



A Hybrid Approach for Automatic Exudates Detection in Eye Fundus Image

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Abstract - Diabetic retinopathy is an eye disease that is caused by damaging of the retinal blood vessels due to long term diabetes. It is important to automatically detect the DR lesions at early stage in order to prevent the further vision loss. Exudates are bright lesions that are considered as primary sign of this disease. In this paper, a hybrid approach is proposed for automatic detection of exudates from eye fundus images. In this approach, unsharp masking is used for preprocessing, region based segmentation is used for candidate detection and then pixel based classification is used to determine the severity level of the disease. The proposed method is tested the image-level as well as at pixel-level on publically available database DIARETDB1 that contain total 89 fundus images and results in 98.12 % specificity and 90.83% sensitivity considering the pixel-level evaluation, while it is 86.04% and 91.06% respectively on image-level evaluation .

Keywords – Automatic Detection, diabetic retinopathy, exudates, fundus image, optic disc.

I. INTRODUCTION

Diabetic retinopathy is a common disease now days that can prevail in anyone having type 1 diabetes or type 2 diabetes [1]. The chance of being affected by this disease depends on the period of ones having diabetes. The long term diabetes leads to high level of blood sugar that causes damage by altering the blood flow in retinal blood vessels. It is common that in the early stage, diabetic retinopathy shows no symptoms and hence without undergoing medical examination it is not possible to detect the presence of disease. Exudative retinopathy is a condition defined by the presence of white or yellow mass that occurs due to leakage of fats and proteins along with water from blood vessels in the retina. It is essential to detect the presence of exudates in the fundus oculi because accumulation of these exudates may lead to complete blindness. There are so many methods in literature that are used to detect the presence of exudates in the fundus images. Broadly the automatic detection methods are divided into three categories: - (i) thresholding methods, (ii) morphological approach and (iii) artificial neural network approach.

One of the first published papers on exudate detection [3] depends on the use of global and local thresholding technique on green channel images. In [4], adaptive intensity thresholding combined with recursive region growing segmentation (RRGS) is used to detect the exudates. In [5] dynamic thresholding technique is used on the locally contrast enhanced image for exudates detection. PCA (principal component analysis) based method is used for OD detection and then integration of dynamic thresholding and edge detection is done to remove any false positive candidate. Maximum entropy thresholding technique is used in [6] to filter out the bright exudates pixels from the preprocessed image. The problem with this method was that in some images noise appears as bright candidate which results in false positives. In [7] optimal thresholding of instantaneous amplitude (IA) components is used to locate exudate candidates. Then partial least squares (PLS) is applied to characterize the image into exudate free or one having exudates.

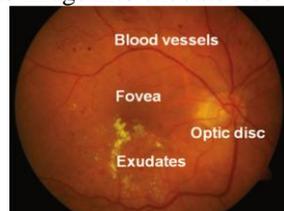


Fig.1: Retinal image showing Exudates

The detection of exudates using morphological approach is very extensive, few of the important morphological techniques are discussed here. In [8], the high grey level variation of the exudates is used to find the candidate lesions and morphological reconstruction technique is used to determine their contours. In this approach morphological filtering techniques are also used to detect the optic disc. In [9], a technique based on optimally adjusted morphological operators is used for exudate detection from low contrast images. In [10], another variant of morphological technique that is Differential Morphological Profile (DMP) which involves the use of combined morphological operators such as opening and closing by reconstruction with variable size structuring elements and the derivatives of the resulting profiles.

In [11], a new segmentation method based on mathematical morphology is proposed that not only detect the exudates but also detect the bright structures resulted due to reflections and artefacts in the image that can easily be removed to obtain only the exudate candidates. In [12], morphological operations are used on the processed I-band of the fundus image. In the I-band saturation level of intensity channel is high, hence optic disc and exudates can be detected more efficiently. Then, fuzzy logic is used to classify the severity level of the disease.

Under artificial neural network approach in [13], exudates are detected using back propagation neural network model. The features identified by decision tree and genetic algorithm- correlation based feature selection approach are used as inputs to the BPN model. In [14], a multilayer perceptron neural network model is used to identify the presence of exudates in the fundus images. Inputs for this model are derived from color, size, and strength of edge and texture features of the candidate lesions. Other approaches used for exudate detection includes k-means clustering [15]. In this approach exudates are classified as hard or soft exudates on the basis of their threshold and edge energy. Many more approaches have been used for the automatic detection of exudates but their results have not satisfied the limits of sensitivity, specificity and accuracy.

In this paper, a new hybrid approach based on simple methods of preprocessing, segmentation and classification is proposed. We based our work on the simple techniques so that it can be easy, fast and of low computational complexity. The drawbacks of various methods studied in literature such as high count of false positives due to non-removal of bright artefacts, unremoved part of optic disc and reflections along the retinal blood vessels may contribute to candidate lesions. All these drawbacks are considered seriously and hence removed to increase the accuracy of the proposed method .

The method is tested on database – Diartedb1 [2] to check the specificity, sensitivity and accuracy of the proposed algorithm. Diartedb1 database contains total 89 colour fundus images of which 84 contain at least mild nonproliferative signs (Ma) and 47 contain severe nonproliferative signs (exudates) of the diabetic retinopathy and 5 are normal which do not contain any signs of the diabetic retinopathy according to the evaluation result of all the experts. The 50 degree field-of-view digital fundus camera is used to capture images with varying imaging settings and without preprocessing. The images contain a varying amount of imaging noise, but the optical aberrations (dispersion, transverse and lateral chromatic, spherical, field curvature, coma, astigmatism, distortion) and photometric accuracy (colour or intensity) are the same. The experts were asked to mark the areas related to the microaneurysms, hemorrhages, and hard and soft exudates. The expert findings are marked as ground truth of this database.

II. METHODOLOGY

The methodology used in this paper is briefed as below:

- (i) Firstly, RGB image is divided into its three channels i.e. red, green and blue channel.
 - (ii) Preprocessing is done only on the green channel since it is the only channel that gives high contrast among all the retinal anatomical structures such as optic disc, blood vessels and the lesions present in the fundus image.
 - (iii) Then, the optic disc is removed from the processed image using connected component analysis.
 - (iv) After removing the optic disc that can contribute largely to false positives, exudates are detected using region based segmentation approach.
 - (v) When exudates are detected the classification of this output image is done on the basis of pixel level intensity/area.
- The following figure shows the flow of algorithm used.

A. Preprocessing

In the methodology adopted we have used green channel of the RGB fundus image. So, firstly all the three channels i.e. red, green and blue are extracted from the RGB image. Then preprocessing techniques used to enhance the contrast, intensity or for removing noise are applied only on the green channel. Green channel is selected because it provides high contrast between the anatomical structures such as blood vessels, optic disc, macula and diabetic retinopathy lesions. In some images there is no proper illumination due to which contrast of the image in green channel is not so good. Hence, to the input green channel image, image adjustment is applied to adjust the intensity values so that contrast in a low contrast image can be improved.

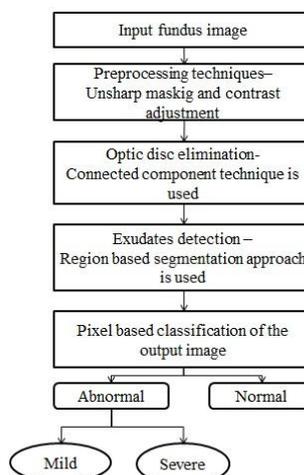


Figure 2: Flow chart showing the methodology adopted.

Then, unsharp masking (USM) is applied on contrast adjusted image. USM returns an enhanced version of the processed input image, where the image features, such as edges, have been sharpened using this method, as shown in fig. 4(c). Three parameters i.e. amount, radius and threshold are used to define the extent of USM applied over the image. After these preprocessing techniques applied over the image, the processed image is then converted to binary image that contain only 0's and 1's represented by black and white respectively.

B. Optic Disc Elimination

The removal of Optic disc from the fundus image is very essential while detecting exudates. Since the intensity and color of the optic disc is very much similar to that of the exudates, it can contribute to the false positives. There are several methods in literature survey that are used for removal of optic disc from the fundus image as discussed above. In this approach we use simple pixel based technique called connected component removal method. As we know optic disc has the largest bright area in the fundus image, as shown in processed binary image in fig. 4(d). All the pixels that come under the optic disc are highly connected to each other, but still in many images the connectivity is not so good that they can be removed easily by using area based approach. In the proposed technique, firstly all the pixels that are connected to each other are summed up and from the plot of this summed pixels against pixel locations as shown in fig.4(e), a point of maximum summed pixels is determined that depicts the location of optic disc. After the location of optic disc is obtained then all the optic disc pixels are made connected by using simple approach of filling that area with 1's. Then the area of optic disc is removed by masking. The image after removing optic disc is shown in fig.4 (f).

C. Exudate Detection

After the removal of optic disc from the fundus image, next step is to detect the exudates. The binary image left after the removal of optic disc is used for further processing in automatic detection of exudates. A hybrid approach based on minimum area detection and region based segmentation is used for exudate detection. In this approach firstly the minimum area that can be covered by exudates is detected from the binary fundus image using region property of the image. The areas detected are then sorted according to the descending order in a matrix and from this matrix the minimum required area is selected. All the pixels that have connectivity larger than the minimum value are taken as exudates and rest are discarded as they can be due to some noise. The resultant figure is shown in fig. 4(f). This approach can also be named as region based segmentation because here exudates are detected using the region property of the pixels of the fundus image. We have used simple pixel based techniques so that it can be easy for ophthalmologists to use this method. Also this technique is very fast and effective.

D. Classification of Disease

Classification of the disease on the basis of how much exudates are present in the retinal image is very important. By classifying the disease it is easy for ophthalmologists to take the right decision. The classification here is done in two phases, in the first phase the fundus image is classified into normal or abnormal fundus image. Then, in the second phase, the abnormal fundus image is further classified into mild disease or severe disease on the basis of area covered under exudates. For the first phase, simply a threshold value on the basis of pixel count is set on the output image. Any image having pixel count less than the threshold value is considered as normal and the ones that exceed the threshold value are considered as abnormal images. Then, for the abnormal images, again a threshold value is set that will be based on the area covered by the exudates in the abnormal images. If the area coming under the exudates exceeds the threshold value then the disease is classified as severe otherwise it is classified as the mild category disease. The classification approach used in the proposed work is very simple. As we have worked on the pixels in this approach it is easy for the users to understand the working of this hybrid approach.

III. EVALUATION AND PERFORMANCE ANALYSIS

For automated detection of lesions in fundus images two measures are mostly used: sensitivity and specificity. Confusion matrix is used for measuring the sensitivity and specificity.

Predicted class →	C1(YES)	C2(NO)
Actual class ↓		
C1(YES)	TP	FN
C2(NO)	FP	TN

Fig. 3:Confusion Matrix

The sensitivity is defined as the ability of a test to detect correctly people with a disease or condition.

$$Sensitivity = TP / (TP + FN) (1)$$

The specificity is defined as the ability of a test to exclude properly people without a disease or condition.

$$Specificity = TN / (TN + FP) (2)$$

The accuracy is the proportion of true results (both true positives and true negatives) among the total number of cases examined. It is also used as a statistical measure of how well a diagnostic test correctly identifies or excludes a condition. It can be calculated as:

$$Accuracy = TP + TN / (TP + TN + FP + FN) (3)$$

TP (True positive): Sick people correctly diagnosed as sick i.e. abnormal image detected as abnormal.

FP (False positive): Healthy people incorrectly identified as sick i.e. normal image detected as abnormal.

TN (True negative): Healthy people correctly identified as healthy i.e. normal image detected as normal.

FN (False negative): Sick people incorrectly identified as healthy i.e. abnormal image detected as normal.

We are also using accuracy as third parameter to check the effectiveness of the proposed algorithm.

IV. RESULTS AND DISCUSSION

The proposed approach is implemented in MATLAB R2014a and is tested over Diartedb1 database. Diartedb1 contains total 89 images out of which 84 images contain mild non-proliferative signs according to all experts participated in the evaluation. Only 47 images contain exudates and other images may contain some signs of haemorrhages and microaneurysms according to the ground truth marked by the experts. We have chosen sensitivity, specificity and accuracy to measure the performance of the algorithm at the pixel level. This evaluation considers the four values such as true positive (TP), true negative (TN), false positive (FP), false negative (FN) as discussed above.

The sensitivity, specificity and accuracy can be measured in two ways i.e. either on image basis or pixel basis. On the pixel basis, each image pixel is validated against the ground truth and then the evaluation is done. On the other hand, in image basis evaluation, only number of images containing exudates is checked against that provided by the ground truth. In this work, we have measured the performance parameters on image as well as pixel basis. The results for image basis are given in the Table 1 below.

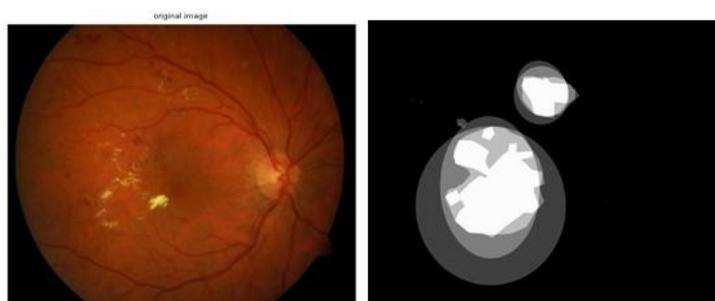
The results for sensitivity, specificity and accuracy on the pixel basis are given in the Table 2. We have shown the results only for some selected images here.

Table 1 Image Base Evaluation

Sr.No.	Database	True positives (TP)	True negatives (TN)	False positives (FP)	False negatives (FN)	Sensitivity	Specificity	Accuracy
1.	Diartedb1	42	37	6	4	91.33%	86.04%	88.76%

Table 2 Pixel Base Evaluation

Sr. no.	Database/ image	True positives (TP)	True negatives (TN)	False positives (FP)	False negatives (FN)	Sensitivity (%)	Specificity (%)	Accuracy (%)
1.	Diartedb1/ image001	5	95	0	0	100	100	100
2.	Image 002	3	96	1	0	100	98.97	99
3.	Image 005	14	84	2	0	100	97.67	98
4.	Image 009	5	95	0	1	83.33	100	99.09
5.	Image 014	12	88	0	0	100	100	100
6.	Image 015	10	89	1	0	100	98.89	99
7.	Image 016	17	82	0	1	100	98.80	99
8.	Image 019	20	78	2	0	100	97.50	98
9.	Image 024	7	93	0	0	100	100	100
10.	Image 035	4	95	1	0	100	98.96	99
11.	Image 037	0	100	0	0	100	100	100
12.	Image 042	0	99	1	0	100	99	99
13.	Image 53	14	83	1	2	87.50	98.81	97
Overall Results						90.83	98.12	99



(a) Original Fundus image

(b) Ground truth

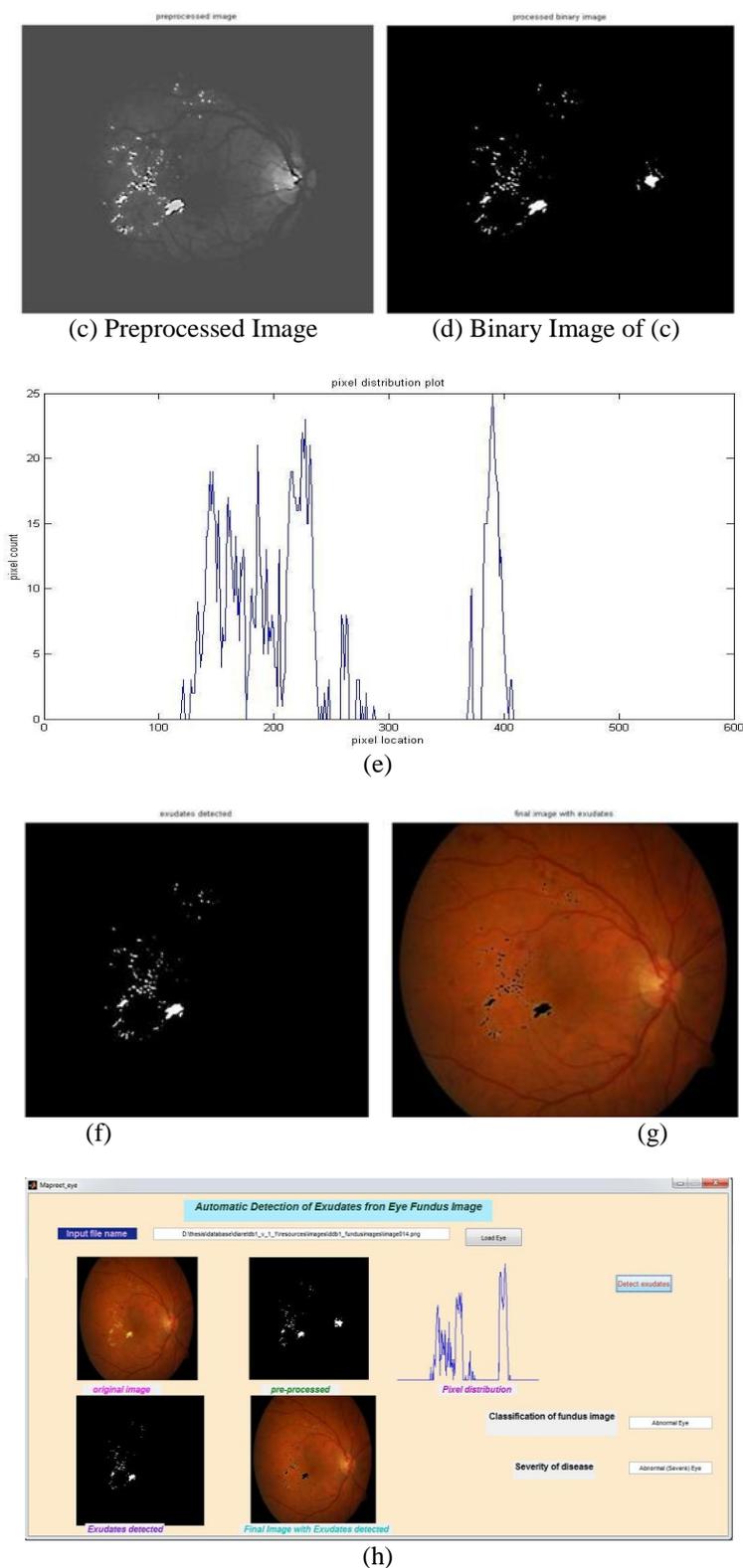


Figure 4: (a) Input image, (b) Ground truth labelled by experts for the input image; (c) Preprocessed image after applying unsharp masking; (d) Binary preprocessed image showing exudates alongwith optic disc detected; (e) Graph between location of pixels vs no. of pixels showing location of optic disc at 389; (f) Image with optic disc removed; (g) Final image with exudates detected, and (h) Graphical user interface for the proposed work showing all the results.

The overall results obtained from pixel basis evaluation are 90.83% sensitivity, 98.12% specificity and 99% accuracy. Results obtained by the proposed technique are shown in fig 4(a)-(h). Graphical user interface (GUI) shows all these results alongwith classification results i.e. severity level of disease (exudates) in a fundus image.

The proposed method has been compared with recently used approaches i.e. morphological operations by MohdFazli et al. in [17] and region based approach by Mohamed Omar et al. in [18]. The comparison has done on the basis of average sensitivity and then the ROC curve has also plotted, fig.5 to show the relative operating characteristics of these methods in comparison to the proposed method.

Table 3 Comparison of Exudate Detection Techniques Using the Diaretdb1 Database

Sr.No.	Method	Average Sensitivity
1.	MohdFazli, et al [17]	82.39%
2.	Mohamed Omar, et al [18]	85.39%
3.	Proposed Method	90.83%

The ROC curve evaluates the discriminatory ability of a test to correctly pick diseased and non-diseased subjects.

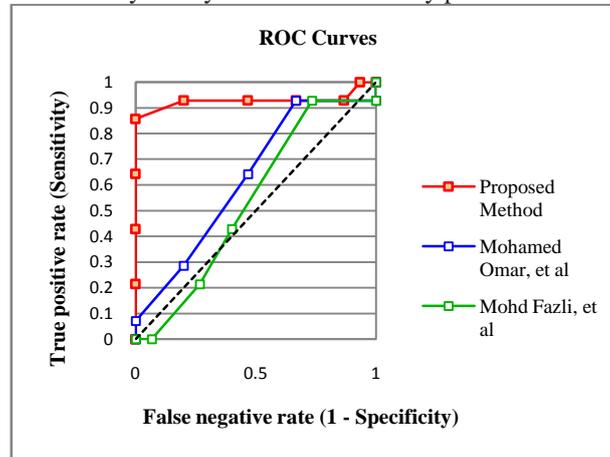


Fig. 5: ROC curve showing comparison of various methods.

Here, ROC curve shows the comparison of various methods used for automatic detection of exudates. From ROC curve analysis it can be said that the performance of the proposed method is higher than that of the other two methods since AUC (area under curve) of the proposed method is highest i.e. 0.929 while that of others is 0.626 and 0.538.

V. CONCLUSION

In this paper, we have proposed a hybrid approach for exudate segmentation approach which is based on the combination of unsharp masking, region based segmentation and pixel based classification. Unsharp masking is used in preprocessing step to enhance the contrast of the fundus image. Optic disc is the main anatomical structure that contributes highly to the false positives, hence it is removed by using connected component approach. Then region based segmentation approach is used for exudate detection and classification of the disease is done on the basis of pixel count. This method has been proven to be robust and consistent with improved performance over the previously reported techniques. On the image-level, our proposed method achieved Accuracy value of 88.86% and white that on pixel-level it is 99% on the publicly available dataset DIARETDB1. With these results, the proposed technique has gained higher accuracy in comparison to several other state-of-the-art approaches.

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