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Optic Disc Localization by Blood Vessel Enhancement Using Frangii Filter.

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ABSTRACT

This paper suggests method for optical disc localization in retinal images that is more effective and reliable than other methods. The algorithm starts with new blood vessel enhancement by using Frangii integral filter .This in turn combined with morphological operators for detection of four main blood vessels oriented along 0 °,45°,90°,135° respectively .All of these vessel are having essential information for initial optic disc localization ,where we acquire two images that are divided in horizontal or vertical orientations . Every division is averaged which creates 2D step function and cumulative sum of those fields is done resulting in initial optic disc localization Final disc localization is done by vessel convergence algorithm. optical disc was localized with accuracy of 100% with computation time of 8.97 seconds.

Keywords: optic disc, blood vessel, Frangii filter

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INTRODUCTION

Optical disc is most important retinal parts for detection. Under normal conditions, optical disc appears to be circular yellowish disk, that is brighter than surroundings .It is region from which retinal veins and arteries come out and spread, covering retina [1].corresponding changes in shape, color, depth help for detecting diseases associated with OD for ex: Glaucoma, Neo vascularization on disc and papilledema[2][3].Also it helps as a reference point for detection of other diseases like Fovea and retinal vasculature[1],[4]. Many methods are proposed for detecting OD, which are basically divided into two approaches: Appearance-based and Model based methods [5].Appearance based depends on shape characters and fact is that OD is brighter region of retinal images. Examples of this approach are given in [6]-[9].these methods usually fail in presence of diseased signs and poor quality of images.

Model based methods use the information of vessel and based on thing that vessel originate from OD. This is most effective in presence of images with retinal diseases .Examples of this approach are geometric model proposed by Foracchia et al [1],in which retinal blood vessels are assumed as two parabolas ,in which vertex is located in OD position .Fuzzy convergence is voting algorithm developed by Hoover et al[10], in which originating vessel map convergence point near OD center is determined. Kande et al[11] proposed for identifying region having most vessel branches ,and further OD localization .Youssif et al[4] and Frank terHaar[12] proposed for fitting of vascular orientations on directional model ,where OD located where matching is maximum .Tobin et al[13] proposed for segmenting retinal vasculature and considered several OD and vessel properties .Mahfouz et al.[5] developed a technique where two projections of certain image features the encode the X and Y coordinates of the OD are obtained. Lu proposed a circular transformation designed to capture both the circular shape of the OD and the image variations across the OD boundary [14] Lu et al also proposed a line operator designed to capture

Circular brightness structures [15] Welfer et al [16] proposed an image adaptive method based on a vascular structure model using morphological operators to detect the OD region. Abramoff et al[17]used KNN regression to build a regression model of the OD position.

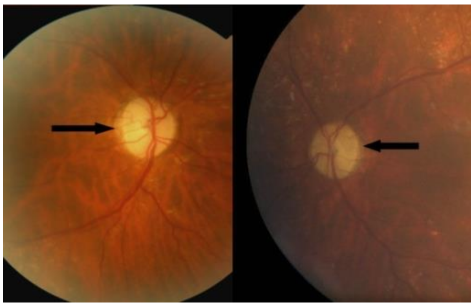


FIG.1.Arrow Mark Indicating OD

PROPOSED METHOD

This method consists of several steps. In the first step red channel component of each RGB retinal images is selected because it provides best contrast and the most relevant visual information[20].Resizing of this image is performed because this method is tested in different data sets and we need to maintain the coherence of parameters. In the next step a binary mask BW is created based on the method proposed by Haar [12].A threshold is applied red channel component followed by morphological operations .Only the BW white pixels are consider for further calculations .A new vessel enhancement is proposed.

Vessel Enhancement

It is a technique to improve visualization of images. For this vessel enhancement we use Frangii filter. Frangii et al [4].proposed a multi-scale vessel technique for assigning values from 0 to 1 to each point of an image .This assigned value reflects the confidence of a point being inside a vessel. In 3D images,for a single scale σs,a response at a point x is calculated as

$$F_\sigma^{3d}(x) = \begin{cases} 0 \;\; if\ \lambda_2 \geq 0\ or\ \lambda_3 \geq 0, \\ \left(1 - e^{-\frac{R^2}{2\alpha^2}}\right) e^{-\frac{R^2}{2\beta^2}} \left(1 - e^{-\frac{s^2}{2c^2}}\right) else \end{cases}$$

Where $\lambda_i s$ are eigen values of Hessian matrix H(x), $R_\alpha = |\lambda_2|/|\lambda_3|$, $R_b = |\lambda_1| \sqrt[2]{|\lambda_2 \lambda_3|}$,

S= ($\sqrt[2]{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}$), α,β,c are constant normalization factors .For 2D Images it can be developed as

$$F_\sigma^{2D}(x) = \begin{cases} 0 \;\; if\ \lambda_2 \geq 0 \\ e^{-\frac{R^2}{2\beta^2}} \left(1 - e^{-\frac{s^2}{2c^2}}\right) otherwise \end{cases}$$

Where $R_b = |\lambda_1|/|\lambda_2|$ and S = ($\sqrt[2]{\lambda_1^2 + \lambda_2^2}$)

We use frangi's vessel enhancement due to its good performance .Frangi's method is similar to the concept of normalized derivatives proposed by Lindeberg to deal with multi scale normalization[23].

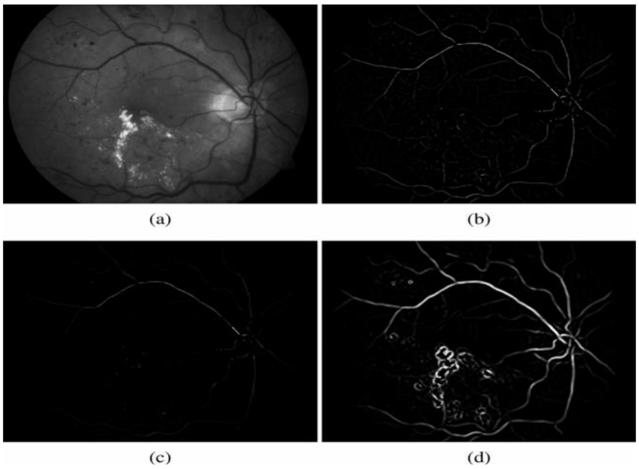


FIG.2.Vessel Enhancement Examples. (a) Retinal image. (b) Result of the proposed Vessel Enhancement V.(c) Result of proposed Weighted Vessel Enhancement.(d) Result of Vessel Enhancement proposed by Frangi.

Four Main Vessels orientation

The retinal blood vessels originate from optic disc vertically and spreadout horizontally[5].Even though other regions in the retina are having vertical vessels they are thinner than vessels around the OD. In between the horizontal and vertical directions vessels are mainly oblique(approximately 45°and 135°)[4].Morphological operators help for determining the four main blood vessel orientations α={0°,45°,90°,135°} [25].The morphological opening of τ by a line structuring element S with an angle θ and a length l, can be defined as

$$\gamma = \tau * s_l^\theta$$

The orientation vessel enhancement in the α orientation is defined as the summation of the maxima obtained for each l value ,with

$$\gamma^\alpha = \sum_{k=1}^{5} \max_{\forall\theta}\left(\tau * s_{5k}^\theta\right)$$

For each α={0°,45°,90°,135°},the following θ values are used specifically:

$\gamma^{0^\circ}, \theta = \{0^\circ, 15^\circ, 30^\circ, 45^\circ, 135^\circ, 150^\circ, 165^\circ\}$
$\gamma^{45^\circ}, \theta = \{30^\circ, 40^\circ, 50^\circ, 60^\circ\}$
$\gamma^{90^\circ}, \theta = \{45^\circ, 60^\circ, 75^\circ, 90^\circ, 105^\circ, 120^\circ, 135^\circ\}$
$\gamma^{135^\circ}, \theta = \{120^\circ, 130^\circ, 140^\circ, 150^\circ\}$

Therefore by defining minimum length values of these five pixels, we can avoid lesions.

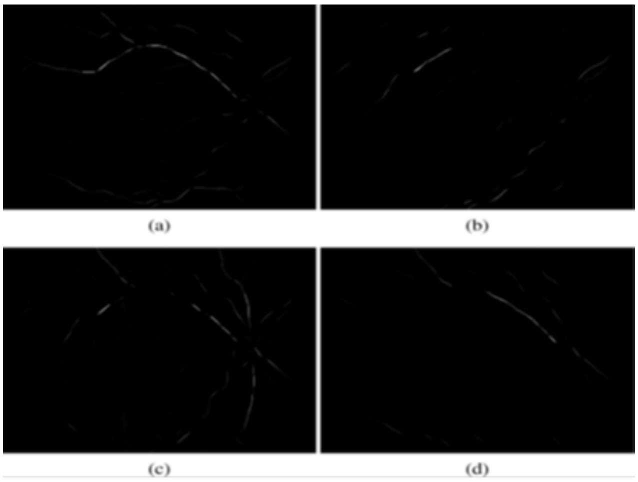


FIG. 3.Four Main Vessels Orientations for the single retinal image (a)γ^{0° (b)γ^{45°(c)γ^{90° and (d)γ^{135°.

Initial OD Detection:

Orientation vessel enhancement functions γ^{α} will provide all essential information for determining initial OD detection designated by (p_x, p_y).For calculating these horizontal and vertical coordinates are found out separately. For finding out these two functions are created by equations:

$$f_1 = \gamma^{0^\circ} - \gamma^{90^\circ}$$
$$f_2 = \gamma^{90^\circ} + \gamma^{45^\circ} + \gamma^{135^\circ}$$

Even though vessels emerging from OD have vertical orientation, they can exhibit certain variation. This situation arises when vessels branch out horizontally also. In order to improve reliability we need to consider horizontal and vertical orientations along with oblique orientations. The difference as shown above help in determination of horizontal coordinatep_x whereas for determining vertical coordinate p_y we use vertical and oblique orientations. The function $f_1(x, y)$with domain [1,N]×[1,M],where N,M are respectively number of rows and columns is d-times subdivided in vertical direction, creating r_i(i=1,…,d+1),equally disjoint regions. Following a 2-D step function $\emptyset_U^d(f_1)$ is defined as

$$\emptyset_U^d(f_1) = \bigcup_{i=1}^{d+1} \frac{\sum\sum_{\forall(x,y)\epsilon(r_i \wedge BW} f_1(x, y)}{\sum\sum_{\forall(x,y)\epsilon r_i} BW}$$

Where BW is binary mask, d is the number of divisions and U indicates vertical, indicates orientation of divisions.$\emptyset_U^d(f_1)$ performs average of $f_1(x, y)$ at each vertical region r_i.

Values ε, ϵ are respectively maximum and minimum number of divisions. For suppressing abrupt changes from cumulative sum fields Gaussian filters are used.

Next $f_1(x, y)$ is subdivided and cumulative sum fields of corresponding 2-D step functions $\emptyset_U^d(f_1)$ is done with following equation

$$\Phi_U(f_1) = \sum_{d=\epsilon}^{\epsilon} \emptyset_U^d(f_1)$$

In large number of retinal images, (p_x, p_y) determines correct localization of OD, but in few cases it may be slightly outside OD region. Previously described approach is having few similarities followed by Mahfouz et al [5].In this method we are using different vessel detector and using vessels oblique orientations.

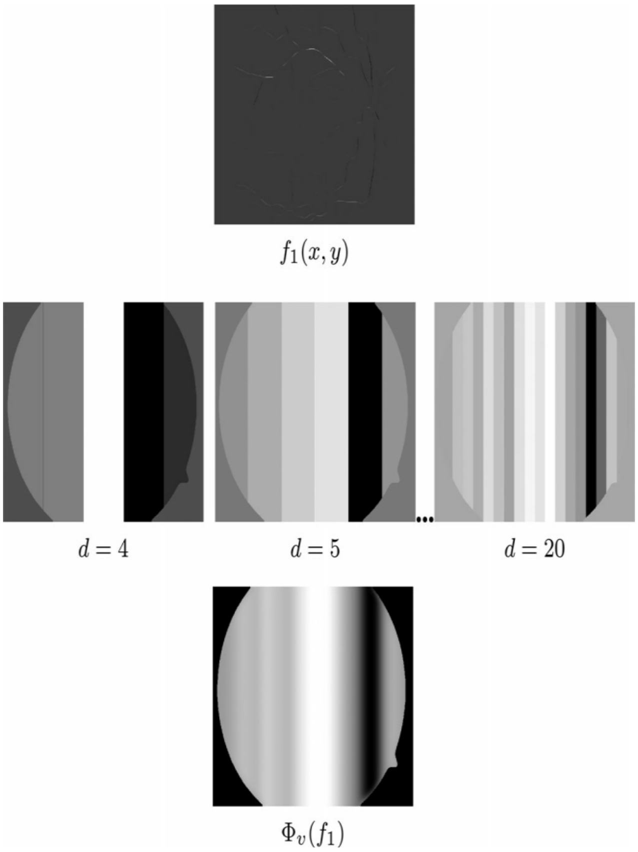


FIG.4.Computation of the verticalfield ∅(f1)

Final Localization of OD:

This is final step of OD localization. For achieving this technique based on two features was developed: high convergence of vessels and high intensity values. Firstly, vessel convergence regions are defined. Maximum point of intensity inside convergence regions, indicated as (c_x, c_y) is calculated in that regionand maximum intensity point is located as (b_x, b_y) is calculated.Our main aim is that to lead initial OD localization (p_x, p_y) to nearby localization of higher vessel convergence (c_x, c_y) and higher intensity(b_x, b_y).To evaluate orientation at every pixel, a structure tensor is used referred by van Vliet et al [26] and Breu et al[27].This yields good characterization of orientations and neighborhoods .Final OD position is found by averaging (p_x, p_y),(c_x, c_y),(b_x, b_y)[1].

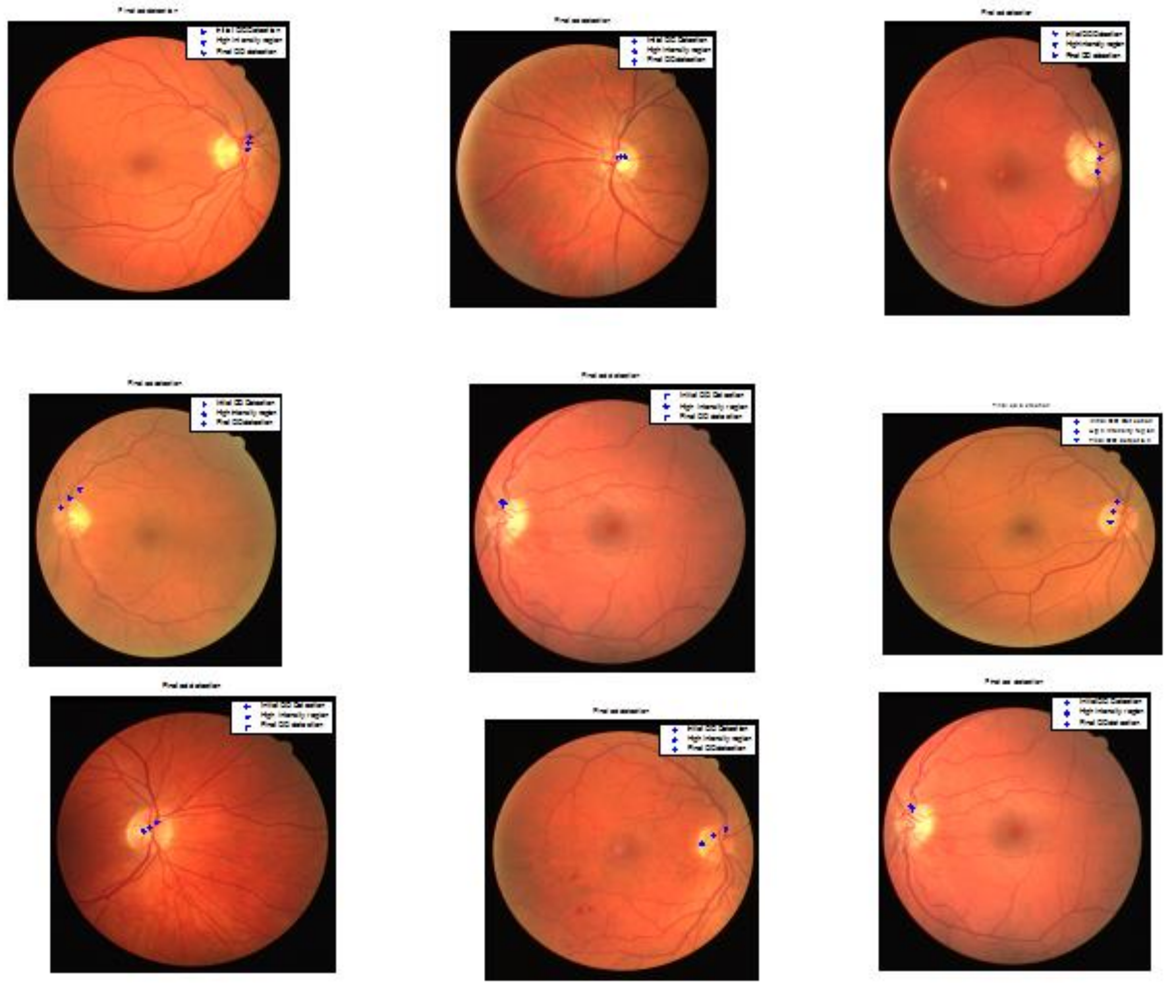
RESULTS

The MATLAB algorithm of this method was implemented. The OD localization accuracy of 99.17% was obtained for the retinal images with a computation time of 8.97 seconds and OD center error is reduced to 7.18 pixels

Image parame—ters	Foracchia [1]	Youssif [4]	Welfer [16]	Hoover [10]	Mahfouz [5]	Yu [2]	Lu [15]	Lu [14]	Haar [12]	Aquino [36]	Lowell [37]	Tobin [13]	Ramakanth [18]	Abramoff [17]	Soares	Our method
Time	2 min	3.5 min	7.89 s	4 min	0.65 s	4.7 s	nr	5 s	Nr	1.67 s	Nr	Nr	0.2 s	30 s	18.34 s	8.97 s
OD Center Error	nr	23 pix	Nr	29 pix	nr	nr	nr	Nr	Nr	nr	Nr	Nr	nr	9.75 pix	26.52 pix	7.18 pix
Accuracy	97.53%	99.17 %	98.45 %	88.89 %	97.06%	99.08 %	97.04 %	99.50 %	97.79 %	98.83 %	99 %	80.80 %	99.03 %	99.90%	99.15 %	99.17%

nr- Not reported TABLE SHOWING: Optic Disc Localization Methods Comparison

IMAGES ALONG WITH THEIR OPTIC DISCS:



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