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Automatic Detection of Glaucoma and Diabetic Retinopathy in Retinal Images

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Abstract— The early detection and treatment of retinal eye disease is critical to avoid preventable vision loss. Glaucoma is a chronic disease which if not detected in early stages can lead to permanent blindness. The medical techniques used by ophthalmologists like HRT and OCT is costly and time consuming. Hence there is a need to develop automatic computer aided system which can detect glaucoma efficiently and in less time. The states of retinal blood vessels can be used to detect some diseases like diabetes. Diabetic Retinopathy (DR) is an eye disease which occurs due to diabetes. The risk of the disease increases with age and therefore, middle aged and older diabetics are prone to Diabetic Retinopathy. The DR is characterized by the presence of exudates. Exudates are the initial stages of DR; with the damaged conditions in blood vessel the retina begins to leak extra fluid and low amount of blood in to the eye. Hence the detection of exudates is very much important.

Keywords— Diabetic Retinopathy, Exudates, Glaucoma.

I. INTRODUCTION

Currently, there is an increasing interest in establishing automatic systems that screen a huge number of people for vision threatening diseases like glaucoma and diabetic retinopathy and to provide an automated detection of the disease. The early detection and treatment of retinal eye disease is critical to avoid preventable vision loss. Conventionally, retinal diseases identification techniques are based on manual observations which consume time. The most common way via which glaucoma can be detected is by finding cup-disk ratio. Detection of optic disk is essential in developing automatic diagnosis systems and its segmentation is a crucial and a vital step. Another significant contribution of this proposed work is that another ocular parameter i.e. Rim to Disc Ratio is computed and is used along with Cup to Disc Ratio for classifying the images as glaucoma tic or normal. This is a more efficient and robust method of classification as it increases the reliability.

The DR affect retina in many ways. Blood vessels get altered, exudates are secreted, and Hemorrhages occurs, swelling appears in the retina. Exudates are the initial stages of DR, with the damaged conditions in blood vessel the retina begins to leak extra fluid and low amount of blood in to the eye. Hence detection of exudates is very much important to detect the level of DR. Early diagnosis and treatment has been shown to prevent visual loss and blindness. Retinal images obtained by the fundus camera are used to diagnose DR. Automated methods of DR screening help to save time, cost and vision of patients.

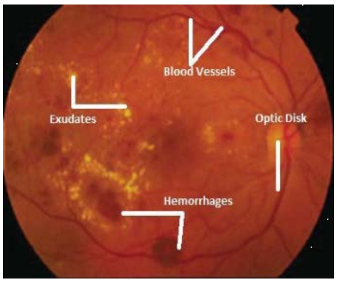

Fig.1.1 Fundus image with lesions

In this work we develop a system that will be able to identify patients with DR from the color images obtained from the retina of the patient. These types of images are called fundus images. In order to perform a task without inserting any command code, simple and user-friendly software is created to facilitate the user when operating the interface. In addition, it benefits the organization by reducing their cost in the long run .As patients in the non-proliferative and proliferative classes are prone to losing their vision, there is a need to identify and notify the affected patients to go for early treatment. Otherwise, the consequences will be irreversible.

However these patients usually perceive no symptoms until the later stages, when visual loss develops and treatment is less effective. Therefore annual eye fundus examination is necessary to ensure timely treatment application. The primary aim of this project was to develop a system that will be able to identify patients with Glaucoma, and Diabetic retinopathy from color images obtained from the retina of the patient.(These types of images are called fundus images).After the detection of exudates , Map the grading of Diabetic Retinopathy (DR) based on the statistical features of the exudates in fundus images to manage the disease appropriately to decrease the chances of vision impairment. An automated detection system will help to identify the diseases at earlier stages.

The project is designed with the fundamental knowledge in digital image processing, basics of statistics, Classifiers, artificial neural network and fundamental mathematics involving matrices. The program is developed using Math works MATLAB software, which it is presented in a Graphical User Interface. The concepts of Digital Imaging are covered in the following Digital Image, Image Pre-processing, Image Analysis and Classification.

II. LITERATURE SURVEY

Glaucoma progression precedes some structural changes in the retina which aid ophthalmologists to detect glaucoma at an early stage and stop its progression. Fundoscopy (also known as ophthalmoscopy) and Optical Coherence Tomography (OCT) are two modern biomedical imaging techniques that enable ophthalmologists in examining the inner details of eye to detect abnormalities. These diagnostic techniques are time consuming. Automated analysis of retinal images has the potential to reduce the time, which clinicians need to look at the images, which can expect more patients to be screened and more consistent diagnoses can be given in a time efficient Manner.

Automated grading of DR was done by many researchers. The methodologies used in the existing algorithms and techniques follow somewhat similar flow of process. Many techniques are based on mathematical morphology, neural networks, pattern recognition, region growing techniques; fuzzy C-means clustering, Gabor filter banks. Several methods were applied to detect optic Disc. Such as Principal component analysis (PCA). Where the candidate regions for optic disc were derived by clustering of brighter pixels. Splat based representation is an image resampling technique for an irregular grid. This technique is used to maximize the diversity of training samples. To separate the boundaries of hemorrhages from retinal background using scale specific image over segmentation. It performs in two steps, Separating the blood and retinal background by using gradient magnitude technique. To perform watershed segmentation. There are multiple medical tests are available, but on behalf of some tests image processing techniques are applied on the retinal fundus images and getting more accurate result through it.

III. GLAUCOMA DETECTION METHODOLOGY

Our proposed technique provides a novel algorithm to detect glaucoma from digital fundus image using a hybrid feature set. In biomedical imaging glaucoma detection is one of the active researches being done in the field of autonomous glaucoma detection systems to provide state of art computer aided design (CAD) tool that can aid ophthalmologists in early glaucoma detection. Many image processing, computer vision and machine learning techniques and tools are being used to excel in this research field and come up with more accurate results that might help in more accurate and early glaucoma diagnosis.

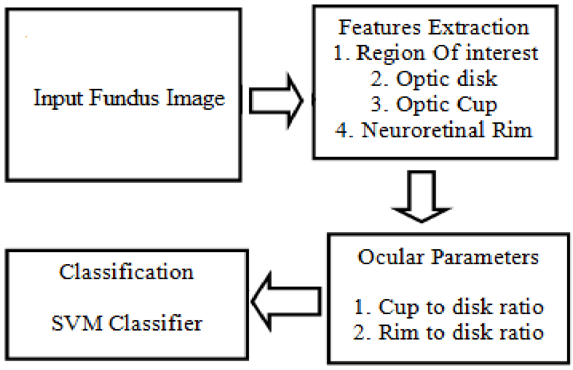

Fig.3.1 Overall System architecture

RGB fundus image is used as an input. A fundus camera is used to take pictures of the inner surface of the eye .Since glaucoma affects optic disk and optic cup by changing cup to disk ratio and rim to disk ratio therefore proper segmentation of both the features is essential for glaucoma detection. The system has been identified to have the following modules:

A. Region Of Interest(ROI)

B. OD Segmentation

C. OC Segmentation

D. Neuroretinal rim

E. Classification

A. Region of interest module

RGB fundus image is used as an input. In order to detect glaucoma, the most important region of interest is optic disk. Thus, instead of processing on the whole retinal image, region around optic disk is extracted. This ROI is a small image which helps in faster processing and large automated screening of glaucoma.

B. OD Segmentation Module

To detect optic disk, red channel of ROI is used , optic disk appears to be the brightest and blood vessels are also suppressed in this channel. Hence it is easier and accurate to segment optic disk in red channel of input fundus image. Otsu thresholding technique is used to segment the optic disk which makes the segmentation independent of image quality.

C. OC Segmentation Module

Optic cup is segmented using green component of ROI image. Statistical features such as mean and standard deviation for green channel of ROI image are calculated. These features help in making the method adaptive of image quality. Mean X and standard deviation σ are obtained as:

$$X=1/N*xi \quad (1)$$

$$\sigma 2 = 1/N * (xi - X)2$$

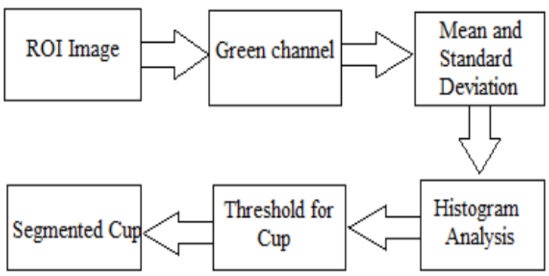

Fig.3.2 Block Diagram for optic cup segmentation

Standard deviation is defined as the square root of variance. Histogram of green channel is examined. It is a graphical representation of number of pixels with respect to gray levels in digital image. The histogram of each image is examined to determine threshold level for segmenting optic disk and optic cup. it is determined experimentally that optic cup lies at an intensity level given by,

$$Tcup = Mean + 3*Standard\ deviation \quad (2)$$

Where Tcup is the intensity level which is decided as a threshold value for segmenting optic cup.

D. Neuroretinal Rim

Neuroretinal rim is the region located between the edge of optic disk and optic cup. After segmenting the optic disk , Figure 3.3.(a) and optic cup Figure 3.3.(b), NRR is obtained by subtracting optic cup from optic disk. NRR is shown in Figure 3.3.(c).

The changes in appearance of this area help in identifying damage to the disk due to glaucoma. Thickness of the rim is an important feature to detect whether the fundus image is glaucoma tic or not. The healthy optic disk is thicker in inferior portion then in superior, then nasally and thinnest temporally. In a glaucoma tic eye, cup increases in its area vertically reducing the thickness of the rim in infero - temporal disk sectors. Thus rim-disk ratio for infero-temporal region and infero-nasal region of the rim can be evaluated to determine glaucoma.

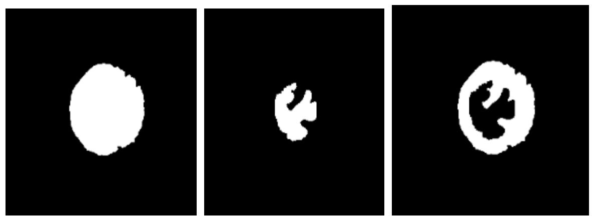

Fig.3.3 (a) Segmented optic disk, (b) Segmented optic cup, (c) Neuroretinal rim

E. Classification

Classification of images as glaucoma tic or healthy is done on the basis of two parameters; Cup to disk ratio and rim to disk ratio.

1. Cup to disk ratio

The first parameter that we use to detect glaucoma is CDR i.e. cup-disc ratio. CDR is defined as ratio of total segmented cup area to total segmented disk area.

CDR = Optic Cup Area/Optic Cup Area (3)

Cup area and disk area are obtained by summing all the white pixels in segmented cup and disk. This calculated CDR is used for screening of Glaucoma. If CDR is greater than 0.3(globally accepted value), the fundus image under test is said to be glaucoma tic else it is healthy.

2. Rim to disk ratio

The CDR in itself is not one of the best predictors of whether the eye is glaucomatic. Many a times a person has been diagnosed inappropriately due to large optic cup in presence of large optic disc and has healthy rim tissues. Thus Neuroretinal rim tissue plays a vital role in glaucoma detection. Rim to disk ratio is evaluated for both eyes using the algorithm mentioned above. It is defined as

RDR1=Rim area in infero-temporal region/Disk area(Right)

RDR2=Rim area in infero-nasal region/Disk area (Left) (4)

After analyzing a database of 25 images, value of 0.35 is decided as threshold for classifying images as glaucomatic or not. If RDR is less than equal to 0.35, fundus image is considered to be glaucomatic else it is glaucoma free. Both these parameters are calculated to train the SVM classifier for detecting glaucoma so as to increase the reliability and robustness of the system. For classifying the fundus images as glaucomatic or healthy, SVM was used.

IV. DR DETECTION METHODOLOGY

Diabetic retinopathy (DR) is the most frequent micro vascular complication of diabetes and can lead to several retinal abnormalities including micro aneurysms, exudates, dot and blot hemorrhages, and cotton wool spots. Automated early detection of these abnormalities could limit the severity of the disease and assist ophthalmologists in investigating and treating the disease more efficiently. Exudates lesion on retinopathy retinal images was segmented by different image processing techniques. One of these signs is exudates that appear differently in a yellowish or white color with varying sizes, shape, and locations. Exudates are the protein deposits. The size and location of exudates are important information for an ophthalmologist to show the severity of disease. An automatic exudate detection system would be useful to detect and distinguish in retinal images of screening programs three-stage blood vessel segmentation algorithm using fundus photographs.

A Typical screening process involves the acquisition of retinal images from the patient followed by manual examination of each individual image by medical experts in order to identify signs of DR. An efficient classifier for automatic detection of DR are playing vital role in the field of medical image processing. This proposed technique endows with reliable method to detect the presence of retinal hemorrhage in digital fundus image to reduce the computation time. Acquired retinal images are pre-processed and set of features are extracted.

An Optic disc (OD) segmentation algorithm that detects the OD boundary and the location of vessel origin (VO) pixel is used here for the detection of exudate. OD segmentation algorithm that is robust to fundus images with varying FOV, illuminations and pathologies. For the first step, circular structuring elements are found to be preferable over the linear structuring elements for extracting bright regions after morphological reconstruction. In the second step, double cross validation with feature ranking leads to feature reduction for classification of the bright probable OD regions from the non-OD regions.

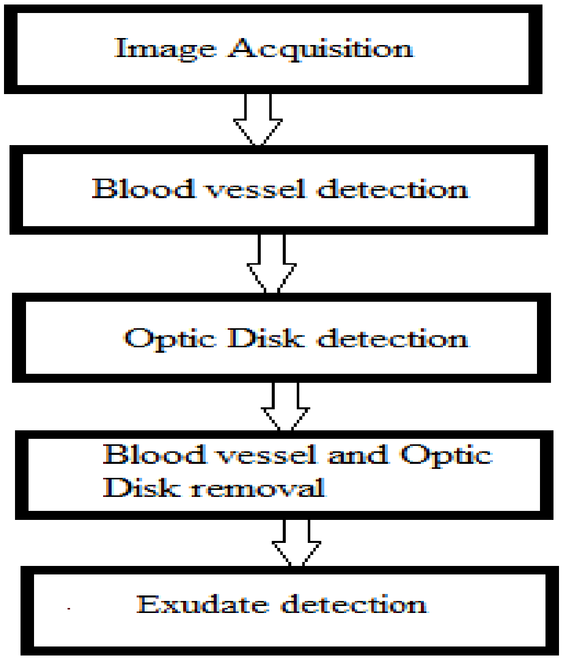

Fig.4.1 Flow chart for detecting exudates

The green channel of RGB image was used in the proposed method since it provides the best Vessel / Background contrast. Consist of 4 stages, i.e. Blood vessel segmentation, OD Segmentation, OD elimination, Exudate Detection and grading of DR

A. Blood vessel segmentation

In the first stage, the green plane of a fundus image is pre-processed to extract a binary image after high-pass filtering, and another binary image from the morphologically reconstructed enhanced image for the vessel regions.

Fig .4.2 Extracted blood vessel

Next, the regions common to both the binary images are extracted as the major vessels. The thick and predominant vessel pixels are extracted as major vessels. Major vessels regions are identified as the intersecting regions between threshold versions of two preprocessed images, i.e., the high-pass filtered image and tophat transformed image.

B. OD Segmentation

OD Is the largest bright circle in the Image. OD Detection allows eliminating the background and its destructive effects on the proposed method..

OD and the position of vessel origin (VO) are the main anatomical features in retinal fundus images. The VO position is an important. The top two selected features are indicative of thick major blood vessels in the bright region neighborhood (Vessel-Sum), and the compact structure of a bright region (Solidity).

The bright probable OD is a region with maximum Vessel-Sum and Solidity. Maximization of these two features among classified bright probable OD regions locates the best candidate region for the OD. Although OD is generally the brightest element in retinal images, the entire OD region is not equally brightly illuminated.

For accurate boundary detection of the complete OD, it is imperative to detect all bright OD regions. To facilitate this, we propose a three-step approach, As a pre-processing step, the green plane of each color fundus image is resized. Following image resizing, the pixel intensities are scaled in the range [0,1], followed by contrast enhancement, resulting in image I. Next, I is morphologically eroded using a structuring element (se), followed by image reconstruction .

The selected structural element is a disk whose radius r increases in each iteration (r = 2; 4; 6; 8). The next step is to separate the regions that are more probable of being the OD from the false positive non-OD regions . For this purpose, 21 region-based features are extracted for each bright region. These 21 features comprise of 14 structural features, 4 pixel-intensity based features, 2 combination features and one Vessel-Sum feature. The 14 structural features include area, bounding box dimensions, convex area, eccentricity, equivalent diameter, Euler number, extent, filled area, major axis length, minor axis length, orientation, perimeter and solidity computed using the **'regionprops'** command in MATLAB. In the neighborhood of bright region 'Re **.**Vessel-Sum and region solidity are most significant in identifying OD regions among the classified bright probable OD regions.

The reconstructed image ,Binarized reconstructed image, Final binarized reconstructed images are shown below .

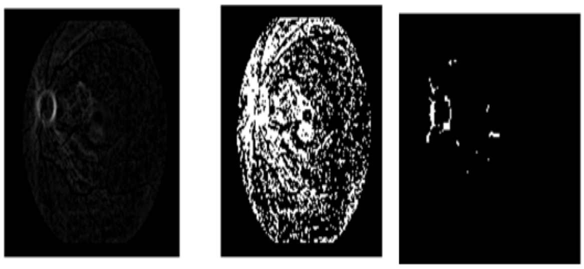

Fig4.3 a) Reconstructed image, b) binarized reconstructed image, c)Final binarized reconstructed image

Fig.4.4 The vessel sum computed for test image

For computing the Vessel-sum at each bright region (Re), first a circular mask is generated whose center is at the centroid of Re with _ pixels radius. Next, the circular mask is imposed on the major blood vessel image Iv and the sum of all vessel pixel intensities lying within the masked circle is computed as the vessel-sum function (Vessel-Sum(Re). Thus, the best bright candidate region for OD is detected as a bright probable OD region with Maximum Vessel-Sum and Solidity (MaxVeSS). OD in a retinal fundus image is generally the brightest and the most compact structure lying in the vicinity of blood vessels that are the thickest at the point of vessel origin and become narrow as they branch away from the OD. After detecting the bright regions in the image we have to eliminate OD so that remaining region contain only the exudates.

C. OD Elimination

We have to eliminate the OD since the reconstructed image consists of both OD and exudates. Masks are generated for corresponding reconstructed image. The mask which can cover the OD in the retinal image is selected. Then compare this image with the reconstructed image , whenever a brighter region corresponding to the position of mask is found we get a 1 , otherwise a 0. After the comparison stage we get an image with OD only. Further this image is subtracted from the reconstructed image to detect exudates only.

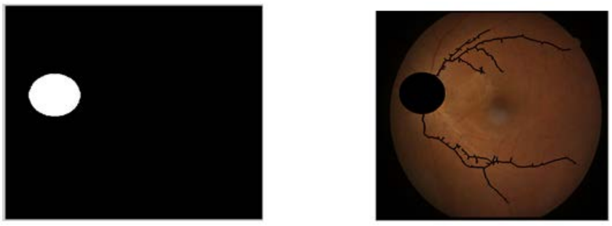

Fig.4.5 .a) The mask corresponding to OD b) The mask covering the OD Region

D. Exudate Detection

The intensity plays important role in detection of exudates. An image can has multiple regional maxima in term of intensity and texture but only a single global maxima which has intensities larger than or equal to threshold (110) (the band of exudates) and has similar determined texture. The texture based statistical features are area, intensity, entropy, smoothness and exudates region. Among these statistical features here we taking area and intensity for grading the level of DR.

The system is realized in the selected software i.e., MATLAB using the image processing toolbox.

V. RESULT AND ANALYSIS

The proposed system consists of glaucoma detection stage and DR detection stage.

A. *Glaucoma Detection*

An RGB Fundus image is given as the input , After extracting the features from fundus images such as optic disk, optic cup and Neuroretinal rim, ocular parameters such as CDR and RDR.An SVM classifier is used to classify the image in to glaucomatous and non-glaucomatous.The 40 training samples consisted of 20 glaucomatic images and 20 normal images. Out of 20 testing samples, 15 were glaucomatic and 5 were normal. Table I Represents result of CDR and RDR computed by proposed method for the test images and their ground truth. It was found that all the glaucomatic images were classified as glaucomatic by SVM classifier while out of 5 normal images, 1 is wrongly classified as Glaucomatic.

The sensitivity specificity, and accuracy measures were used to quantify the results achieved by the detection method. These measures were chosen based on the related work. When a test result is positive, the individual can manifest the disease, which is called "True Positive" (TP) or cannot express it, which is known as "False Positive" (FP). On the other hand, when the result is negative, the individual cannot have the disease, which is known as "True Negative" (TN) or can have it, what is called "False Negative (FN)".

The sensitivity is defined as the ability of a test to detect correctly people with a disease or condition. The specificity **i**s defined as the ability of a test to exclude properly people without a disease or condition. Accuracy is the overall per-pixel success rate of the classifier. That is the accuracy can be calculated as the overall effectiveness of sensitivity and specificity.

An accuracy of 90% with 100% sensitivity and 80% specificity was obtained for the SVM classifier with 40 training and 20 testing samples. The 40 training samples consisted of 20 glaucomatic images and 20 normal images. Out of 20 testing samples, 15 were glaucomatic and 5 were normal.

B. *DR Detection*

The Diabetic Retinopathy (DR) level in humans can be detected by scanning the human fundus image for the presence of Exudates. The performance of the proposed OD segmentation algorithms tested on fundus images. All the images collected have fully visible Optic disk. OD has eliminated from the images with higher accuracy. The morphological operations for removing the blood vessel network have yielded 100% results. Lastly, the exudates have been classified as low, medium, severe, and normal.

The results showed that current technique can identify the exudate regions in retinopathy images with high accuracy. The performance of the proposed method was evaluated using different database both quantatively and qualitatively. Due to some error caused during the blood vessel extraction stage the vessel-sum computation may not be occur properly . it causes an in correct detection of OD region for few images. By our proposed algorithm The region with higher value of vessel sum is considered as the OD region , the presence of unwanted brighter region in blood vessel extraction stage may make changes in vessel sum computations thus leading to incorrect detection of exudate.

The performance parameters specificity, sensitivity, accuracy were calculated for the proposed method. An accuracy of 95% with 92.3% sensitivity and 100% specificity was obtained with 40 training and 20 testing samples. The 40 training samples consisted of 30 DR images and 10 normal images. Out of 20 testing samples, 12 were DR images and 8 were normal.

TABLE 1. Results of Ocular parameters CDR and RDR to detect glaucoma and their ground truth

Sample	CDR	RDR1	RDR2	Exp.Results	Ground Truth	Compared results
1	0.9544	0.027	0.0263	Glaucoma	Glaucoma	Yes
2	0.6878	0.1327	0.2243	Glaucoma	Glaucoma	Yes
3	0.7126	0.1656	0.1254	Glaucoma	Glaucoma	Yes
4	0.7011	0.12	0.2137	Glaucoma	Glaucoma	Yes
5	0.6668	0.1134	0.166	Glaucoma	Glaucoma	Yes
6	0.712	0.1617	0.1245	Glaucoma	Glaucoma	Yes
7	0.6206	0.0801	0.2504	Glaucoma	Glaucoma	Yes
8	0.5712	0.1315	0.3149	Glaucoma	Glaucoma	Yes
9	0.6646	0.1286	0.2261	Glaucoma	Glaucoma	Yes
10	0.6039	0.1511	0.2944	Glaucoma	Glaucoma	Yes
11	0.5532	0.1221	0.2123	Glaucoma	Glaucoma	Yes
12	0.6254	0.1286	0.218	Glaucoma	Glaucoma	Yes
13	0.6186	0.1635	0.2186	Glaucoma	Glaucoma	Yes
14	0.5962	0.1486	0.1248	Glaucoma	Glaucoma	Yes
15	0.6342	0.1271	0.1564	Glaucoma	Glaucoma	Yes
16	0.4217	0.1945	0.4614	Normal	Normal	Yes
17	0.4216	0.1544	0.4154	Normal	Normal	Yes
18	0.522	0.0233	0.3763	Glaucoma	Normal	No
19	0.3243	0.2606	0.4575	Normal	Normal	Yes
20	0.5482	0.1386	0.405	Normal	Normal	Yes

VI.CONCLUSION

An efficient technique to detect glaucoma and DR is proposed and implemented. An efficient system for glaucoma detection is performed at first. The method adopted in this paper for early detection of glaucoma disease in humans is reliable and shows accurate results. An efficient automated system for DR is implemented successfully with higher accuracy**.** Early detection of diabetic retinopathy is very important because it enables timely treatment that can ease the burden of the disease on the patients and their families by maintaining a sufficient quality of vision and preventing severe vision loss and blindness. The proposed techniques work effectively even on a poor computing system. The results of this work can be developed to produce an automated system to detect exudates. The method implemented can be used for screening of patients eyeballs for detecting level of DR in a cost effective manner. This technique helps in determining levels of DR in its early stage and thus preventing vision loss.

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