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RESEARCH ARTICLE

QUALITY ASSESSMENT AND GRADING OF DIABETIC RETINOPATHY

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ABSTRACT

Diabetes, caused due to lack of insulin in human blood. This affects some parts of human body one such important organ is eye leading to Diabetic Retinopathy. Diabetic Retinopathy, a complication in diabetic patients, causes damage to retina which in later stages may lead to blindness. The disorder can be detected by regular scanning of the retina of diabetic patients. However, Indian Ophthalmologists to Indian population ratio is 1:90000 which is not proportional necessitating to automation of the system. The proposed system, using Image processing techniques, requires retinal fundus image of an eye taken from fundus camera. But sometimes it is difficult for the system to process due to the dark images leading to misinterpretation in the results. Hence system performs the quality assessment of image by dividing Image into blocks, extracting first order histogram features from retinal image, detecting exudates using AND logic and finally grading the Diabetic Retinopathy as mild, moderate or severe. This paper mainly focuses its content on Image Quality assessment and Retinopathy Grading System. System has achieved 90.9% and 90% of sensitivity and specificity in quality assessment of retinal image.

INTRODUCTION

The most challenging disorder in today's generation is Diabetes. Though Diabetes is preventive, it is seen as almost inevitable for every individual with their lifestyles. Among 80% of patients who have Diabetes for 10 years or more are likely to be suffer from Diabetic retinopathy, a retinal disorder, leading to vision loss. Since the vision of any individual is precious it needs to be cared the most. During early stage of diabetic retinopathy, NPDR, blood vessels are bulged resulting in soft exudates. In later stages, PDR, abnormal blood vessels are formed. These vessels burst and bleed since those are weak. This forms another type of exudates known as hard exudates. In any of these stages the vision of eye will be reduced and even may result to complete vision loss because of these exudates in macula region of retina. Hence conclusion can be drawn that presence of exudates are key in detecting Diabetic Retinopathy and hence grading it.

Method followed to detect Diabetic Retinopathy is regular screening of retina using fundus camera. A research shows that regular screening for diabetic retinopathy could reduces the numbers of people at least by 90% in new cases who develop vision-threatening retinopathy. The estimate of the actual number of diabetics in India is around 40 million and is expected to reach 70 million by 2025. During their lifetime, nearly half of the nation's estimated 16 million people with diabetes will develop some degree of diabetic retinopathy, and as many as 25,000 people go blind annually. However, it is estimated that the ratio of ophthalmologist to population is 1:90000 in India. This ratio seems not to be proportional as DR needs aggressive screening. Thus it necessitates the need of automated system.

This paper presents an automated system which aims to achieve two purposes. First, analyze the quality of the images. Second, grade the diabetic retinopathy by detecting the maculae and exudates region and then grade the DR as mild, moderate and severe.

LITERATURE SURVEY

With respect to the Quality Analysis, Radhe *et al* [1], the input image accepted is converted to gray and then using the bit plan separation, contrast enhancement and morphological processing are applied to extract the blood vessels. By using the digital wavelet transforms and the energy feature coefficients are used to get the features and then trained to PNN (probabilistic neural network) and Classification is done with the help of segmentation like K-means Clustering method thereby extracting the exudates determining whether the retina is normal or abnormal and then Morphological operations are applied on segmented image for smoothening the exudates part. But the image without the exudates cannot be used to analyze the Image quality. In the paper described by the Ramon Pires [2] *et al*, In this methodology, a reference image with assured quality is assumed to be known and quantitative measures of quality for any image are extracted by comparisons with the

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reference. It is said that the macular region has a distinguishable contrast in comparison with the remaining regions, and they are interested in the content of the center of retinal images. They selected a set of images centered on the macular region as well as a set of images not centered on the macular region (centered on the optic disc or in any other location on the retina). Then, calculated similarities between a given image and the reference images (positive and negative), with respect to their central regions and created a feature vector for later classification. But this method only considers centered region images, images whose maculae lies little apart are neglected where sometimes these are of important considerations.

In the paper described by the Vinita R *et al*[3] ,they used the two formats for quality assessment by using the focus assessment algorithm using prewitt operator to classify the image as "blurred", "borderline" or "focused" and color assessment algorithm using histogram back projection to classify the image as "bright" ,"dark" or "normal". This involves problem such as the image which becomes blurred can be bright or dark so this limitation even persists in this method .All the methods perform the quality assessment in some or other way with certain problems .The paper describes a different way to assess the quality. With respect to Exudates detection we have, Anurag *et al*. [4] blood vessels of different thicknesses are extracted using open and close operations. Exudates are extracted from open and close operations using filters of different sizes. Micro aneurysms and Hemorrhages are segmented using morphological filters that exploit their local 'dark patch' property. Herbert *et al*.[5] the extraction of low-level local features from retinal images, the aggregation of those local features into mid-level BossaNova features, and then the classification of those BossaNova features by a Support Vector Machine (SVM) classifier.

Carla *et al*. [6] the cumulative distribution functions of the instantaneous amplitude, the instantaneous frequency magnitude, and the relative instantaneous frequency angle from multiple scales are used as texture feature vectors. Archana *et al*. [7] the size of exudates, microaneursyms are detected and identified later this information is fed to artificial neural network to detect diabetic retinopathy. All the methods discussed above detect the exudates efficiently but the methods presented in the paper is far simple using AND logic [12] of two different images to detect the exudates. With respect to grading, Vasanthi *et al* [8] proposed the method to detect the exudates using morphological operation and segmenting the hard exudates segmentation to extract the third order histogram features to train the classifier ANFIS and ELM classifier to grade the exudates as mild moderate and severe. But the classifier degrades the performance when the image to test is beyond the training limit so sometimes it may fail.

In the paper described by Niranjan [9], it's clear that the diabetic retinopathy grading includes some of the important diabetic retinopathy properties too, such as blood vessels and micro aneurysms so he performed ANOVA test to classify the exudates as mild moderate and severe But sometimes this leads to failure because the blood vessel oriented result affects the exudates affected region and even detecting may lead to wrong result sometimes especially with respect to the micro aneurysms. In the paper described by the Madura *et al* [10], the exudates are detected using fuzzy C means algorithm and texture features are extracted, according to the extent of features extracted, classification is done using different types of classifiers, such as neural networks. Efficiency of the classifier is calculated in terms of its efficiency to classify normal images into normal and abnormal images as abnormal. Area and perimeter of blood vessels were used as the input parameters to multilayer feed forward neural network for classification into different retinopathy stages. The paper describes the DR grading using region properties as described in next section.

Proposed Method

The proposed system overcomes the disadvantages of existing system by analyzing the quality analysis of the image and detecting the maculae as well as exudates detection efficiently and grading Diabetic Retinopathy by considering the area and region of exudates in to account.

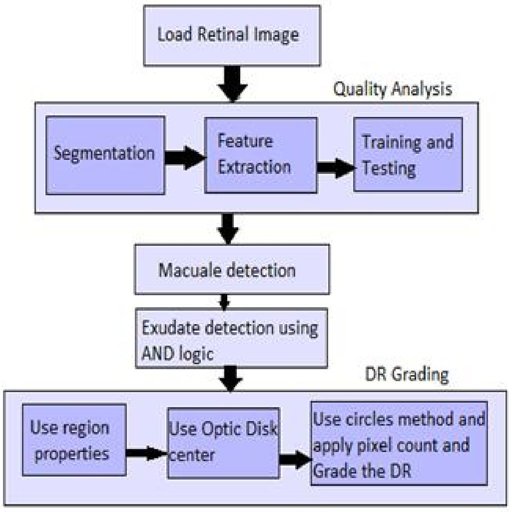


Figure1 Describes the proposed system

As shown in the Figure1 after loading the retinal image in the first step it undergoes quality analysis test where image is divided into blocks. First order histogram features are extracted from each block of the image and the dataset ready. After the dataset preparation it is fed to SVM classifier to train and then test the sample After passing the quality test the image will be used to detect maculae as well as exudates using AND Logic and then exudates detected image is used for grading DR, where we perform the labeling and applying region properties and extract the optic disk center and by plotting concentric circles at certain distance apart we grade the Diabetic retinopathy as mild, moderate and severe.

MATERIALS AND METHODOLOGY

Dataset

Here we are using standard public database DIARETDB0 which can be used for scientific research purposes. We totally have 69 images. These images were captured with 50 degree field-of-view using digital fundus camera. Every image is at the resolution of 1500×1152 pixels and are in PNG format.

METHODOLOGY

Quality Analysis of Retinal Image

Typically, the exudates detection starts with preprocessing the retinal image. But it is observed that all retinal images will not uniform in terms of intensity. Some of them will be dark wherein the non-exudates like optic disk, blood vessels, micro aneurysms will be misinterpreted as exudates. To overcome such misinterpretations our system first checks the quality of retinal image by extracting image features. 49 out of 69 images are taken as training set for quality analysis. 25 images are of good quality and another 24 are of bad quality. These images are sorted manually as good and bad quality. Since the database used has only 69 images each retinal image is segmented into 80 segments after resizing it to 50% to increase the dataset. Each segment is of 75×72 pixels. We have extracted total of three histogram features [17] energy, mean and variance from three color bands red, blue and green of each segment. Energy, mean and variance are calculated using probability P equation as follows.

$$p=H/M \qquad (1)$$

$$Energy=\sum(p*p) \qquad (2)$$

$$Mean=\sum(p*g) \qquad (3)$$

$$Variance=[\sum p*(g-mean)]^2 \qquad (4)$$

Where H is the histogram of the image calculated using inline function and m is the no of blocks, and g is the gray level vector. Hence total of nine features from each segment of each images are extracted. The matrix size 3920×9 has been created. Support vector machine (SVM) classifier is used for classifying image in quality analysis. The dataset prepared is fed to SVM classifier and training is given. Sample is taken and tested against the classifier to say whether the image is of good quality as shown in figure 2 or bad quality as shown in figure 3.

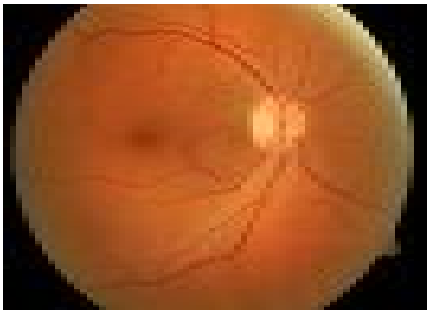


Figure2 Quality passed image

Figure3 Quality failed image.

Maculae Detection

While performing the maculae [14] detection, optic disk needs to be detected first. In optic disk [13] detection, the input retinal image which is of good quality is taken. Since green channel contains more information we extract green channel from the quality passed image. We calculate the mean and apply median filter but sometimes the exudates which are as bright as optic disk are wrongly detected as optic disk so Adaptive histogram technique is used to enhance the image and smooth the image using disk, this is in order to detect the bright region and apply the connected component analysis to find the largest region and consider it as optic disk. Using the centroid of region properties the center of optic disk is detected and maculae is plotted by shifting center to 220 pixels.

Exudates detection

The retinal fundus image is first preprocessed to standardize its size to 576x720 and the image is converted to grayscale and intensity of the grayscale image is then adjusted. This standard size helps in easy manipulation. Morphological closing which consisted of dilate followed by erode is applied to removed the blood vessels. The dilate function expands the exudates area while erode function removes the blood vessels. The image is then converted to double-precision value for function "colfilt" to mark the exudates region before converted back to uint8 .Then image is converted back to binary using the function "im2bw" with a threshold value to filter out the exudates. The location of the optical disk is detected by the brightest point on the grayscale image. It is usually the maximum value and a circular mask is then created to cover it. The regions of the exudates are obtained after the removal of the circular border. Morphological closing is then applied to the image. The dilate function is to fill the exudates while erode function is to expand their sizes. AND logic [12] is used to remove noise for the detection of exudates. Regions with exudates are marked out after applying column filter but this includes non-exudates such as hemorrhages and has to be removed as noise. Thus the left, images are applied with AND LOGIC to find the Exudates portions.

The first row of images in figure3 gives us the image after morphological processing[15] and the second rows of images of figure3 shows images after the filters applying and removal of optical disk and third rows of figure3 images shows the AND logic between first two images and the last image gives the exudates presence image.

Diabetic Retinopathy Grading

Once the exudates are analyzed image is taken to first check whether the image has exudates if not then no grading is required else grading is performed as by taking the exudates detected image three concentric circles are drawn with center equal to center of macula and its radius as diameter of the optic disk and increment the two circles drawing in terms optic disk radius. Get pixel list of all connected components and check each the pixel's position in those three circles using distance formula as shown in equations 4, 5 and 6.

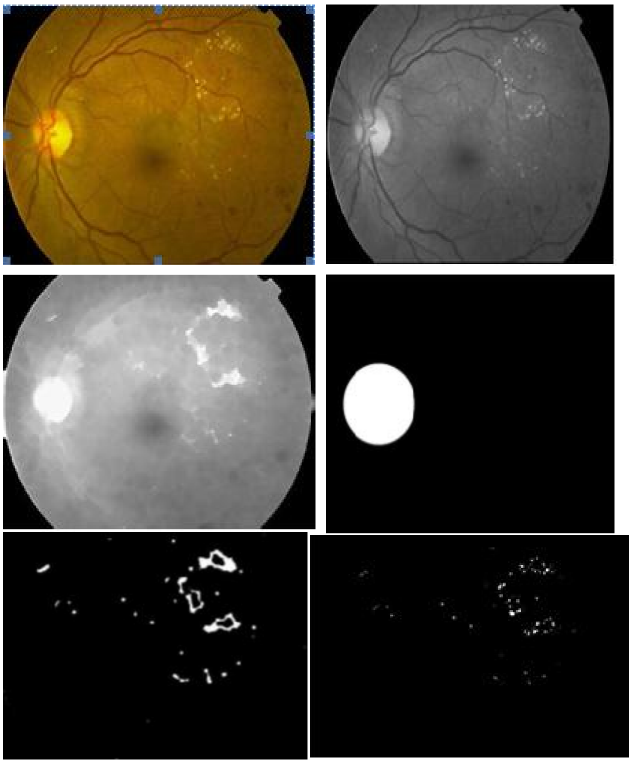


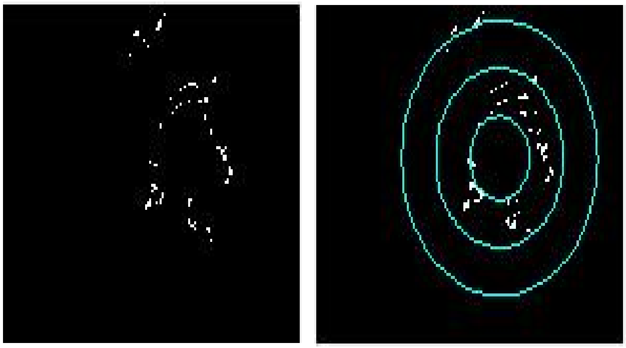
Figure3 Steps describing the detection of exudates.

x and y indicates the pixel position, x_0 and y_0 indicates the center of the optic disc detected and r indicates the radius of circle i.e., inner most, middle or outer most circle.

$$(x - x_0)^2 + (y - y_0)^2 > r^2 \quad (4)$$
$$(x - x_0)^2 + (y - y_0)^2 = r^2 \quad (5)$$
$$(x - x_0)^2 + (y - y_0)^2 < r^2 \quad (6)$$

If the number of pixels are more in inner most circle the Diabetic retinopathy is Severe If the number of pixels are more in middle circle the Diabetic retinopathy is Moderate If the number of pixels are more in outer most circle the Diabetic retinopathy is Mild.

The figure4 describes the exudates image is graded using the region properties and the pixel List that is taken for each of the labeled image. The figure4(a) shows the exudates detected image and The figure4(b) shows the exudates graded image using the concentric circles and results appear as Mild Moderate and Severe.



A B

Figure 4 (A) Exudates detected (B)Grading the Diabetic Retinopathy

RESULTS AND DISCUSSIONS

As we perform the two fold classification for analyzing the quality of the image. we here compute the Sensitivity and Specificity by taking the testing set for positive as 11 and negative as 10 so we have sensitivity and specificity as shown in table1.

Sensitivity and specificity can be calculated using following equations (7) and (8).

$$\text{Sensitivity} = \frac{TP}{TP+FN} = 90.9\% \quad (8)$$
$$\text{Specificity} = \frac{TN}{FP+TN} = 90\% \quad (9)$$

Where TP is true positive, TN is true negative, FP is false positive and FN is false negative

Table 1 Sensitivity and specificity calculated for different color bands for quality assessment.

	TP	FP	TN	FN	Sensitivity	Specificity
Red	11	1	9	0	100%	90%
Green	8	0	10	3	72.7%	100%
Blue	11	10	0	0	100%	0%
RGB	10	1	9	1	90.9%	90%

By taking histogram features such as mean, variance and energy from red, green and blue channels separately the classifier has been trained and tested against testing set. Accordingly, sensitivity and specificity has been computed. According to these two values shown in table1 first-order histogram features extracted from RGB channels shows better results than taking only red, green and blue individually. Specificity and Sensitivity versus color channels shows considering all three channels gives sensitivity and specificity as 90.9% and 90% respectively using block size of 80 for each of the image as shown in figure5.

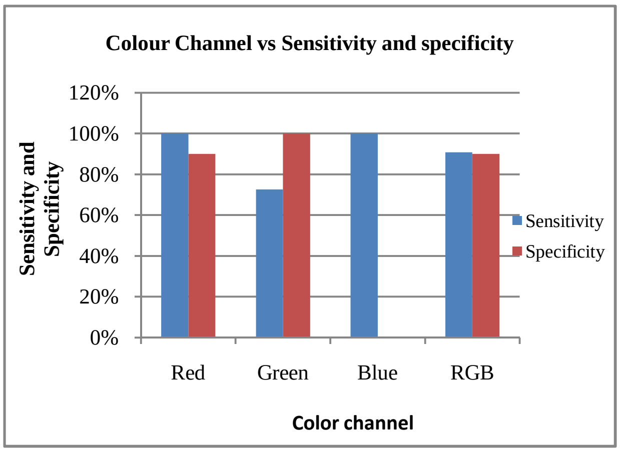
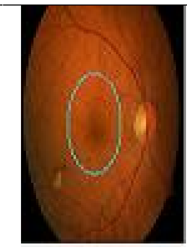
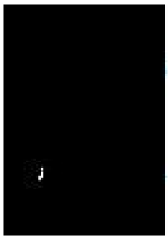
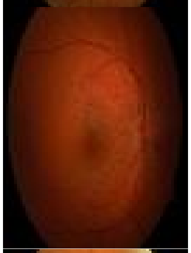
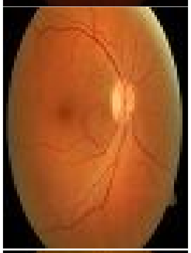
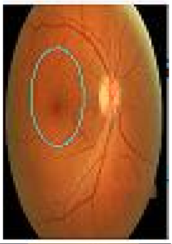
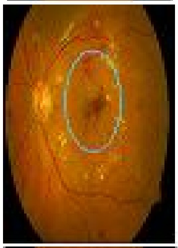
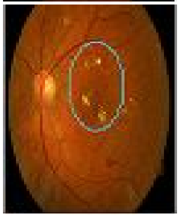
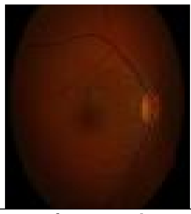


Figure 5 Graph shows Color bands versus Sensitivity and Specificity for block size of 80 for quality assessment.

After taking their retinal image of the patient image is assessed for quality test. If the image passes the quality test further processing takes place else patient image is rejected to avoid misinterpretation as described in the table2. Further processing includes detecting macula region as well as exudates. If the exudates are present then grading of diabetic retinopathy is performed else the patient's eye is considered as normal as shown in table2.

Table3 The result displaying all possible conditions.

Sl no	Patient Name	Patient mobile No	Patient Image	Quality Result	Maculae detection	Exudates Detected	Exudates Image	Severity Grading
1	Amith	8553325733		Quality Passed		Yes		Mild
2	Abdul	8123396913		Quality Failed	--	--	--	--
3.	Pavan	9739981072		Quality Passed		No	--	--
4.	Keshav	8884287576		Quality Passed		Yes		Moderate
5.	Nitish	8792188849		Quality Passed		Yes		Severe
6.	Abhilash	8123414448		Quality Failed	--	--	--	--

*Patient name and mobile number as per in the table 2 are fictitious. This is just to show the working of the proposed system.

CONCLUSIONS

From this paper, we conclude that the system developed using MATLAB provides the efficient way to analyze the quality of the image prior further processing and then to grade the severity of Diabetic retinopathy by considering the area and position of exudates formed. This system definitely helps the diabetic patients to get necessary information about status of retina periodically in easy way and also essentially reduces work load of the doctor by automation of the system.

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