Optic Disc Detection Using Combined Approach of Level Set Method and Morphological operations

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Abstract—Optic disk (OD) is the most vital landmark of the eye. It is the vertical oval (or circle) in the back of the eye where retinal nerve fibers combine to form the optic nerve. In retinal image analysis, localization and segmentation of OD is of immense importance as it helps in diagnosing various eye abnormalities like Diabetic Retinopathy, Diabetic Maculopathy and Glaucoma. In this paper, optic disc detection method has been proposed, which uses morphological operations along with the Level Set Evolution. The technique discussed in this paper was evaluated using 184 fundus images obtained from the publicly available database DIARETDB1 and DIARETDB0 and showed an average accuracy of 99.45% and 99.19%, respectively for the localizing the Optic disc. Also, the proposed method has overcome the problem of detecting a very low visible OD of various sizes by proper contour initialization.

Keywords—Optic disk, exudates, macula, diabetic retinopathy, diabetic maculopathy, glaucoma

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I. INTRODUCTION

Eye is one of the important and complex sensory organs in our body responsible for vision. Being so small, yet eye has so many working parts hidden inside it. The main part of the eye is retina which allows the perception of light and vision because of the presence of rods and cones. The fundus of the eye is the inner surface located opposite to the lens and it includes the bright region called optic disc, dark region called macula with the centre named fovea. Fundus photography done for capturing this using specialized fundus camera visualizes these main landmarks of the eye. These landmarks of the eye are useful for the detection of various eye diseases. One of the important pre-requisite for automated diagnosis of Diabetic Retinopathy (DR), Glaucoma, Diabetic Maculopathy(DM), etc. is notably to locate the accurate position of the optic disc (OD). In addition, the correct optic disk detection can also be used for approximating other landmarks of the eye such as macula and fovea.

II. PROPERTIES OF OPTIC DISC

This anatomical structure is circular in shape with bright appearance where rods and cones are absent. It is present at the back of the eye where retinal nerve fibers combine to form the optic nerve. So, it acts as an entrance for the blood vessels to the retina and also referred to as the ONH-optic nerve head as it is the point that connects the optic nerve to the retina. A normal optic disc varies from pink to orange in color having a pale centre depicted as the optic cup. Generally, optic disc is

Fig.1. Fundus image depicting various retinal features
present in the middle third of the image because of the position of the imaging device as depicted in the Figure 1. As OD area is deprived of light-sensing cells, so it is also named as blind spot. Its diameter ranges from 80 to 100 pixels but OD size varies from patient to patient.

The detection

III. NEED FOR OPTIC DISC DETECTION

Optic disk detection is the very important pre-processing step needs to be done for the detection of many eye diseases, which have been discussed as follows:

A. Diabetic Retinopathy

It leads to pathological changes in the retinal vessel structure such as microvascular abnormalities, neovascularisations, microaneurysms, exudates and haemorrhages. Amongst these exudates appears with similar contrast, color and intensity to OD. So, its prior detection and removal is required in order to avoid wrong detection of other features.

B. Diabetic Maculopathy

Diabetic macular edema is the complication visible after diabetic retinopathy which is caused by the swelling of the retina due to leakage of fluid and formation of various lesions within the central macula which is responsible for sharp and high-acuity color vision due to large concentration of cones. So, it results in the most sharp vision loss. In this case, the contrast and color of the lesions matches with that of the optic disc. So, its prior detection again adds to be the important preprocessing step. The severity of DM can be detected by the location of exudates present. The more the exudates are towards the centre (macula), the more severe is the DM and in some techniques the macula is detected using the location and diameter of OD.

C. Glaucoma

This diabetic eye abnormality is condition observed because of the increase in the intraocular pressure (IOP) as result of which the optic nerve is affected. Glaucoma leads to increase in the cup area and hence ONH gets shifted towards the nasal side. Thus, cup/disc ratio is used for detection of glaucoma. So, in this case the detection of OD stands again as the main step.

IV. RELATED WORK

Ahmed Wasif et al. (2009) [1] had used extended maxima operator, minima imposition, and watershed transformation to detect Optic Disc. The images used in this case were taken from STARE and DRIVE databases and showed an accuracy of 96.7%. D. Welfer et al. (2010) [2] had worked for the detection of Optic Disc using morphological operations by finding the main vascular tree of the retina. The retinal images used for evaluation were obtained from DRIVE and DIARETDB1 databases, computing mean overlap of 41.47% and 43.65% respectively. This method was designed to be robust under various conditions likely to be found in the fundus eye. Daniel Welfer et al. (2013) [3] used morphological operations namely, reconstruction, h-minima, h-maxima and top hat transformation. The fundus images acquired for evaluation were gathered from DIARETDB1 and DRIVE databases and depicted an accuracy of 97.75% and 100%. Muhammad Zubair et al. (2013) [4] had used morphological operations for enhancement as well as segmentation of OD through operations like CLAHE, contrast stretching and extended minima. Images used are taken from MESSIDOR database showing an accuracy of 98.65%.

M. Usman Akram et al. (2010) [5] applied Canny edge detection operator and Hough Transform for the detection of Optic Disc using the fundus images from DRIVE database and acquired an accuracy of 97.7% with DIARETDB1. But in case of [6] Diego Marin et al. (2015) have used Prewitt edge detector and Hough transform for the detection of Optic disk by using fundus images from MESSIDOR and MESSIDOR-2 and getting Jaccard and Dice coefficients (JC and DC) to be 0.87 and 0.92.

H. Yu et al. (2012) [7] had proposed optic disc segmentation approach based on the directional matched filtering and LSM. For localization of OD, vessel patterns are used and the LSM used in this approach combines both local and region gradient information. MESSIDOR database was used for computing performance through Williams Index which was calculated to be 0.95. Hung-Kuei et al. (2012) [8] had adopted Gradient Vector Flow (GVF) snake model as a result of which OD was detected irrespective of irregular disc boundaries and vessel interference. Databases used in this case are STARE and DRIVE which segmented 95% disc boundaries correctly. M. Caroline et al. (2015) [9] had used Active Contour model based on GVF with the initial contour is derived from Hough transformation. Images taken for performance evaluation are taken from RIM-ONE database and evaluated using Hausdorff distance and 94% of the cases
were correctly located. On the other hand, entropy of vascular structure was used by Ana Maria et al. (2012) [10] for locating OD using fundus images from DRIVE and STARE. Matched filtering was adopted to compute the vascular tree followed by the formation of entropy map. This approach is more robust because only the high intensity regions of the image were taken into consideration so as to find the maximum entropy which was depicted to be OD and it was validly located in 115 images from 121.

OD is known to be the main landmark of the fundus image and needs to be detected for diagnosis of certain diabetic eye diseases as discussed in section III. So, in various papers it has been detected as a part of preprocessing step. Among these [12, 13, 14] had adopted morphological operations for detection of OD. A.Sopharak et al. (2008) [12] had performed Otsu thresholding after the enhancement process where as Jagadish Nayak et al. (2009) [13] had chosen the threshold to be 3.2 times the standard deviation value. On the other side, Marwan D. Saleh et al. (2012) [14] had computed the thresholded value as max (Contrast stretched image)-10. Fengshou Yin et al. (2012) [15] had combined both Hough transformation and canny edge detection with deformable model to identify the OD boundary and have the least effect of the bright objects due to their irregularity as it was in case of [12]. Asha Merin Jose et al. (2015) [16] had used both morphological operations combined with the level-set methodology. In this paper, morphological operations are used for preprocessing and then hybrid LSM is applied. Although this method gives the exact boundary of the OD, it needs lot of preliminary processing for removing the blood vessels and bright regions.

Harris Corner approach was used by Nilanjan Dey et al. (2012) [17] for detection of OD and finally computing cup to disc ratio for diagnosing Glaucoma. Meysam Tavakoli et al.

### TABLE I. LITERATURE SURVEY

<table>
<thead>
<tr>
<th>NAME OF THE AUTHOR / YEAR</th>
<th>METHOD USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hung et al. / 2012 [8]</td>
<td>GVF deformable model</td>
</tr>
<tr>
<td>Ana Maria et al. / 2012 [10]</td>
<td>Matched filter and entropy map</td>
</tr>
</tbody>
</table>
(2013) [18] had detected OD using Radon transform (RT). If the peak is detected in the Radon space, ONH is assumed to be present there as there is high contrast between the background and the ONH. Mahfouz et al. [19] obtained OD using two projections of retinal image features. Anum Abdul Salam et al. [20] determined the location of OD in which vessel based features where used along with SVM classifier. Murugan Raman et al. [21] mainly for focused on the low resolution retinal images for OD detection.

M. Elena et al. (2019) [22] have detected OD using two phases namely, extraction of spectral information from the three channels of the image and finding which channel is most appropriate using Shannon information content. Although they have used the information from all the three channels, there is a requirement of knowing the approximate size of OD in prior. Similarly, Jen Hong Tan et al. (2017) [23] also worked on the three channels of image and segmented the OD using neural network with the accuracy of 92.68%.

Through literature survey depicted by Table I, it had been found that various authors had adopted the morphological techniques for the detection of OD, but some bright spots (exudates) interfere in the detection which have same contrast and intensity as that of OD as shown in fig. 2. On the other hand, Hough transform was also used for OD detection but it is efficient if the edges are detected well in prior but have least effect of the bright objects. Few authors had applied deformable models and produces more accurate boundary of OD but time is needed in removing blood vessels and bright components beforehand. So, there is an utmost need for a method which detects OD of any visibility and size with better accuracy, less pre-processing and removal of other exudates beforehand. Although Muragan et al.[22] have worked on low resolution retinal images, attained the accuracy of 96.96%.

V. PROPOSED METHODOLOGY

A. Materials

The fundus images essential for the proposed system were taken from the publically available databases [24] DIARETDB1 and DIARETDB0, which are the standard Diabetic Retinopathy database with calibration level 1 and 0 respectively. 184 color fundus images are taken in total of size 1500 x 1152 that are captured with FOV (Field Of View) of 50 degrees using a digital fundus camera. The images are of varied amount of illumination, color, noise, etc. These images present in this database are taken from the Kuopio university hospital and selected by the four different experts.

B. Performance Measures

To quantitatively evaluate the performance of our method, comparison between the segmented results and the manually marked OD by the ophthalmologist was carried out. Ground truths marked by the expert were taken from the GMS Hospital, Chandigarh.

In this paper, specificity, sensitivity and accuracy are chosen for evaluation of the proposed method. The four values taken into consideration in this evaluation are: true positive (TP) i.e. correctly identified area, true negative (TN) i.e. correctly rejected area, false positive (FP) i.e. incorrectly identified area and false negative (FN) i.e. incorrectly rejected area. Using these quantities, evaluation measures are described in (1) to (3):

Specificity (True Negative Rate) = TN / (TN+FP)  \hspace{1cm} (1)
Sensitivity (True Positive Rate) = TP / (TP+FN)  \hspace{1cm} (2)
Accuracy = (TP+TN) / (TP+TN+FP+FN)  \hspace{1cm} (3)

Specificity computes the proportion of negatives being identified correctly and sensitivity computes the proportion of positives being identified correctly.
C. Methodology

The proposed method follows the Algorithm 1 to segment the Optic disc in two main steps:

1) Contour Initialization: In the proposed method, firstly red and green components of the image are extracted. Then in order to remove the background noise, median filtering is done using 9x9 neighborhood. Blood vessels present in image can reduce the accuracy, so they are removed before hand by performing closing operation with disc shaped structuring element (SE1) of size 8 [12]. Next, the bright objects are enhanced by performing top-hat transform using SE2-Disc (size 20) as in [14]. The size of SE2 has to large enough to obtain the optic disc’s central brightest region. After the enhancement of bright portion thresholding is done using Otsu method. This is followed by removal of unwanted objects by performing erosion using SE3 as disk of size 4 because due to thresholding all the bright objects are detected which may include exudates as well. Hence, by taking SE of smaller size, small bright objects like exudates can be removed. This whole process is repeated for both components. For choosing the initial contour, that component is selected which gives only one connected component after the last step. As shown in fig. 3(k) red component is giving only one connected component, so it is chosen as the initial contour after performing erosion so as to fit the contour properly inside the OD for better detection [as depicted in fig. 3(m)].

2) Distance Regularized Level Set Evolution (DRLSE): Li Chunming et al. [11] proposed a variant of level set method which maintains the regularity of LSF (Level Set Function) intrinsically during its evolution without the requirement of re-initialization. They had used the Distance regularization term forcing LSF’s gradient magnitude to one of its minimum and hence, preserving the optimal shape of LSF as well as the external energy term. As a result of which, requirement of re-initializing is eliminated.

Use of morphological operations along with DRLSE, results in more accurate detection of OD. In the proposed method, DRLSE has been used by first computing the initial contour using morphological operations and thresholding as discussed in section V.C (II). After evolving the level set, the obtained final contour is shown in fig. 4(n) depicting the localization of OD.

Algorithm 1: Pseudo code for the detection of OD.

```
1:   input: RGB fundus Image (I_{RGB})
2:   output: Image showing OD boundary (I_{OD})
3:   begin
4:     I_{R} ← Red Component of I_{RGB}.
5:     I_{G} ← Green Component of I_{RGB}.
6:     repeat 7 to 12 for I_k where k=R,G
7:     M_{F_k} ← median filter (I_k).
8:     C_{l_k} ← inclose (SE1, M_{F_k}).
9:     T_{k} ← tophat (SE2, C_{l_k}).
10:    Th_k ← Otsuthresholding (T_{k}).
11:    E_{R_k} ← imerode (SE3, Th_k).
12:    cc_k ← connected component (E_{R_k}).
13:    if ( cc_R = cc_G = 1) or ( cc_R = 1 and cc_G ≠ 1)
14:      C_{initial} ← E_{R_k}.
15:    else
16:      C_{initial} ← E_{G_k}.
17: end
18:   I_{OD} ← DRLSE (C_{initial}).
19: end
20: return I_{OD}.
```

VI. EXPERIMENTAL RESULTS

For the evaluation purpose, 70 images from publically available database DIARETDB1 and 114 images from DIARETDB0 were taken into consideration which has fundus images having different sizes of OD as well as varied illumination and location of OD. These 184 images were taken to extensively test our proposed technique. After calculating the four parameters discussed in previous section, performance parameters of each image were computed as shown in table II. The average sensitivity, specificity and accuracy for DIARETDB1 has been calculated as 97.44%, 99.16% and 99.45% respectively and for DIARETDB0 these values were calculated as 95.38%, 99.4% and 99.14% respectively. All the images have shown reliable results with few images showing 100% sensitivity depicting that the OD area has been completely detected.

TABLE II. PERFORMANCE MEASURES FOR DIARETDB1

<table>
<thead>
<tr>
<th>Image</th>
<th>Sensitivity (in %)</th>
<th>Specificity (in %)</th>
<th>Accuracy (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image_001</td>
<td>90.25</td>
<td>99.84</td>
<td>99.66</td>
</tr>
<tr>
<td>Image_002</td>
<td>98.44</td>
<td>99.72</td>
<td>99.70</td>
</tr>
<tr>
<td>Image_003</td>
<td>98.30</td>
<td>99.81</td>
<td>99.78</td>
</tr>
<tr>
<td>Image_004</td>
<td>94.61</td>
<td>99.75</td>
<td>99.64</td>
</tr>
<tr>
<td>Image_005</td>
<td>100</td>
<td>98.65</td>
<td>98.69</td>
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<tr>
<td>Image_006</td>
<td>99.19</td>
<td>99.68</td>
<td>99.67</td>
</tr>
<tr>
<td>Image_007</td>
<td>100</td>
<td>99.51</td>
<td>99.52</td>
</tr>
<tr>
<td>Image_008</td>
<td>100</td>
<td>99.69</td>
<td>99.69</td>
</tr>
<tr>
<td>Image_009</td>
<td>93.73</td>
<td>99.83</td>
<td>99.71</td>
</tr>
<tr>
<td>Image_010</td>
<td>100</td>
<td>99.49</td>
<td>99.50</td>
</tr>
</tbody>
</table>
Fig. 4: Graphical representation of Performance measures using both databases

The different performance measures obtained for the two databases have been shown in fig. 4. All the performance measures have shown reliable values for both the databases. The databases used in this paper consist of different classes of DR containing numerous lesions which hinder the detection of OD. But after the calculation of various evaluation parameters it is clear that the proposed technique detects OD irrespective of any class of DR. Also, in few images the OD is not visible clearly but still the proposed method has detected the complete OD.

Fig. 5 depicts the detected OD (in red color) along with the marked OD by ophthalmologist (in black) using the images of DIARETDB1. From these images it has been concluded that even if the size of OD is different, it has been detected accurately by the proposed system. Similarly, fig. 6 depicts the detected OD overlaid on the ground truth marked by ophthalmologist using the images of DIARETDB0.

Fig. 5: Detected OD overlaid on marked ground truth (in black) using images from DIARETDB1
TABLE III. COMPARISON OF VARIOUS TECHNIQUES

<table>
<thead>
<tr>
<th>AUTHOR</th>
<th>DATABASE 1</th>
<th>DATABASE 2</th>
<th>ACCURACY 1</th>
<th>ACCURACY 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahfouz et al. [19]</td>
<td>DIARETDB1</td>
<td></td>
<td>97.8%</td>
<td></td>
</tr>
<tr>
<td>M.Usman et al. [5]</td>
<td>DIARETDB1</td>
<td>DIARETDB0</td>
<td>93.7%</td>
<td>93.2%</td>
</tr>
<tr>
<td>Proposed technique</td>
<td>DIARETDB1</td>
<td></td>
<td>99.45%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DIARETDB0</td>
<td></td>
<td>99.19%</td>
<td></td>
</tr>
</tbody>
</table>

Mahfouz et al. [19] and M. Usman et al. [5] have also worked on the same databases, so the proposed method is compared with them. The proposed method showed the best accuracy of 99.45% on an average using retinal images from DIARETDB1 which is optimum as compared to other techniques as depicted from the table III. This depicts that the proposed technique has detected OD correctly irrespective of the class of Diabetic Retinopathy (DR) because of the combined approach of morphological operations and Level Set Method (LSM).

VII. CONCLUSION

The methodology for detection of OD has been presented in this paper. Through the literature survey it has been seen that detection of OD is the most fundamental step in automated diagnosis of various diabetic eye diseases. Hence, accurate analysis and examination of OD is required. The proposed technique segments the OD with better accuracy. The main problems found in localization of accurate OD are the presence of exudates in the fundus image as well as the improper illumination. But our technique detects OD accurately with entire boundary shape as found in the image irrespective of its proper visibility and presence of exudates.

In order to find the initial contour, the proposed technique do not use only one component for all the images rather it selects the component which shows only one connected component after the pre-processing of both the components. When only one component is used for obtaining the initial contour, it may results in the incorrect contour detection because of improper brightness. On the other hand, the other component may give better initial contour. Also, in few images the OD is not visible clearly but still the proposed method has detected the complete OD. This is due to the fact that the initial contour has been located correctly.

On comparing the segmented results with the manually marked ground truths the accuracy achieved through this technique is 99.45% and 99.19% using retinal images taken from DIARETDB1 and DIARETDB0 databases respectively. If the optic disc is detected with better accuracy, it helps in more accurate detection of various lesions like exudates and finally, better detection of DR and DM.

ACKNOWLEDGMENT

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REFERENCES


