International Journal of Computer Information Systems and Industrial Management Applications.
ISSN 2150-7988 Volume 7 (2015) pp. 131–138

Detection of Laser Marks from Retinal Images for Improved Diagnosis of Diabetic Retinopathy

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Abstract: **Eye diseases such as diabetic retinopathy may cause blindness. It affects the central vision of the person and in some cases causes severe blindness. Diabetic retinopathy is a progressive disease so at the advance stages of diabetic Retinopathy further disease progression is stopped using laser treatment. Laser treatment leaves behind marks on the retinal surface that causes misbehaviors in automated retinal diagnostic system. These laser marks hinders the further analysis of the retinal images so it is desirable to detect laser marks and remove them to avoid any unnecessary processing. In this paper we have proposed a method that uses techniques from image processing and machine learning to help segment out the laser marks from the retinal images. Our method uses techniques to remove uneven illumination from the images using various morphological operations. The system uses Minimum distance classifier using a feature set extracted from the laser marks in retinal images. The evaluation of the proposed system is done on a locally gathered dataset of patients suffering from different Retinal diseases. The result of our system are based on various parameters like accuracy, specificity and sensitivity. A fair comparison with any other technique is not possible due to limited literature on laser marks detection from Fundus images. The results of our method has shown that the laser marks from retinal images are detected with good accuracy though there are some failure cases but the result is still acceptable.**

Keywords: Diabetic retinopathy, Retinal images, Laser treatment, Morphological Operation, laser marks, Feature extraction.

I. Introduction

Diabetic eye diseases are a group of eye diseases that occur as complication to diabetes. All can cause severe vision loss or even blindness. Diabetic eye disease includes: Diabetic retinopathy that affects retinal blood vessels. Cataract, that causes clouding of the eye's lens. Glaucoma that causes optic nerve damage and vision loss due to increase in fluid pressure inside the eye. Diabetic retinopathy is the most common diabetic eye disease and one of the leading causes of blindness [1].
Common symptoms of Diabetic retinopathy include blurred vision, flashes and sudden loss of vision [2]. Diabetic retinopathy is classified in two types, Non-proliferative diabetic retinopathy (NPDR) and Proliferative diabetic retinopathy (PDR) as shown in figure.1 [3]. NPDR, also known as background Diabetic retinopathy contains the mild or early signs of diabetic retinopathy. Proliferative diabetic retinopathy is the advanced stage; at this stage photocoagulation (laser treatment) is used to further stop the leakage of blood and fluid into the retina. A laser beam of light is used to create the small burns in area of the retina with abnormal blood vessels that seals the leak. This treatment depends on the stage of DR and it is used to stop the further progression of the disease [3]. Figure 2 shows healthy and DR images respectively. Laser treatment is used to slow disease progression by stopping the leakage of blood in to the retina [3]. In consequence of that it usually leaves behind scars and other

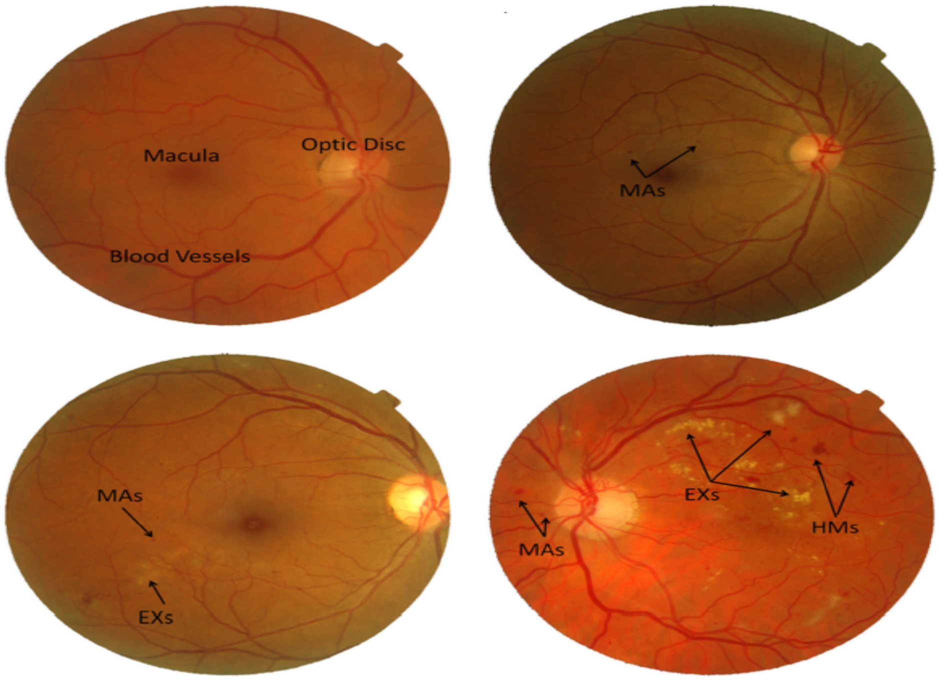

Figure. 1: Stages of Diabetic Retinopathy

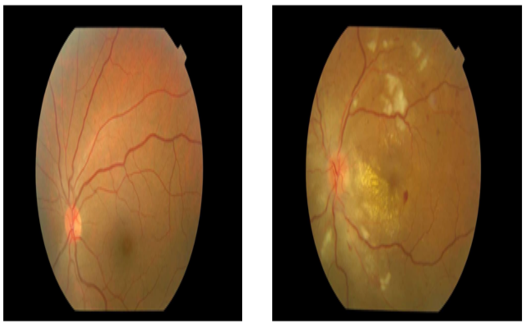

Figure. 2: (a). Normal retinal image (b). Retinal image with exudates

marks that hinder the image assessment methods of DR [4]. Retinal laser treatment is widely used, so the detection of the marks formed by it and the evaluation of those marks is an important problem to address. In result to laser treatment mark are usually formed as small and circular spots or as large and asymmetric spots in the retina as shown in figure-3.

These spots affect the ability for the automated or manual diagnosis of the retinal images. The automated analysis of digital images may reduce the human grading workload and therefore it is useful to increase the cost effectiveness of DR screening initiatives. There are number of methods in literature for automated diagnosis of DR. CAD based systems has revolutionized the field of medical image diagnostic. A number of methods for retinal image enhancement and segmentation have been proposed. In [5] two approaches were used to find laser marks, one was the generic parameter classification (GPC) that relied on color, focus, contrast and illumination features of the retinal images and the other was structural parameter classification that relied on color and structure information, structure information was gathered by calculating the gradient map of the image and then applying various morphological operation and finally in both cases these features were fed to feed forward neural network to classify image as either containing laser or not containing laser marks. Reza *et al.* [6] proposed a method that uses green channel along with variable or fixed thresholding technique as a pre-processing step for the detection of optic disc or exudates from colored fundus images. Uneven illumination in intensity channel was equalized using Adaptive and local contrast enhancement techniques [7-9]. Niemeijer *et al.* [10] presented a thresholding scheme which was employed to differentiate between the cotton wool spots and hard exudates. A region growing technique was used to detect micro-aneurysms [11]. Fuzzy C-means clustering based technique was used to segment retinal images followed by some pre-processing steps i.e. color normalization and contrast enhancement. For Classification of the clustered data a set of features like, color, intensity and texture etc. were extracted. Best features were identified using genetic based algorithm. And then a multilayer neural network was used to classify the selected features [12].

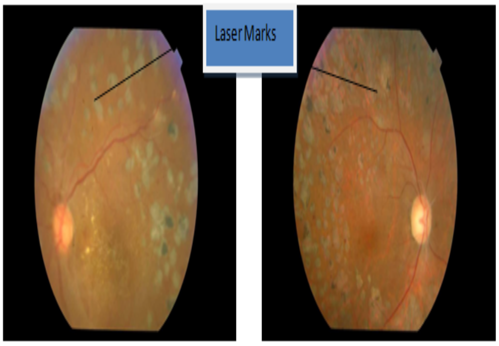

Figure. 3: Images with Laser Marks

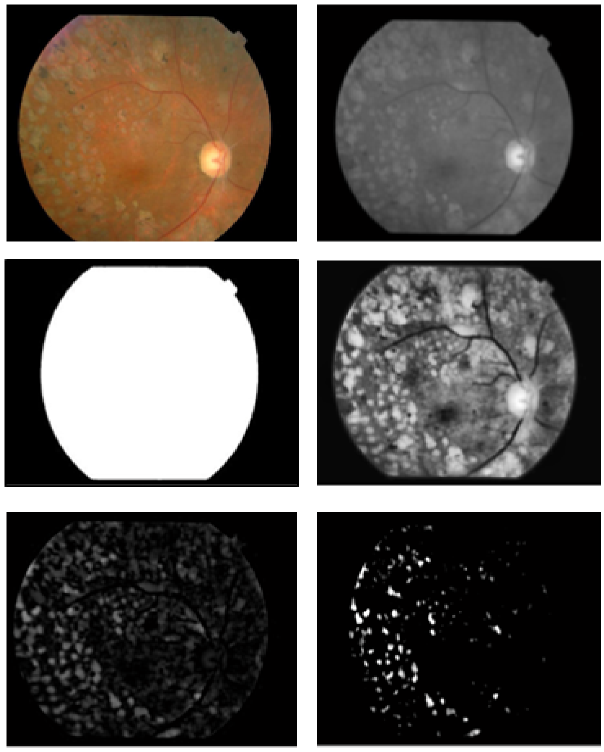

Figure. 4: Preprocessing (a).Original Image (b).Filtered image (c).Background Mask (d).Clip Limit Adaptive histogram equalized Image (e).Background estimated image (f).Contrast Enhanced version of (e)

II. Proposed System

Image processing and machine learning based systems plays an essential role in medical diagnostic. Computer Aided Diagnostics (CAD) has set new paths to the detection of various diseases. Similarly CAD is playing a vital role in diagnosis of Diabetic retinopathy. Figure 5 shows the complete setup from preprocessing to the classification of retinal images. Our proposed system also uses techniques based on machine learning and image processing and is divided into 3 steps, the retinal image input and its pre processing, candidate region detection and then feature set formulation and classification of the marks as laser marks using minimum distance classifier.

A. Pre-Processing

The retinal images in the data set often contains noise and lack proper illumination due to unknown noise and camera settings. Thus the acquired retinal image is passed through various pre processing steps to remove those undesired artifacts that include green channel extraction, Adapt. Histogram Equalization and Background illumination estimation. Adaptive Contrast Enhancement technique is applied on the image to improve the contrast between the retinal surface and the laser marks using a W*W sliding window assuming that the window should contain the statistical representative distribution of the local variation of laser marks.
Where I is the Green channel of the image and Φ_w is the exponential sigmoid function of a window size. And Φ_{Imin} and Φ_{Imax} are maximum and minimum intensity values of the green channel. In green channel of the retinal images laser marks looks bright as compared to red and blue so green channel is extracted out for further processing. Circular averaging filter is applied on the green channel to reduce the noise further by blurring effect and Clip limit Adaptive histogram equalization is applied to improve contrast between the laser marks and background. Background illumination causes a lot of problem while extracting the region of interest from the image and gives a lot of noisy artifacts to deal with if not handled beforehand so to estimate the background illumination morphological opening operation is performed using equation 2 [13].A complete description of the preprocessing step on an image is shown in figure 4.

$$I_c = 255\frac{\Phi_w(\phi_I) - \Phi_w(\phi_{Imin})}{\Phi_w(\phi_{Imax}) - \Phi_w(\phi_{Imin})} \quad (1)$$

$$f \circ b = (f \oplus b) \ominus b \quad (2)$$

Where symbol $\circ$ represents morphological opening, b represents structuring element, symbol $\ominus$ represents erosion and symbol $\oplus$ represents dilation of the result after erosion. This gives us the background illumination estimate that when subtracted from the Original image gives an image that has uniform background but is now a bit too dark that needs enhancement. Contrast enhancement is used to improve the contrast of laser marks for easy and better detection of laser marks.

B. Candidate Region

The preprocessing i.e. green channel extraction, smoothing, background estimation and contrast enhancement removes some of the undesired artifact from the image by suppressing and smoothing down all the noise.
A threshold value for the pre processed image is calculated using Otsu's method. Otsu's method works in such a way so as to minimize the intra class variance which is defined as the sum of variance of the individual classes and is given by equation (3). Here w1 and w2 are the probabilities of the two participating classes and t is the separating threshold and σ_1^1, σ_2^2 are the of these classes. As a result of this thresholding technique laser marks along with some other unwanted exudates regions are extracted out. So in order to get only

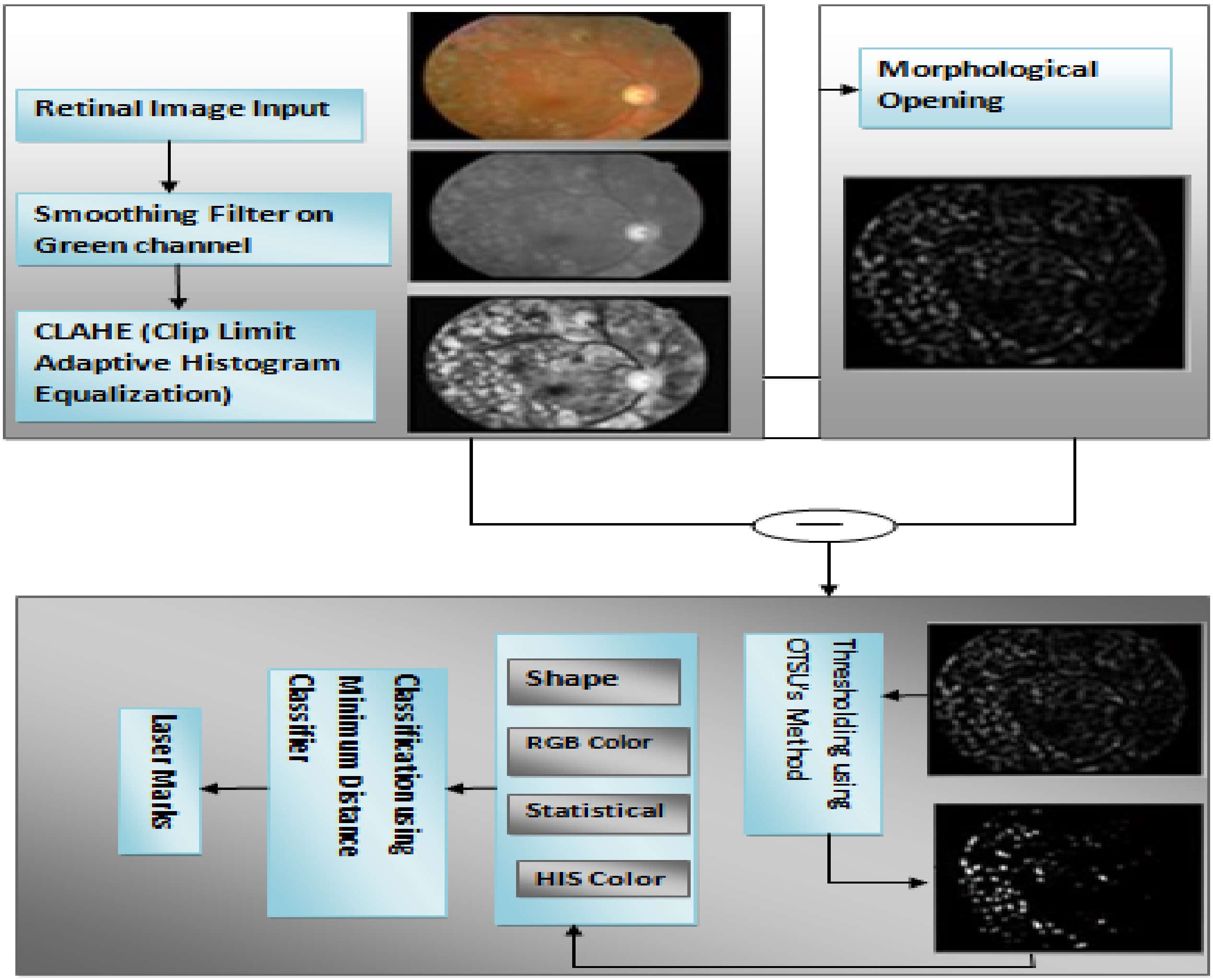

Figure. 5: System Block Diagram

the laser marks out of the image we further used minimum distance classifier.

$$\sigma_w^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t) \quad (3)$$

Furthermore this image is passed through some post Processing steps to remove further undesired candidate regions from the binary image that includes morphological filling operation. The resultant image is shown in figure 6.

III. Classification

Classification entails broad range of application in classifying images or parts of images according to our desired needs. All the classification algorithms are based on the fact that the image under test represents some set of features. The candidate region extraction phase extracts all possible candidate regions. The threshold value is kept low so no region with laser marks should be missed out. All marks other than laser marks are removed during classification phase.

A. Feature set formulation

Laser marks appear as small and circular marks or as large and asymmetric spots in the retina. These spots may present a bright or dark appearance. The candidate region extraction phase extracts all potential marks. Let us suppose a retinal image x containing z potential laser marks, then the formulated set containing the laser marks are represented as x= y_1, y_2, y_3,....,y_z. In order to extract out all the laser marks from retinal image, each candidate region is represented by feature set. A candidate region is taken as a sample for classification and its features are extracted that represents that candidate region. Let us suppose a candidate region R from an image x containing m features then the feature vector would be represented as R=x_1,x_2,x_3,x_4,..., x_m. A brief description of the formulated feature set is given as follows:

1) Compactness(x1)

It measures how efficiently a boundary measures the area inside it. In other words it's the measure of shape defined by C=P^2/(4πA), where p and A are the perimeter length and area of the candidate region, respectively

2) Max Hue(x2)

Hue represents the element of visual representation and its maximum value is taken as a feature.

3) Max saturation(x3)

It is the measure of the intensity of the color in the image and its maximum value in an object is taken as a feature for classification.

4) Standard deviation of saturation(x4)

First Image is converted from RGB to HIS model than its saturation channel is extracted out and then standard deviation of saturation for al l the candidate pixels are used as feature for classification.

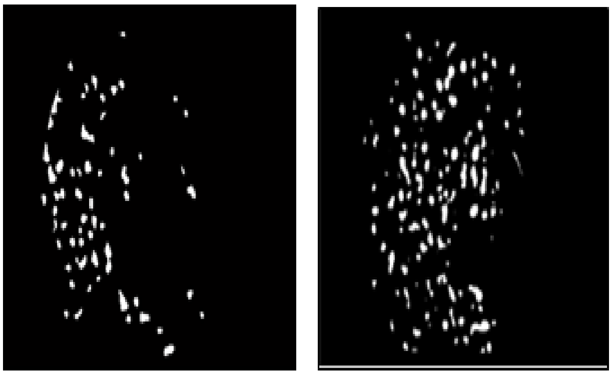

Figure. 6: Candidate Region

5) Intensity mean (x5)

It is the measure of the mean of the intensity value for all pixels in a candidate region.

6) Intensity max(x6)

It gives the maximum value in the intensity channel of the candidate region.

7) Intensity standard deviation(x7)

It tells about the standard deviation of intensity in its candidate region.

8) Mean Red channel(x8)

It gives the measure of mean value of an Red plane in RGB model.

9) Max Red channel(x9)

It gives the measure of maximum value of a Red plane in candidate region Max Green channel(x10): It gives the measure of maximum value of a Green plane in candidate region. Entropy(x11): Value of all pixels in minimum bounding square region across candidate region Eccentricity(x12): It is the distance between the ellipse foci divided by its major axis.

10) Max Green channel(x10)

It gives the measure of maximum value of a Green plane in candidate region.

11) Entropy(x11)

Value of all pixels in minimum bounding square region across candidate region

12) Eccentricity(x12)

It is the distance between the ellipse foci divided by its major axis.

B. Feature Selection

These twelve features are selected out from twenty different features using statistical test. The test we used to select the features out of these 20 features is wilcoxon rank sum test. Which checks whether the normal or abnormal class median values differ significantly?

Table 1: Extracted Features

Features	**Mean $\mp$ STD**
1. Compactness	0.537 $\mp$ .2104
2. Max hue	0.1108 $\mp$ 0.0157
3. Max Saturation	0.6395 $\mp$ 0.0609
4. St. deviation of saturation	0.0235 $\mp$ 0.0106
5. Intensity Mean	0.6379 $\mp$ 0.0854
6. Intensity Max	0.6808 $\mp$ 0.1017
7. Intensity St. deviation	0.0178 $\mp$ 0.0085
8. Mean Red Channel	0.6379 $\mp$ 0.0854
9. Max Red Channel	0.6808 $\mp$ 0.1017
10. Max Green Channel	0.5191 $\mp$ 0.0941
11. Entropy	0.167 $\mp$ 0.3507
12. Eccentricity	0.7565 $\mp$ 0.1390

C. Minimum Distance classifier

In candidate region detection a minimal threshold value was taken in order to ensure that maximum possible regions should be segmented. All false region will be removed in this phase of proposed method. In order to classify the candidate region as a laser marks we have used Minimum distance classifier [14]. We have used a supervised classification technique. A training set having features as shown in table [1] is formed using multiple images and then used minimum distance classifier to get a decisive boundary based on the trends of the training data. The minimum distance classifier is given as equation 4

$$D_j(x) = \| x - m_j \|,$$
$$where \qquad m_j = \frac{1}{N_j \sum x_j} \tag{4}$$

In equation 4 'x' is the feature vector of the unknown input and mj(As shown in table 1) is the perfect noise free feature vectors or the mean vector we get after training phase. Table 1. Shows the feature values of the training phase

IV. Experimental Result

The evaluation of proposed system is performed on a locally gathered dataset of patients suffering from different retinal diseases. The dataset consists of 380 images with 1504 x 1296 resolution. The images are captured using top con 50EX mydriatic camera. These images are manually labeled as laser treated or not with help of ophthalmologists. The dataset contains a total 51 images which are treated with laser and contain some or more laser marks. The remaining images contain some image from normal patients and others with different levels of retinal diseases but without any laser operation.

A. Results

This section evaluates the performance of the proposed method for the detection of laser marks. The performance measure of the proposed system is defined by sensitivity, specificity and accuracy. Sensitivity defines the true positive rate and specificity defines true negative rate. These performance evaluation measures are given by equations 5, 6, and 7 respectively.

$$Sensitivity = \frac{T_P}{T_P + F_N} \tag{5}$$

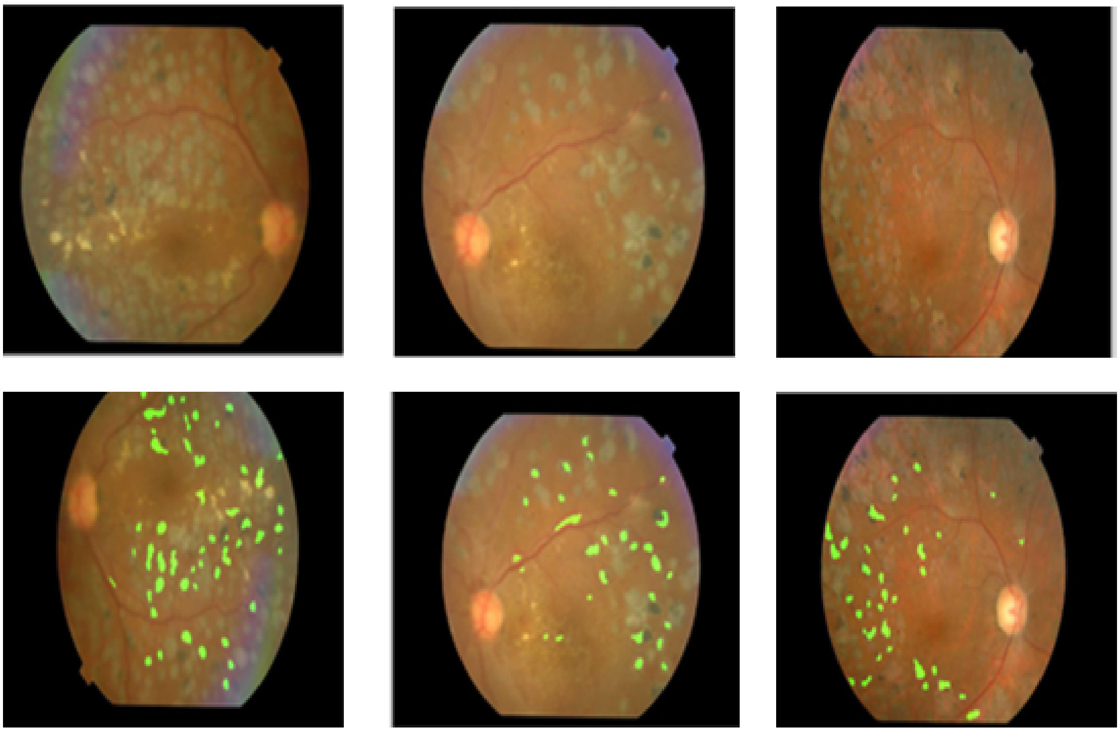

Figure. 7: Row-1 Input Retinal Images and Row-2 Output

Table 2: Confusion Matrix

Actual/Predicted	Yes	No
Yes	48	3
No	9	320

$$Specificity = \frac{T_N}{T_N + F_P} \quad (6)$$

$$Accuracy = \frac{T_P + T_N}{T_P + P_N + F_P + F_N} \quad (7)$$

Where
TP (True positives) means that the laser marks are correctly classified
TN (True negative) means that the Non laser marks are correctly classified.
FP (false positive) means that the Non laser marks are incorrectly classified as having laser marks.
FN (false negative) means that the laser marks are incorrectly classified as not laser marks.
Table.2 shows confusion matrix for the performance evaluation of the proposed method
The results of the confusion matrix suggests that out of 51 laser operated images 48 are correctly predicted as having laser marks and 3 are predicted as not having laser marks. Whereas only 9 images are non laser images are predicted as having laser marks and 320 are correctly predicted as having no laser marks. Table-3 shows the different performance parameter results for proposed system
The results demonstrate that the proposed system detects laser operated images with great accuracy. Although there are some failure case but still the results are acceptable. A fair comparison with any other technique is not possible because of the limited available literature for laser mark detection and also lack of a benchmark dataset. Fig.7 shows some results on digital retinal images. Fig-8 shows the complete algorithm on image.

Table 3: Evaluation Result of Proposed Method

Total Images	Laser Treated	Sensitivity	Specificity	Accuracy
380	51	0.94	0.97	0.96

V. Conclusion

Digital retinal images are widely being used for automated diagnosis of different retinal diseases. Laser operation is normally carried out at advanced stages of retinal diseases to avoid further or complete vision loss. This treatment generates laser burn marks on the surface of retina and can be falsely detected as abnormal marks by automated system. In this paper, we presented a simple and straight forward but affective method for laser marks detection. The main motivation is to facilitate automated diagnosis methods and to avoid false detection of abnormal regions due to these laser marks. The proposed system extracted all possible regions which may be considered as laser marks using different image processing techniques and then the true laser mark regions are extracted using minimum distance classifier and a number of features. The proposed system has been evaluated by using various parameters like sensitivity, specificity and accuracy and the result has shown that the laser marks are detected with great accuracy although there are some failure cases but the results are still acceptable. The proposed system can be used to assist computer aided diagnostic systems for retinal diseases to improve their results by separating the

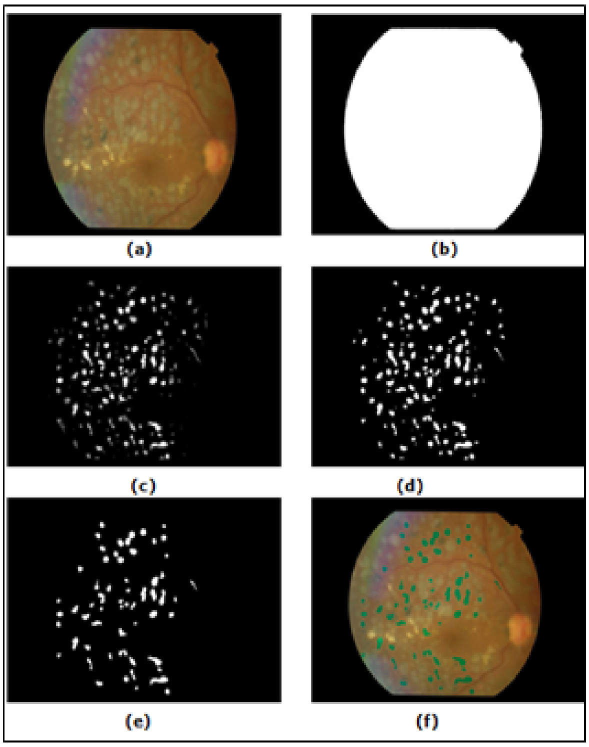

Figure. 8: (a).Original Image having laser marks (b).Background mask (c).Image before applying threshold (d).Image After Applying threshold (e).Binary Map of Image having Laser Marks Only (f). Original Image with labeled green colored laser marks

laser operated cases from actual abnormal cases.

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