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POLAR TRANSFORM FOR SEGMENTATION OF OPTIC DISK IN FUNDUS IMAGES

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Abstract: A method to detect and segment optic disk (OD) in fundus eye images using polar transform present is presented in this paper. Optic disk is the small blind spot on the surface of the retina which generally appears elliptical in shape. Blood vessels present in the retina converge towards the optic disk and may lead to segmentation errors because the pixels representing the blood vessels may be misinterpreted as the pixels belonging to the optic disk. As the OD region is highly pronounced in the red channel image, it is alone considered in this work for segmenting the OD. As an additional step the morphological operations are applied to suppress the blood vessels further. Since the optic disk has big similarities with the spiral coordinate system, in this paper adaptive polar transform is proposed to detect the optic disk pixels and the subsequently the OD region is approximated by fitting an eclipse. The proposed algorithm comprises of three steps. (1) Pre-processing, (2) Forward and inverse polar transformation, (3) Optic Disk detection. The proposed methodology is tested on two different publicly available datasets namely DRIVE and STARE datasets.

Keywords: Optic disk, fundus image, segmentation, polar transforms, adaptive thresholding, morphological operations.

1. INTRODUCTION

India is experiencing an unprecedented increase in people being affected by non-communicable diseases due to the substantial drift in life style and food habits [1]. The life style changes have not only affected our country, but globally and non-communicable diseases accounts for 80% of the global burden of disease. [2] Though cancer and cardiac abnormalities contribute to mortality, blindness due to Diabetic Retinopathy and glaucoma has resulted in chronic disability [3].

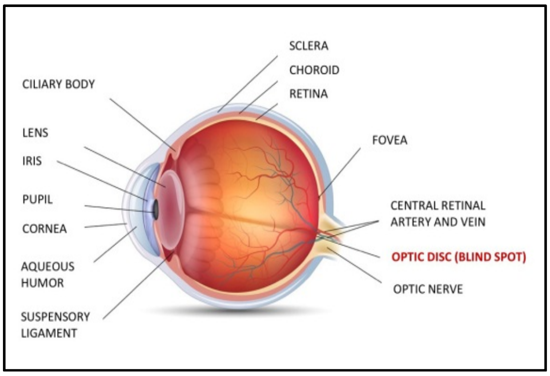
A. Fundus Imaging and Eye related Diseases

The retina is the innermost layer of the eye. It consists of photoreceptors that convert the incoming light into a neural signal which is further processed in the visual cortex of the brain [4]. Fundus imaging is based on making the light incident on the retina and then projecting the reflected light onto an imaging plane. Fundus imaging produced 2D representation of the eye. Fundus imaging is widely used by ophthalmologists in localization and segmentation of retinal structures and segmentation of various eye related abnormalities namely blood vessel related abnormalities, pigment epithelium related abnormalities and choroid related abnormalities.

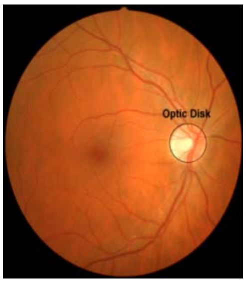
Many important diseases manifest themselves in the retina. Most important of include diabetic retinopathy and Glaucoma. **Diabetic retinopathy (DR)** is a complication of diabetes mellitus and the second most common cause of blindness and visual loss. Studies indicate that by periodic screening and early diagnosis visual loss in DR patients can be prevented [5]. The optic nerves get damagedwhen the pressure inside the eye suddenly increases and this condition is called **glaucoma** which may due to blindness [6]. The characteristics of glaucoma is cupping of the optic disc. Ophthalmologists use the cup-to-disc ratio which is the ratio of the optic disc cup and the neuro-retinal rim surface areas for assessing the presence and progression of glaucoma[10]. So, in creating a CAD system for the detection of retinal diseases, the first part would be to accurately segment the optic disk and optic cup. This paper focuses on the methodology related to optic disk localization and segmentation.

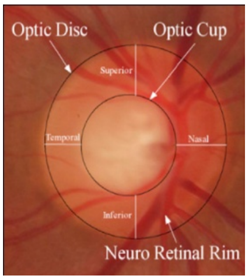
B. Optic Disk

Fig.1 (a) shows the anatomy of the human eye. The optic disk shown in Fig. 1(b) is a bright region generally elliptical in shape with all the blood vessels converging towards its center [7]. The optic cup shown in Fig. 1 (c) is the white, cup-like area in the center of the optic disc. While creating an automated system for retinal diseases, the presence of Optic Disk sometimes leads to misclassification or false positives as pathologies like exudates and lesions also appear elliptical in shape [8].



(a)





(b) (c)

Fig. 1 (a) Human Eye, (b) Fundus Retinal Image, (c) Optic Disk and Optic Cup

Poor illumination conditions during image acquisition leads to issues such as boundary artifacts, missing edges and poor textural contrast and all these makes accurate detection and segmentation of the OD quite difficult [9] . Further the OD boundary cannot be generalized as the converging blood vessels results in a fused boundary. The major objective of the proposed work is the automatic detection and segmentation of optic disc (OD) region in retina. The proposed system can be used in eye clinics and hospitals to detect and diagnose retinal diseases, and it can be used as a second reader to assist ophthalmologist in diagnosing retinal diseases.

2. PREVIOUS STUDY

Mathematical morphology was employed by the authors in [11] to model the vascular structures present in the retinal image. Green channel image was used to detect the blood vessels and next watershed transform was applied to find the OD position. The authors in [12] used three different methods namely maximum difference, maximum variance and low pass method to identify the likely OD candidate pixels. Then a voting scheme was proposed to select the best candidate pixels obtained out of the three methods. The results showed that maximum variance method was efficient in detecting the correct OD pixels and then circular Hough transform was used to compute the circular approximation of the OD region. The proposed method was tested on MESSIDOR dataset and the result is promising.
As the pre-processing step the authors in [13] first employed Hough transform as an initial level set to approximate the active contours of the OD and then in order to reduce the effect of contrast variance homomorphic filter was applied. Subsequently in order to obtain the exact OD boundary the authors employed selective binary and Gaussian filtering regularized level set [19]. The authors in [14] tried to fit several circled around the OD region using regression based method and then bilinear filtering was used to obtain to select the probable circles that best fits the OD region. The circle with maximum correlation coefficient is considered to exactly approximate the OD region. However the method does not work well on poor quality images.
ORIGA dataset with peripapillary atrophy (PPA) was employed in [15] the authors proposed elimination of PPA which sometime result in improper segmentation of OD to prevent misdetection of PPA as OD the area within the detected disc boundary divided into quarters. Though the proposed method was successful in detecting OD and overlapping a error of 10% as been reported which warrants further studies. The authors in [16] localized the OD based on 1D projection to identified the vertical location of the OD the edge gradient around the OD is calculated and for obtaining the horizontal location of the OD vascular scatter degree is calculated region of interest. The results were tested on four publically available datasets and performance is noticeable.
The authors in [17] delineated the blood vessels using morphological operations before applying the circle of Hough transform in order to localize the OD region. Next to determine the OD boundary polar transform and adaptive thresholding was carried out. This helps in extracting the pixels of the OD region, which is then approximated by fitting an eclipse around the OD boundary in the retinal image. In [18] the authors employed retinex algorithm [20] to normalize the image before applying their proposed optic disc segmentation algorithm. This aided in decreasing the contrast variability of the retinal images. The OD segmentation algorithm was based on fuzzy Hough transform and was tested on the VARIA dataset. The study was carried out only on normal retinal images and future studies are needed to address this limitation

3. METHODOLOGY AND RESULTS

In this work the automatic detection and segmentation of optic disc (OD) region in retina is carried out using polar transform. Fig 2 shows the block diagram of the proposed segmentation method which comprises of three steps. (1) Pre-processing, (2) Forward and inverse polar transformation, (3) Optic Disk detection. This section also gives the results of the proposed optic disk segmentation method. The two publicly available retinal image datasets such as DRIVE and STARE which consists of both normal and abnormal retinal images are used to test the efficacy of the proposed segmentation method.

A. Pre-processing

As the OD region is highly pronounced in the red channel image, it is alone considered in this work for segmenting the OD. Then, speckle noise present if any, is eliminated by applying a 3X3 median filter. Blood vessels present in the retina converge towards the optic disk and these vessels also appear bright as the optic disk region. This may lead to segmentation errors because the pixels representing the blood vessels may be misinterpreted as the pixels belonging to the optic disk. So, morphological operations are applied to blur the blood vessels further. Next the region of interest, which is rectangular region around the optic disk region, is selected for subsequent processing. The pre-processing results are shown in Fig. 3.

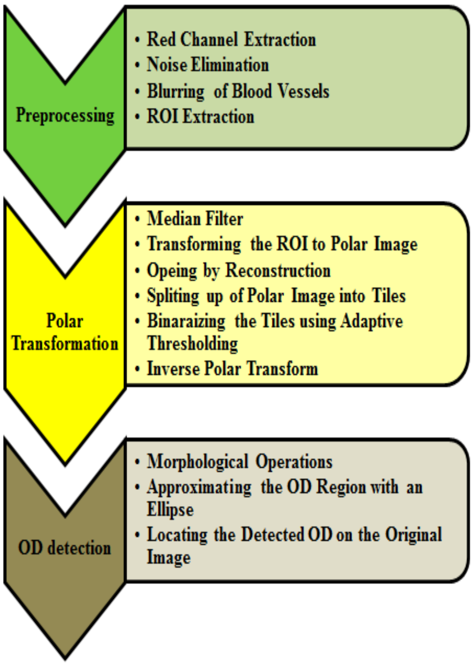


Fig. 2 Block diagram of the proposed optic disk segmentation method

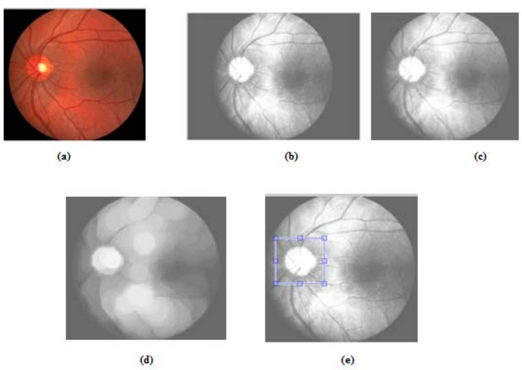


Fig. 3 (a) Original Image (b) Filter Image (c) Red Channel Image (d) ROI Extraction (e) Vessel Blur Image

B. Polar Transformation

Since the optic disk has big similarities with the spiral coordinate system, in this paper log-polar transform (LPT) is proposed to detect the optic disk pixels.

Log-Polar Transform (LPT) [21] is a widely used method to convert an image from the Cartesian coordinates (x, y) to the log-polar coordinates (ρ, θ) using the expressions given in Eqn. 1 and Eqn. 2.

$$\rho = \log_{base\sqrt{(x-x_c)^2+(y-y_c)^2}} \quad (1)$$

$$\theta = \tan^{-1}\frac{y-y_c}{x-x_c} \quad (2)$$

Fig. 4(a) shows how log polar transform (LPT) is carried out in the Cartesian plane and Fig. 4(b) shows the resulting sample distribution in the polar plane.

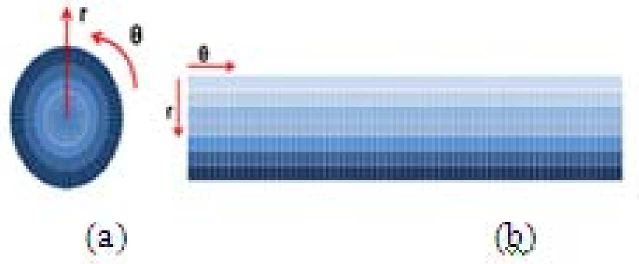


Fig. 4 LPT mapping

After the application of the log polar transform the rectangular ROI region converted from the Cartesian coordinates (x, y) to log-polar coordinates (ρ, θ).

Before applying polar transform on the ROI region, morphological opening followed by a 3 X 3 median filter is applied to smoothen the image and to remove outliers. This is followed by polar transform and the resultant transformed image is shown in Fig. 5 (c). Then to remove the small regions, opening by reconstruction is carried out which is nothing but performing morphological reconstruction, using the eroded image as the marker and the original image as the mask. In morphological opening, erosion typically removes small objects, and the subsequent dilation tends to restore the shape of the objects that remain. However, the accuracy of this restoration depends on the similarity between the shapes and the structuring element. Opening by reconstruction, restores the original shapes of the objects that remain after erosion and the result is shown in Fig. 5 (d).To convert the polar transformed image to binary image, first the image is divided into10 tiles of 36 pixels each and adaptive thresholding is carried out on each tile.

The conventional thresholding operator uses a global threshold for all pixels, whereas adaptive thresholding changes the threshold dynamically over the image. A threshold is calculated for each of the ten tiles separately. If the intensity value of the pixel in a tile is below its corresponding threshold value it is set to black otherwise it is set to white. The binary image obtained after applying adaptive thresholding is shown in Fib. 5 (e)

Finally, inverse polar transform is applied to the binary image which approximates the optic disk region as shown in Fig. 5 (f). This may contain some small regions which will be eliminated in the next step.

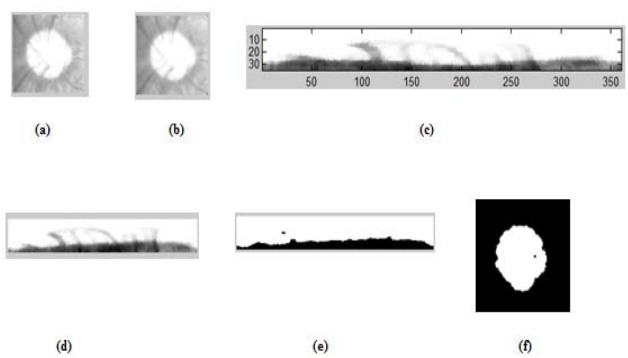


Fig. 5 (a) ROI Image (b) median Filter Image (c) Polar Image (d) Opening by Reconstruction Image (e) Adaptive Threshold Image (f) Inverse Polar Image

C. OD Detection

The small regions if any, for instance the small dot which could be seen in Fig. 5 (f) is eliminated using morphological closing operation and it is shown in Fig. 6 (a). Then to obtain a smooth contour an ellipse is fitted around the optic disk region.

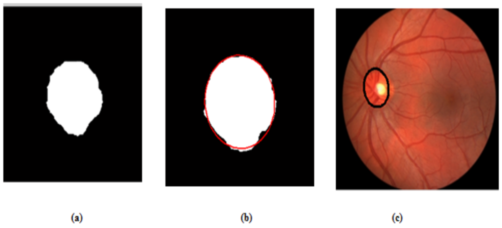


Fig. 6 (a) Close Operation Image (b) Ellipse Fitting (c) Ellipse Fitting in Original Image

The MATLAB function regionprops(), which computes geometrical measurements of image regions, offers several measurements that are based on fitting an ellipse to the region and this function is utilized in this work to fit the ellipse and is shown in Fig. 6 (b). Then the obtained ellipse is mapped onto the original image based on the coordinate positions of the extracted ROI region and the result is shown in Fig. 6 (c). Fig 7 shows the results of the proposed segmentation algorithm applied to four different fundus images derived from STARE and DRIVE databases.

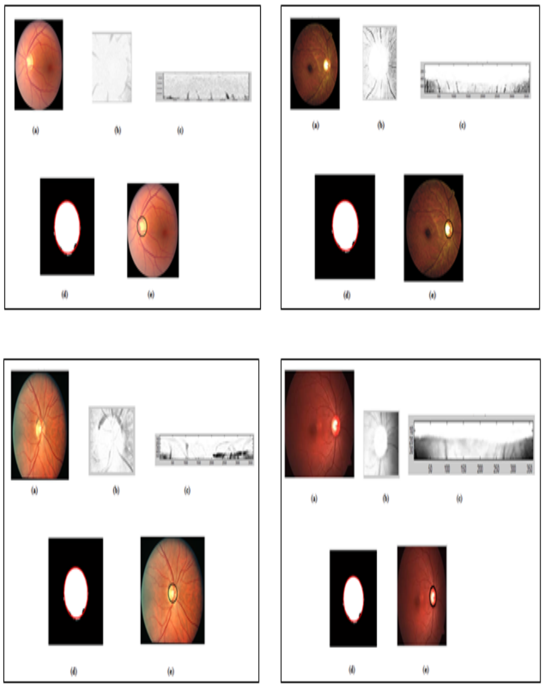


Fig 7 (a) Original Image (b) Cropped Image (c) Polar Image (d) Ellipse Fitting (e) OD Detected Image

4. CONCLUSION

Computer Assisted Diagnosis (CAD) system based on fundus images for retinal diseases relies on fast and accurate segmentation of Optic Disk (OD) and its elimination. The performance of the CAD system will greatly improve when the OD region is eliminated as the presence of the OD region may result in high false positive rates. Since the optic disk has big similarities with the spiral coordinate system, in this paper an attempt has been made to detect and eliminate optic disc using polar transform. As the blood vessels also appear brighter like the OD region, the red channel image alone is considered for further processing. Then blurring is done using morphological operations to suppress the blood vessels present to avoid segmentation errors. The ROI which comprises the OD region is subjected to polar transform and post-processing to accurately segment the OD pixels and subsequently the OD region is approximated by fitting an ellipse. The proposed methodology was tested on the two publicly available fundus databases namely STARE and DRIVE and it was found that the proposed method was efficient in detecting the optic disk. The proposed methodology can be used as an initial module in developing a computer assisted diagnosis system for retinal disease based on fundus eye images.

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