional characteristics of the ONH to improve the efficiency of detection, especially in the case of images of retina affected by pathology.

The performance of a method increases if more optic disc properties are taken into account.
As the proposed method do not segment the ONH, the region growing algorithm can be used taking the found co-ordinate as seed point to segment and find the region of ONH taking new centroid as the center.

Instead of using orientation strength for finding the blood vessel maximum response of pixel and an adaptive thresholding can be used for a better result (Rangayyan et al[2])., the thresholding process used by santhi et al [22] can be beneficial .

As there is less work done in detecting fovea so, this work can be extended to detect fovea and macular region.

Table 1: Comparation table for the two databases

	Computational Time	**Mean Distance**	**Maximum Distance**	**Minimum Distance**	**No. of Correctdetection**	**Success rate**
STARE	2.1 min	32	59	11	51	61.7%
DRIVE	2.2 min	22	45	6	40	100%

Table 2: Comparing the results of different method taking 60 pixel as threshold value

Optical Nerve Head Detection methods	**DRIVE Databases**	**STARE Databases**	**Other Databases**	**Average Computational time**	**System Enviroment**
Youssif et al. (matched filter) [3]	100%	98.77%		3.5 mins for applying only Matched filters	Centrino 1.7 , 2-MHz,512Mb RAM **Matlab**
Sekhar et al [11] Hough transform	94.7%.	--------------	--------------	--------------	--------------
Hoover et al [5](Fuzzy Convergence)		89%	--------------	--------------	--------------
Rangayyan et al [1] (Hough transform)	90%	44.4%	--------------	-------	P-Core 2 Duo , 2.5-GHz,1.96 GB RAM **Matlab**
Rangayyan et al(gabor & phase portraits)	100%	61.7%	--------------	38 min	P-Core 2 Duo , 2.5-GHz,1.96 GB RAM **Matlab**
Present work(gabor and mean filter)	100%	64.1%	--------------	2.3 min	P-Dual-core , 2-GHz,1.96GB RAM **Matlab**

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