An Approach for Detection of Abnormality and its Severity Classification in Colour Fundus Images

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Abstract- Diabetic macular edema (DME) is a common vision threatening complication of diabetic retinopathy and can lead to irreversible vision loss which can be assessed by detecting exudates (a type of bright lesion) in color fundus images. In this approach, an automatic and efficient method for the detection and classification of DME severity level is proposed. A feature extraction technique is introduced to capture the global characteristics of the fundus images and discriminate the normal from DME images. Clustering-based method is used to segment exudates. Using k-means clustering algorithm, the severity level of DME is determined. The performance of the proposed methodology and features are evaluated against several publicly available datasets.

Keywords- Diabetic macular edema (DME), hard exudates, soft exudates, Motion patterns, Column clustering, K-means clustering

I. INTRODUCTION

Diabetic Macular edema (damage to the retina) caused by complications of diabetes, which can eventually lead to blindness. It is an ocular which affects up to 80% of all patients who have had diabetes for 10 years or more. Despite these intimidating statistics, research indicates that at least 90% of these new cases could be reduced if there was proper and vigilant treatment and monitoring of the eyes. The longer a person has diabetes, the higher his or her chances of developing diabetic retinopathy.

Diabetic retinopathy often has no early warning signs. Even macular edema, which may cause vision loss more rapidly, may not have any warning signs for some time. In general, however, a person with macular edema is likely to have blurred vision, making it hard to do things like read or drive. In some cases, the vision will get better or worse during the day. As new blood vessels form at the back of the eye as a part of proliferative diabetic retinopathy (PDR), they can bleed (ocular hemorrhage) and blur vision. The first time this happens, it may not be very severe. In most cases, it will leave just a few specks of blood, or spots, floating in a person's visual field, though the spots often go away after a few hours. These spots are often followed within a few days or weeks by a much greater leakage of blood, which blurs vision. In extreme cases, a person will only be able to tell light from dark in that eye. It may take the blood anywhere from a few days to months or even years to clear from the inside of the eye, and in some cases the blood will not clear. These types of large hemorrhages tend to happen more than once, often during sleep.

On funduscopic exam, a doctor will see cotton wool spots, flame hemorrhages (similar lesions are also caused by the alpha-toxin of Clostridium novyi), and dot-blot hemorrhages. Elevation of blood-glucose levels can also cause edema (swelling) of the crystalline lens (hyperphacos orbitomyopicosis) as a result of sorbitol (sugar alcohol) accumulating in the lens. This edema often causes severe temporary myopia (nearsightedness). A common sign of hyperphacos orbitomyopicosis is blurring of distance vision while near vision remains adequate.

In literature a very few work have been reported about the detection of exudates and it is observed that algorithms do not find all exudates and detect some false candidates. Several methods have already been implemented to segment the hard exudates.

This proposed method is an easier process which makes use of the pixel intensity of the exudates. The pixels that form exudates are extracted by removing all the unwanted features like blood vessels, Optic Disc (OD) and noise. Then based on the amount and intensity of the exudates the classification is done. Morphological approach has been used in this technique because with the use of region based approach, this accuracy cannot be attained. Also for attaining high sensitivity and specificity, clustering is done where the entire image is subdivided based on the intensity levels (gray scale image) of OD, blood vessels and exudates. Then the feature extraction is done and the final classification is done using K-means clustering.

II.METHODOLOGY

The aim of the entire process is the detection of the abnormality in the fundus images with respect to the exudates and their classification is done. The fundus photographs of the exudates affected retina were collected from The Eye Hospital, Coimbatore. They were captured using high resolution fundus camera. The normal fundus photographs, taken for the diagnostic processes contain noise. If the detection is made with those same images it may lead to malicious results. Hence to improve the image quality, uneven illumination, insufficient contrast between the exudates and the image background pixels and to remove the noises present in the input fundus images we go for the preprocessing step initially. This stage involves a number of steps like resizing the image, gray conversion, date patch removal and brightness adjustment. Initially the fundus image is standardized to 576x720 and the intensity of the grayscale image is then adjusted.

Once the preprocessing is successfully completed, enhancement of the contrast of the image is done. Then the image is analysed which consists of exudates alone and further we calculate the region of interest i.e. where the exudates are present in the image. K-means algorithm and thresholding operation is done to obtain the final result of HE detection and severity level.

INPUT IMAGE

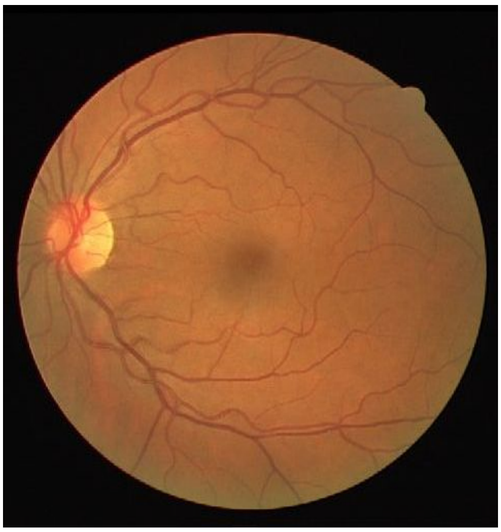


Figure 1. Input Retinal

The main objective of the proposed project is to identify the defective part on the retina of eye caused due to Exudates. For this purpose, an image (Fig.1) is chosen that has been affected by Exudates using a fundus camera which is depicted above. This image consists of optic disk (OD), blood vessels and exudates.

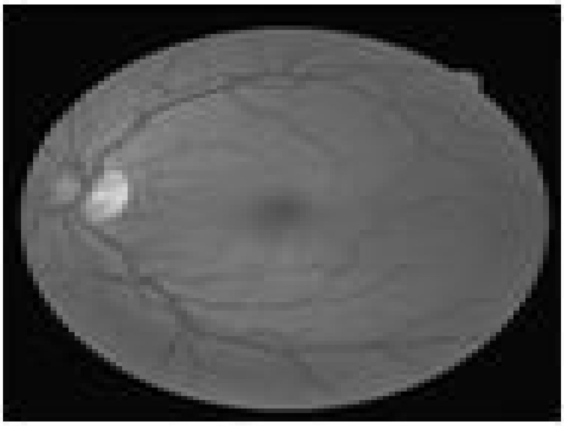


Figure 2. Green channel image

Color fundus images taken during an examination of the fundus are often corrupted by low contrast and noise caused by the acquisition system. To solve this problem, the green channel of the retinal image is used (Fig.2), where HEs appear with a better contrast. Hence, to increase the contrast between HEs and the background, an adaptive histogram equalization image of the green channel is applied.

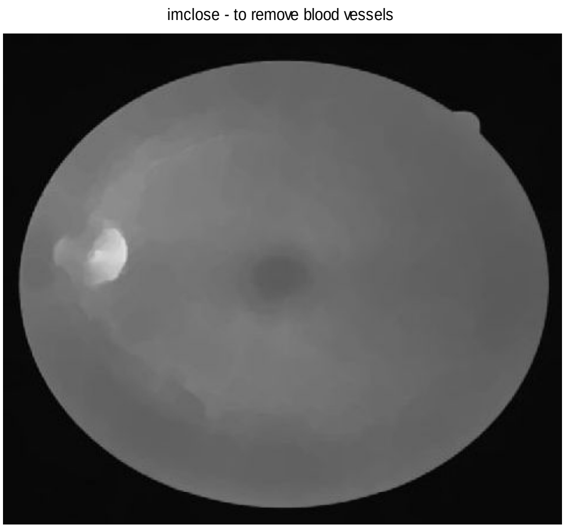


Figure 3. Blood vessels removed image

Since the major focus is only on the region of exudates, the blood vessels in the image are not of much importance. Thus in this stage the blood vessels from the gray scale image have been removed (Fig.3). For doing this we do morphological operation. In this a ball shape is chosen which concentrates on the circular eye and then the blood vessel region which is unclosed is closed automatically. For the process of thresholding the gray values to binary we use the technique called soft thresholding.

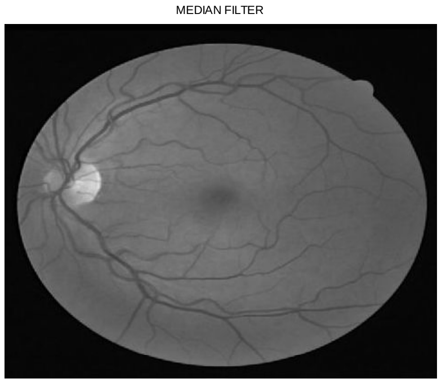


Figure 4. Median filter

The processing has to be done only in the region of interest of the image. To reduce noise of small sizes and preserve the edges, we used a median filter with a window size of 3 × 3 (Fig. 4), applying the equation 1

$$E_{im} = (Io*M) \qquad (1)$$

where Io is the enhanced image, M is the median filter, and Eim is the filtering of the enhanced image.
In order to extract the regions of interest, the k-means clustering algorithm is applied. The k-means algorithm (Fig.5 (a)) is an unsupervised clustering algorithm that classifies the input data points into multiple classes based on their inherent distance from each other [6].

Three features were selected as input for k-means clustering.
(1) We can distinguish the exudates pixels from other pixels by their intensity; therefore the intensity vector of enhanced image was used as an input to the k-means.
(2) The second vector for input k-means clustering was a color. The original color fundus retinal images of red, green, and blue (RGB) space were transformed to HSV space color, the hue band was used because hue components give the color according to human perception.

(3) The distribution measurement of the pixel values would differentiate exudates areas from the others. Thus, the variations of gray levels of enhanced image were calculated using 17 × 17 pixels window. The distribution measurement as in formula 2 was used as a third input vector for the k-means:

$$Sd(x) = \sum_{\epsilon\varepsilon} w(x)^{((\text{ image}(2.c) - \mu_{(\text{image}2.c)}{}^{(x)})\, 2} \qquad (2)$$

Where N is the number of pixels in Windows W(x) and μ (image2,c)(x) is mean value of the enhanced image. Various steps to minimize J (μ, z) in the algorithm are listed as follows.
(1) Choose the vector μ.
(2) Initialize the centroids with k random.
(3) Repeat the following steps until the cluster labels of the image do not change anymore. Minimized J relative to z: z_i^k =1 for k ϵ argmin $\| x_i - \mu_k \|$ (associated xi with the nearest center μ_k). Compute the new centroid for each of the clusters (minimized J relative to z) as in formula 3:

$$\mu_k = \sum_i z_i^k x_i / \sum_i z_i^k \qquad (3)$$

Return to Step 3 until convergence as in (Fig.5 (b)).
Assessing the severity of macular edema is the next task. Here, the macular region which is the circular ROI within 1 optic disc diameter from the center is of key interest as any (Fig.5(c)) HE within this region indicates high risk for DME, requiring immediate attention. The macula in a normal image is relatively darker than other regions in the fundus image and is characterized by (rough) rotational symmetry. This symmetry information is used to establish the risk of exhibiting edema: good degree of symmetry is taken to indicate the abnormality is not inside macula and hence it is declared as a moderate case. Asymmetry of the macula on the other hand implies abnormality is within the macula and hence the case is deemed severe .A method to detect severity of edema based on rotation symmetry has also been used earlier where the symmetry of larger ROI centered on the

macula is considered [7]. A slightly different approach by considering the symmetry of only the macular region is proposed. A symmetry measure s is defined as the second norm of the distance between the histograms of diametrically opposite pair of patches $p(\theta_i)$ and $p(\theta_i+\Pi)$A. In our work, four angular samples (Fig.6) were used to create four patches p (i) from the circular ROI and a histogram of 10 bins was computed for every patch. Since the intensities corresponding to HE contribute mostly to the higher bins in the histogram, only the last five bins are used for measuring the symmetry. A preprocessing step was performed to eliminate any intensity bias as in [8].

A threshold on the symmetry measure s is used for assessing the degree of abnormality of an image as moderate or severe of DME. Let s_{max} and s_{min} and be the maximum and minimum symmetry values for normal images in the training set used for abnormality detection. Then the severity of a given abnormal image I_a is determined by comparing the symmetry measure of this image s (I_a) against a threshold T as follows in equation 4:

$$\text{Severity}(I_a) = \begin{cases} \text{Moderate}, & \text{if } s(Ia) \leq T \\ \text{Severe}, & \text{otherwise} \end{cases} \quad (4)$$

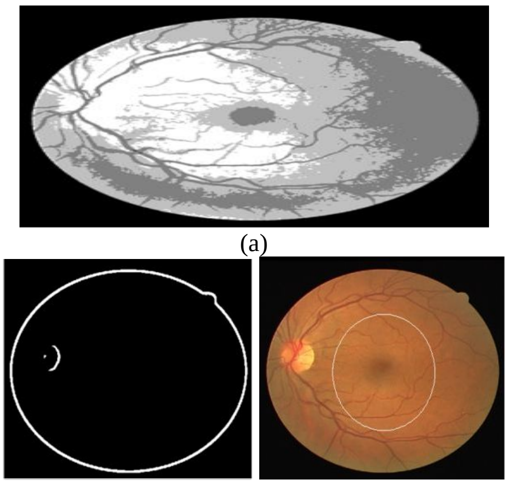
It is desirable to set the threshold to be a percentage of the maximum symmetry value for normal images. Hence, the threshold is selected as in formula 5

$$T = p\,(s_{max} - s_{min}) + s_{min} \quad (5)$$

This definition for permits the value of to be in [0–1]. It is desirable to select a low value for to achieve highest classification accuracy for the severe class of DME images as they require immediate medical attention.

III. EXPERIMENTAL RESULTS

A set of 50 images captured under standard protocols obtained from eye care centers and diabetic retinopathy databases [12] were used for analysis. The algorithm was tested using the training sample. Finally the effect of threshold (T) (on rotational symmetry metric) in severity assessment is studied. The threshold is expressed as a percentage (p) of the symmetry measure S of normal ROIs used in the abnormality detection task. It can be seen that the classification accuracy is high when the value of p is at 25% of the S value for normal.



(a) (b) (c)

Figure 5. (a) K- means clustering (b) Segmented image (c) ROI image

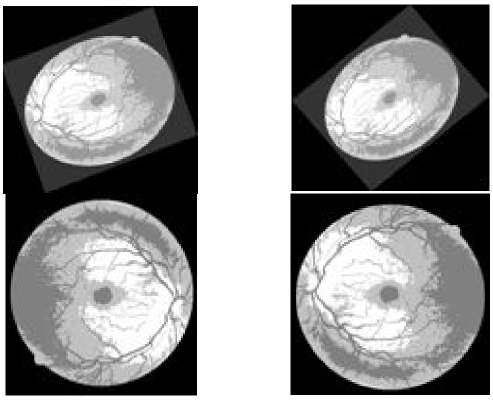


Figure 6. Motion patterns

The classification accuracy for the moderate class falls as the value of p is increased to 75%. This implies that S of the normal ROI is sensitive to intensity variations but does not affect the classification accuracy of severe cases. In the second level, the severity of the abnormality (Fig.7) is assessed by analyzing the rotational asymmetry of the macular region in retina.

Figure 7. Severity classification and its accuracy.

This level facilitates the decision to recommend a patient to a medical expert, based on the proximity of HE to the center of macula. The proposed methodology enhances the existing DR screening infrastructure by helping automate the detection and assessment of DME[9]Expanding the normal class to include non-DME lesions does not compromise the system's performance as the non-DME lesions are generally dark or bright and diffuse. Consequently, they are well separated in the feature space from HEs. This was confirmed experimentally the problem of detecting exudates is very challenging since they present very irregular shapes and have variable texture characteristics (soft and hard exudates). However, the results obtained with this optimized method are encouraging.

VI. CONCLUSION

In this work, a rapid method to detect HEs in ophthalmologic images based on K-means clustering and mathematical morphology operators have been presented. This approach is intended to improve the precision of the diagnosis of DR before the advanced stage with further complications. Pretreatment based on a median filter and an adaptive histogram equalization technique to eliminate noise caused by the acquisition system is used. K-means clustering was used to extract all exudate regions. Thereafter, the optic disks were removed using morphological operators. Finally, a morphological reconstruction followed by a thresholding operation was applied to retain only the exudates and the severity level is determined.

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