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SIGNIFICANCE OF HUMAN RETINAL OPTIC DISK LOCALIZATION IN VARIOUS RETINAL EYE DISEASES

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Optic Disk is one of the prominent features in human fundus images. Automatic localization and segmentation of optic disk can help in early diagnosis of diabetic retinopathies and preventing vision loss. In this paper robust method for optic disk detection and extraction of optic disk boundary is proposed based on morphological operations, smoothing filters and markers controlled watershed transform. This method has shown significant improvements in terms of detection and boundaries extraction of optic disk. This method used two types of markers: internal marker and external marker. These markers first modified the gradient magnitude image and then watershed transformation is applied on this modified gradient magnitude image for boundary extraction. The proposed method has optic disk detection success rate of 100% for Shifa and 87.6% for DIARETDB1 databases. Proposed method achieved average overlap of 51.19% for DIARETDB1 database and 73.98% for Shifa database which is higher than currents methods. Experimental results clearly demonstrate an efficient performance of the proposed algorithm.

Keywords: Retinal images, Optic disk, Image segmentation, Medical image analysis

1. Introduction

Many prominent features: retinal blood vessels, optic disk, and fovea are present in human retinal image (Figure 1) which are widely used in computer-aided diagnosis of eye disease: diabetic retinopathy that affects many diabetic patients. More than 80% of patients with diabetes tend to develop diabetic retinopathy over a period of 10 years. Blindness and vision loss are the most adverse effects of diabetic retinopathy. Using computer based programs, automatic processing of retinal images can increase the efficiency of ophthalmologists. Measurement of width of vessels and intensive curvy vessels determine the patients with hypertension and retinal vascular segmentation is also useful for the detection of various kinds of diabetic retinopathies such as venous beading, and neo vascularization. Optic disk detection can help in detecting the retinal lesions. Diameter of optic disk allows detecting other retina structures, like the fovea region. For example, Gagnon at el. [1] define fovea as circular region located several optic disk diameters away from optic disk center, in temporal side of optic disk. Optic disk is also helpful in segmentation of blood vessels extraction [2]. Also based on optic disk boundary it is possible to diagnose glaucoma [3]. Optic nerve abnormalities can be categorized as congenital or acquired. Congenital optic nerve anomalies are distinguished by the optic disk and surrounding retina. As a general rule, these anomalies are classified according to abnormalities of optic disk size (aplasia, hypoplasiz, megalopapilla) or conformation (titled discs, morning glory disc, optic disc coloboma, optic pit, peripapillary staphyloma) and by the presence of abnormal tissue at the nerve head (pseudoswelling like hyperopia, myelinated fibers, optic disk drusen). Acquired abnormalities of the optic nerve are classified according to the reaction of the optic nerve to insult: cupping, swelling, and atrophy [4].

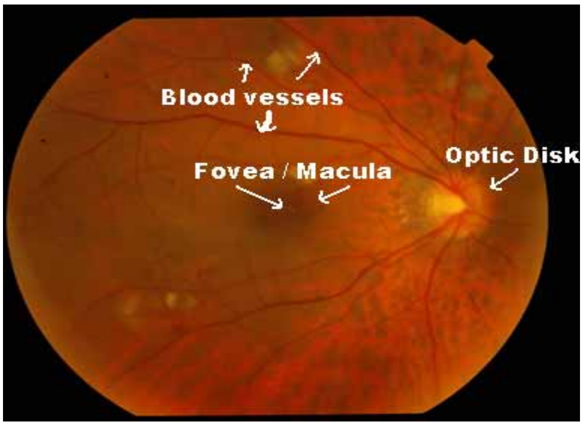

Figure 1. Retinal image from Shifa Database

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1.1. Existing Methods for Optic Disk Detection

Optic disk is a bright yellowish region in human retina from where the blood vessels and optic nerves emerge [5]. Retinal pathologies such as exudates and/or lesions often appears in retinal images which are similar to optic disk in shape, size and pixels intensities, these structures make the detection of optic disk challengeable task. Different techniques have been proposed by researchers in the field for optic disk detection.

Tobin et al. [6] proposed a method based on spatial filtering and Bayesian classifier (trained with 50 images) to extract local features from the retinal vasculature, obtaining a confidence image map. From this confidence image map the point with highest confidence value is chosen as optic disk center. They have reported performance of 81% for correct optic disk detection. Their method relies on accurate detection of the vascular tree. Park et al. [7] proposed to locate optic disk as circular area with large local intensity variability. Blood vessels in optic disk region have low intensity values and optic nerves have higher intensity value. Therefore, higher intensity variation is present in optic disk region as compared to other regions of retinal fundus image, this feature was used first by Sinthanayothin et al. [8]. However, this feature leads to false detection if there exist bright exudates on a dark local background. Walter and Klein [9] detected the optic disk center as the center of the largest and the brightest connected component in the retinal images. Lowell et al. [10] described method based on specialized correlation filter to detect approximately the center of optic disk. This detection filter (template) consists of a Laplacian of Gaussian. They have used a local dataset of retinal images, and reported excellent performance in 99% of images for optic disk detection and 83% of cases in terms of optic disk contours identification. Lupascu et al. [11] used intensity variation of the optic disk and regression based method to fit the circle as optic disk boundary and obtained success rate of 95% and 70% in detection and boundary localization of optic disk respectively. Kande et al. [12] approximated maximum local variance for detection of optic disk and geometric active contour with variational formation for optic disk boundary. Different morphological methods have been applied by Sopharak et al. [13] to detect the optic disk and no information for optic disk boundary detection is given. Stapor et al. [14] also utilized mathematic morphology to detect optic disk and its boundary is extracted based on geodesic reconstruction by dilation

In this paper, a new method for automatic detection of optic disk locus and optic disk boundary extraction is proposed. Moreover, proposed method is designed in such a way that the vessel negative effect on boundary extraction is minimized. In addition computational cost (in term of time) of the proposed method is very low as compared to existing methods.

1.2. Materials and Methods

Proposed method is tested on two databases of retinal images, one is local database and other is publically available on Internet. The local database contains 111 retinal fundus images of dimension 1936×1296 pixels, and obtained from ophthalmology department of Shifa international hospital Islamabad, Pakistan. DIARETDB1 [15] database consists of 89 color fundus images of dimension 1500 ×1152 pixels, captured using a 50^o field-of-view digital fundus camera with varying image settings. This database is created by Machine Vision and Pattern Recognition Laboratory, Lappeenranta University of Technology, Lappeenranta, Finland.

2. Proposed Method

It is observed that optic disk is bright and yellowish region in retinal images. If there are no bright exudates present in retinal images and illumination problem is not severe then pixels with the highest values of intensities corresponds to optic disk. Presence of such problems makes optic disk detection based on intensity information unreliable. Since optic disk is located on main blood vessels, high intensity information is combined with main blood vessels information so that optic disk can be detected reliably. Proposed method has two main steps, optic disk detection and its boundary extraction. Main blood vessels are detected using the following procedure.

The central idea is to identify foreground and background of green channel image “Fg”. Proposed method assumes bright structures as foreground and blood vessels as background. For estimation of background median filter is used. Different sizes of median filter from 3×3 to 70×70 have been applied and Median filter of size 50×50 was selected through experiments based on best

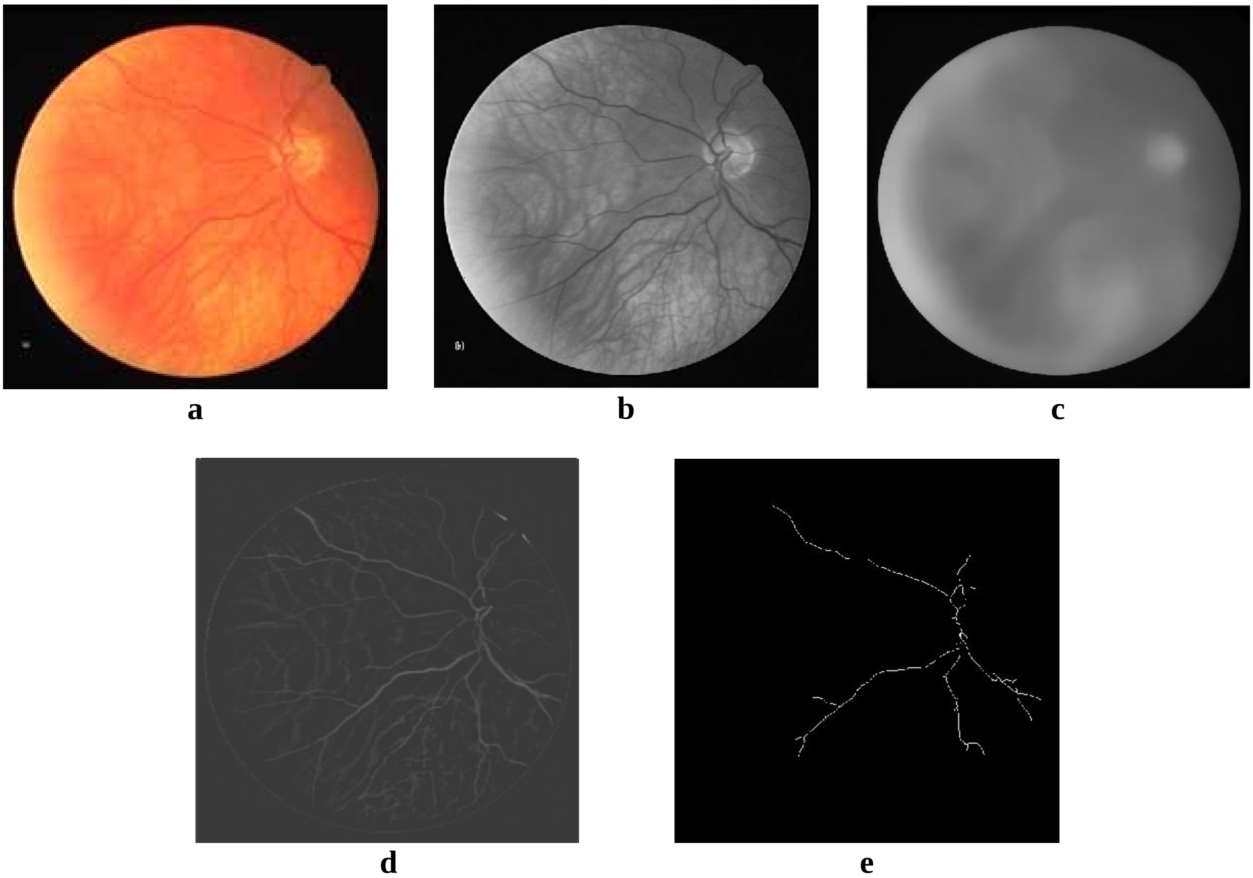

Figure 2. Steps for main vessels segmentation (a) RGB retinal fundus image (b) Green channel “Fg” (c) smoothed image “Fgs” (d) gray-scale vessels image (e) binary main vessels arcade.

performance. After convolution with median filter, the smoothed image “Fgs” is subtracted from original green channel image, as described by

Fv = Fg – Fgs

where “Fv” represent gray scaled blood vessels image. This image is thresholded to obtain binary image of vascular tree then morphological pruning and skeletonisation is performed to remove unimportant vessels branches, because only main vessels tree is of interest as shown in

After the segmentation of main blood vessels, the algorithm to detect a point inside optic disk is given step by step below

Algorithm:

Input : Green channel image

Output : Coordinates of a point inside optic disk

a. Median filter of size 7×7 is applied on green channel
b. Find location of maximum intensity value in this smoothed image
c. Apply a small search window centered at the coordinates of maximum intensity value
d. If search window finds a gray value in main vessels image at the same location then stop searching otherwise, delete this maxima and find next maximum intensity value, repeat this process of change until window finds a gray value in main vessel.
e. The point corresponding to the last maximum intensity value is the point inside optic disk

This algorithm overcomes the problem of false optic disk detection and makes the method robust and fast.

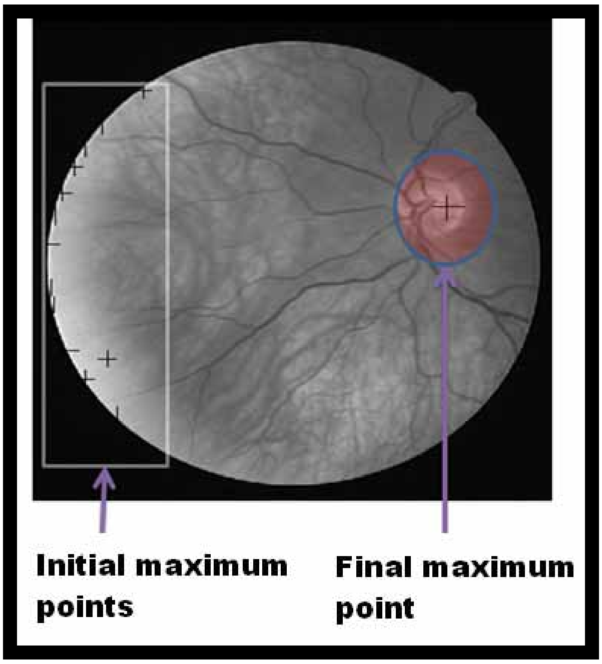

Figure 3. Shifting maxima to correct location

Figure 3 shows the graphical interpretation of optic disk detection algorithm, initial maxima is not the desired location so these are eliminated repeatedly and maxima is shifting towards optic disk. This location of point is used in boundary detection and plays an important role in modification of gradient image which is to be used in watershed transformation [16]. Figure 4 shows some of the correctly detected images from Shifa and DIARETDB1 [15] database. Plus sign in the optic disk shows detection in each image.

After that optic disk boundary extraction is carried out by marker controlled watershed transformation. Two types of markers are used for modification of gradient image: internal marker and external marker. The detected optic disk point is used as internal marker and a circle of predefined size is used as external marker. Red channel of the original RGB image is more suitable for optic disk boundary extraction because vessels effect is not severe in it. Morphological operations are performed on red channel to remove vessels effect and large peaks. Red channel is first closed with octagonal structuring element to further reduce the effect of vessels on optic disk. Then opening is performed with octagonal structuring element to remove large peaks. Reconstruct the opened image to recover boundary shape and obtain the morphological gradient image of the reconstructed image. Coordinates of the detected optic disk point and a circle of predefined size are utilized to make a marker image. Reconstruct the image by taking the marker image and morphological gradient as mask. After that minimum imposition method modifies the gradient image which is further applied with watershed transformation [16] to estimate the boundary of optic disk.

3. Results and Discussion

MATLAB 7.8 has been used as developing tool for the proposed method. Proposed method has been experimented on 89 images of the DIARETDB1 [15] database and 111 images of SHIFA database. Using the DIARETDB1 the success rate for the localization of the optic disk was 87.6% (i.e. 78 correct optic disk detections in a total of 89 images). The reason for the failure in eleven images was due to an incorrect identification of the vascular tree by the method. Due to illumination and vessels disconnectivity, main arcades could not be detected. Thus, for this reason, the method to find the optic disk locus failed. Table 1 summarizes the results obtained by methods available in the literature and by proposed method in relation to the optic disk location for DIARETDB1 database. The results indicate that proposed method provides promising results compared to other available techniques. To achieve these results, correct optic disk detection means a point obtained by proposed method should be within the borders of the manually marked optic disk.

Table 1. Optic disk detection comparison with other researchers for DIARETDB1 database.

S. No.	Method	Detection (%)
1.	Sopharak et al. [13]	59.55
2.	Walter et al. [17]	92.13
3.	Stapor et al. [14]	78.65
4.	Seo et al. [18]	80.89
5.	Lupascu et al. [11]	86.51
6.	Kande et al. [12]	88.76
7.	D.Welfer et al. [19]	97.7
8.	Proposed method	87.6

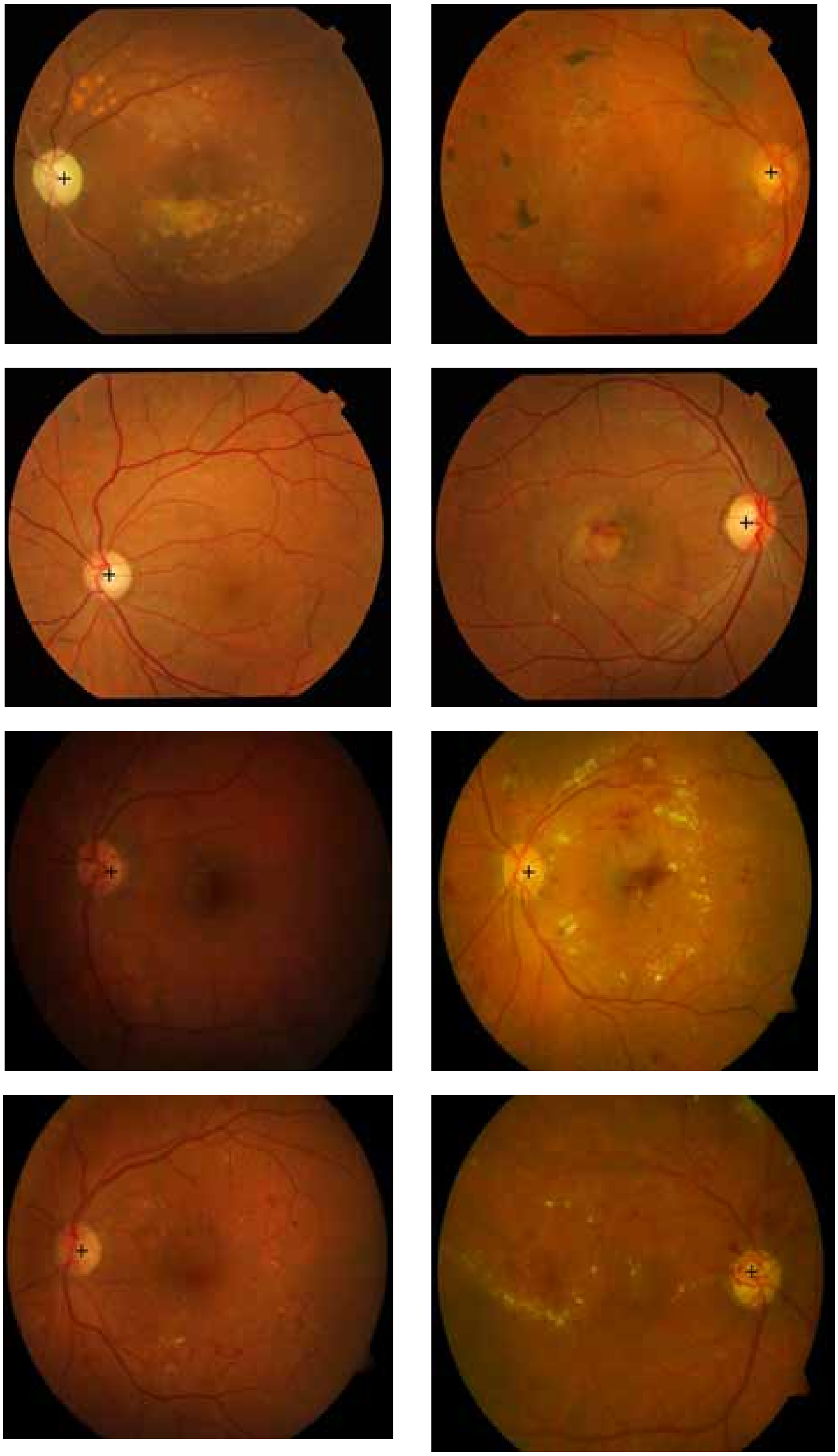

Figure 4. Some correctly detected images

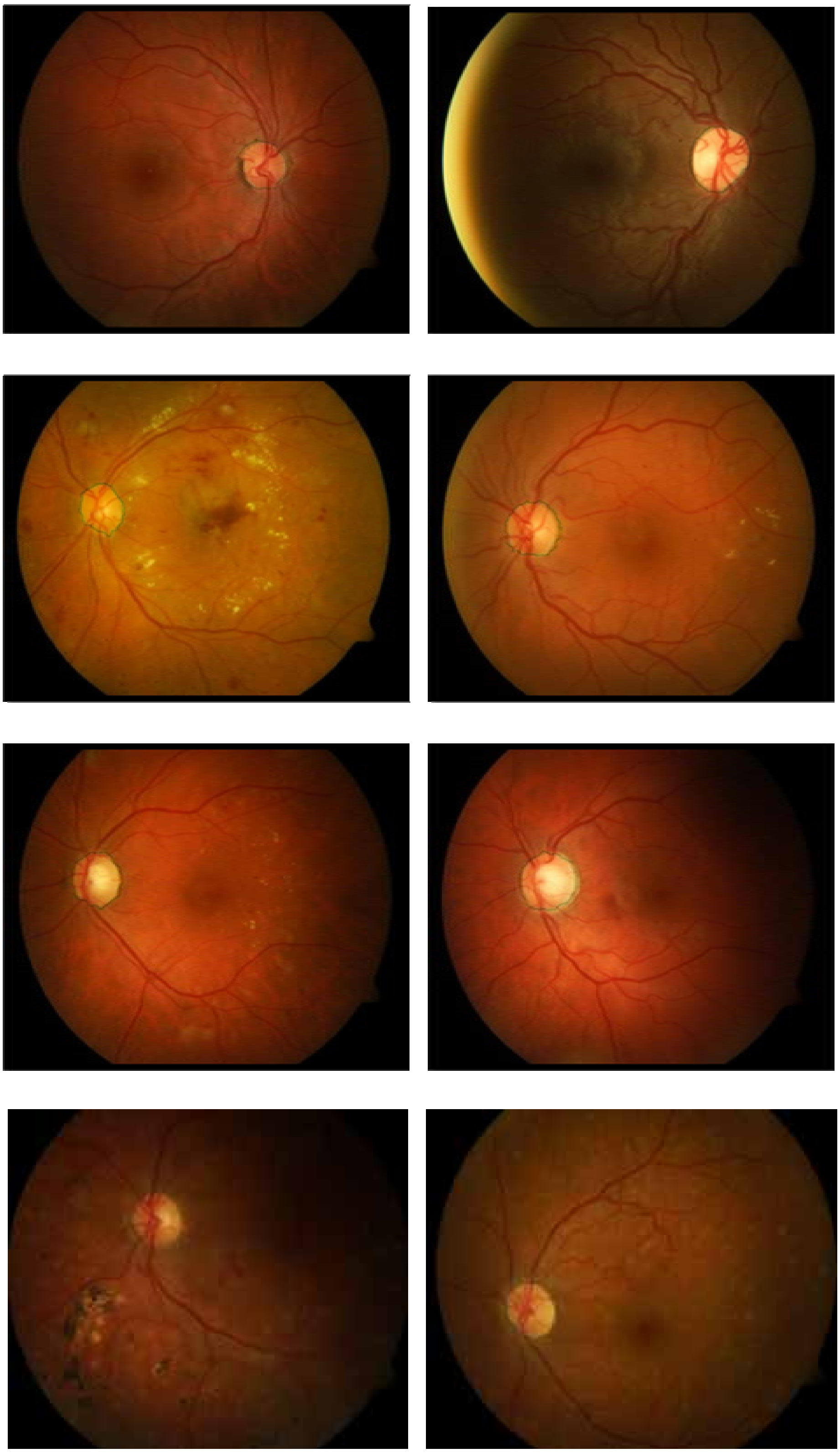

Figure 5. Correct localization for DIARETDB1

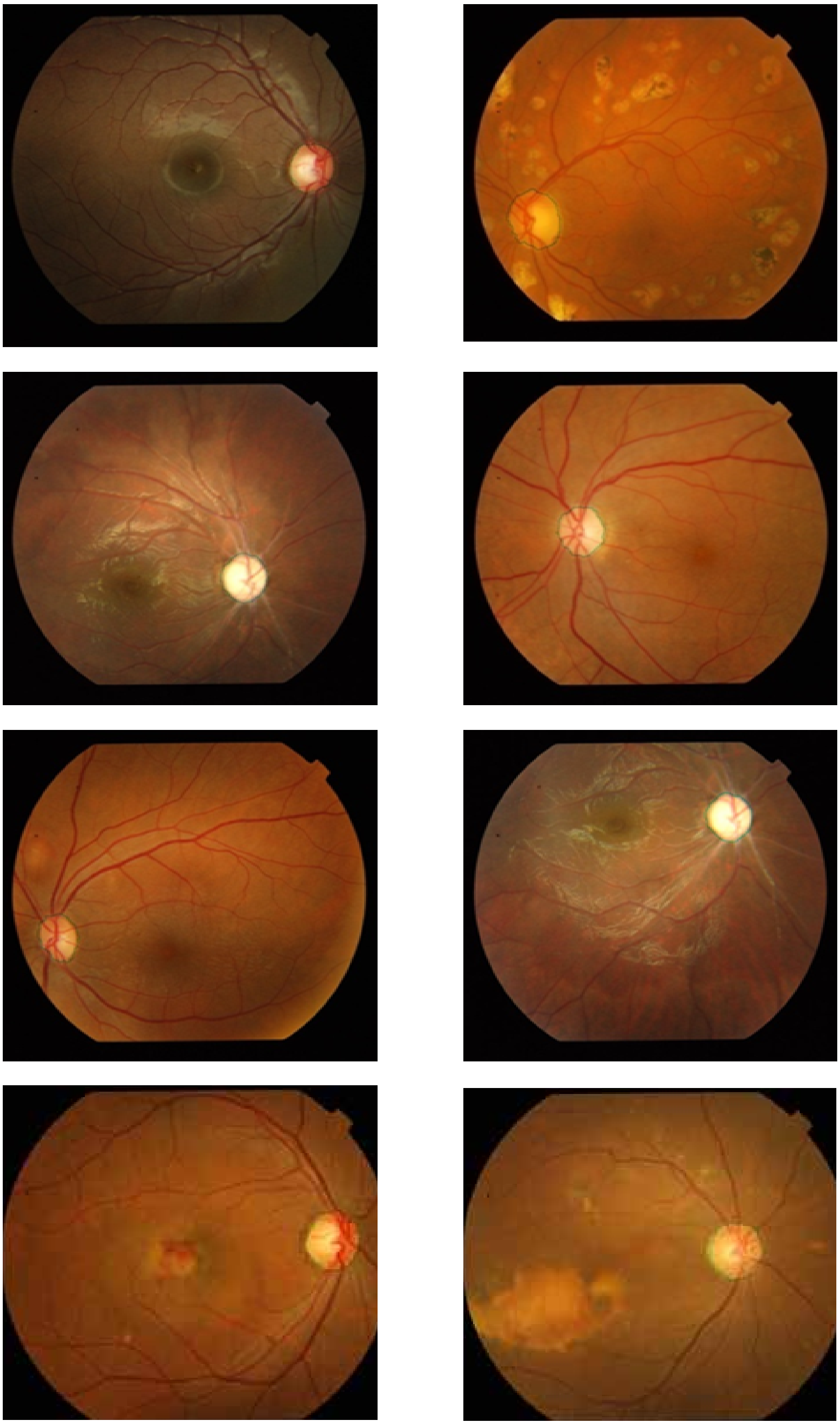

Figure 6. Correct localization for Shifa.

Optic disk detection results on local database are very much attractive. Proposed method success rate of optic disk detection is 100% (i.e. it detected all of the 111 images correctly).

Next proposed method boundary extraction performance is evaluated in term of percentage of average overlap. Manually boundary segmentation was done by expert of the field, 4 different observers manually segmented the optic disk boundaries. Figure 7 explains the concept of overlap in terms of True Positive (TP), False Positive (FP), True Negative (TN) and False Negative (FN). Where green circle represent the actual boundary of optic disk and circle in blue is the boundary obtained automatically using the proposed algorithm.

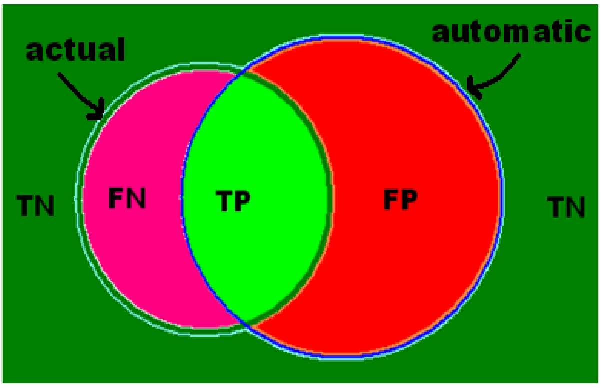

Figure 7. Hypothetical boundaries for overlap

1. TP: The area contained in the actual circle as well as in automatic detected circle.
2. FP: The area contained only in the automatic detected circle and not in the actual circle.
3. TN: The area outside the actual and automatic circles.
4. FN: The area contained only in the actual circle but not in automatic circle.

The overlap between two circles is defined as TP area divided by summed area of TP, FP and FN.

$$\text{overlap} = \frac{TP}{TP + FP + FN}$$

In Table 2, the result of proposed method has been compared with other techniques. It is clear from the figures that average overlap of proposed method is very high and it outperforms the other techniques. Welfer and Walter have bettrer results as compared to proposed method for optic disk detection but average overlap of proposed method is very high. Figures 5 and 6 show some of the correctly localized boundaries of optic disk from DIARETDB1 and Shifa databases respectively.

Table 2. Average overlap comparison with other methods for DIARETDB1 database

S. No.	Method	Overlap (%)
1.	Sopharak et al. [13]	29.79
2.	Walter et al. [9, 17]	37.25
3.	Seo et al. [18]	35.33
4.	Kande et al. [12]	33.18
5.	Stapor et al. [14]	34.10
6.	Lupascu et al. [11]	30.95
7.	D. Welfer et al. [19]	43.65
8.	Proposed Method.	51.19

4. Conclusions

Optic disk is a yellowish round shape anatomical structure where blood vessels enter and leave the human eye. The correct localization of optic disk can help in preventing diabetic retinopathies and vision loss. The detection of optic disk can also help in detection of macula and other structures. Normally the system for optic disk localization consists of two basic stages: stage 1 is detection of optic disk and stage 2 is localization of optic disk. Stage 1 is very important for further processing retinal fundus images. Success rate for optic disk detection by proposed method is 87.6% for DIARETDB1 and 100% for Shifa database. For the localization of optic disk boundary new method based on marker controlled watershed transform has been proposed. The proposed method achieved average overlap 51.19% and 73.98% for DIARETDB1 and Shifa databases respectively and proposed method has the highest average overlap among other existing methods. The experimental results have shown that the proposed method yields attractive performance.

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