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Exudates Detection Methods in Retinal Images Using Image Processing Techniques

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Abstract— Exudates are one of the most common occurring lesions in diabetic retinopathy. Exudates can be identified as areas with hard white or yellowish colors and varying sizes, shapes and locations near the leaking capillaries within the retina. The detection of exudates is the major goal. For this the pre-requisite stage is the detection of optic disc. Once the optic disc is found certain algorithms could be used to detect the presence of exudates. In this paper few methods are used for the detection and the performance of all the methods are compared.

Keywords — Capillaries, diabertic retinopathy, exudates ,optc disks.

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1 INTRODUCTION

India and China are, and will remain, the leading countries in terms of the number of people with diabetes mellitus in the year 2025. Among the 10 leading countries in this respect, five are in Asia. Although only a moderate increase in the total population in China is expected in the next 25 years, China is estimated to contribute almost 38 million people to the global burden of diabetes in the year 2025. India, due to its immense population size and high diabetes prevalence, will contribute 57 million [1]and [2]. These figures are based on estimated population growth, population ageing, and urbanization, but they do not take into account changes in other diabetes-related risk factors.

So, Diabetic screening programmes are necessary in addressing all of these factors when working to eradicate preventable vision loss in diabetic patients. When performing retinal screening for Diabetic Retinopathy [3] some of these clinical presentations are expected to be imaged. Diabetic retinopathy is globally the primary cause of blindness not because, it has the highest incidence and it often remains undetected until severe vision loss occurs. Advances in shape analysis, the development of strategies for the detection and quantitative characterization of blood vessel changes in the retina are of great importance. Automated early detection of the presence of exudates can assist the ophthalmologists to prevent the spread of disease more efficiently.

Direct digital image acquisition using fundus cameras combined with image processing and analysis techniques has the potential to enable automated diabetic retinopathy screening. The normal features of fundus images include optic disk, fovea and blood vessels. Exudates and haemorrhages are the main abnormal features which is the leading cause of blindness in the working age population.

Optic disk is the brightest [4] part in the normal fundus images which can be seen as a pale, round or vertically slightly oval disk. Finding the main components in the fundus images helps in characterizing detected lesions and in identifying false positives. Abnormality detection in images is found to play an important role in many real life applications [5] suggested neural network approach for the detection and classification of exudates. A decision support frame work for deducing the presence or absence of DR are developed and tested [6]. The detection rule is based on binary-hypothesis testing problem which simplifies the problem to yes/no decisions. The results suggest that by biasing the classifier towards DR detection, it is possible to make the classifier achieve good sensitivity.

2 METHODS

2.1 Feature Extration

Here, in this method we use the concept that in normal retinal images the optic disc is the brightest part and next to it comes the exudates. So once after detecting the optic disc, the centre point is determined for extraction of various features in the image. Then the optic disc is removed from the image, thus we are now left with exudates as the next brightest region. Here again we can apply Binary Image [7] and proper threshold value is set and the exudates can be easily identified from the test image. The results are shown in figures 1 and 2.

Figure1. INPUT OPTIC DISK EXTRACTED IMAGE

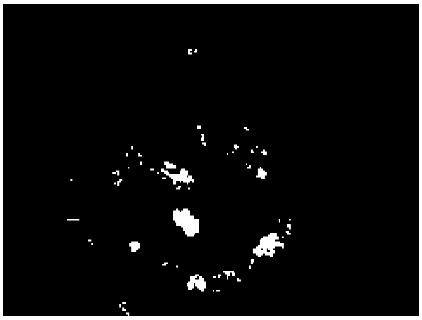

Figure2. OUTPUT BINARY IMAGE SHOWING EXUDATES IN WHITE

2.2 Template Matching

For The concept behind this method is that, a normal and healthy retinal image is taken and it is kept as the reference to isolate the abnormalities in the test image. This reference image acts as the template. Both the reference image and test images are converted from RGB to GRAY levels and then pixel by pixel both the images are compared. During comparison, the additional objects present in the test image get isolated and they are clearly visible in the output. If the test image is normal, then while comparison it gets cancelled as there is no difference of pixel value between the two, where as in the test image with exudates, the optic disc gets cancelled and only exudates are separated in the output. and is shown in figure 3 to 5

The basic requirement of this method is that, we should have a normal and healthy retinal image as reference and the test images must be taken in the same orientation as the reference, it should be of same lighting, angle, etc… It should be taken in the same manner as that of the reference, then only this algorithm will work well or else it would produce wrong result. Hence this basic need must be satisfied to work with this method.

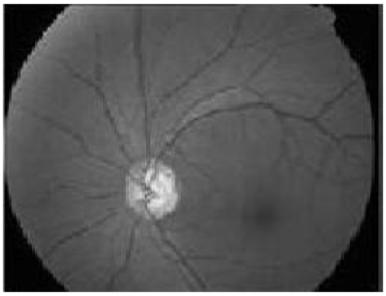

Figure 3. REFERENCE IMAGE

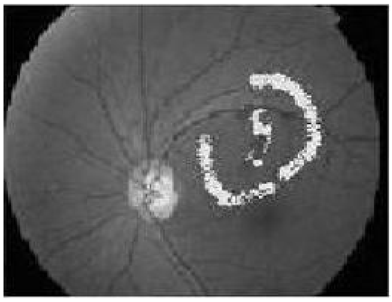

Figure 4. TEST IMAGE

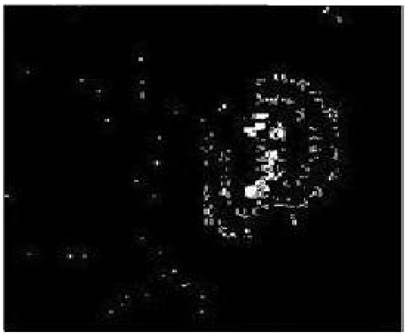

Figure 5. OUTPUT IMAGE WITH EXUDATES DETECTED

2.3 Minimum Distance Discriminant Classifier

Color information has shown to be effective for lesions detection under certain conditions. On the basis of color information, the presence of lesions can be preliminarily detected by using MDD (Minimum Distance Discriminant) classifier based on statistical pattern recognition techniques.

If the background color of a good quality retinal image is sufficiently uniform, then a simple and effective method to separate hard lesions from such background can be easily applied by selecting a proper threshold. However, the limitation of these thresholding techniques is that they typically only work well for the training images, but once an unseen image comes along, they may not be able to accurately detect the exudates. This is because the processing steps require different threshold parameters for different types of retinal images and need user's intervention on a case by case basis. As a result, these thresholding based algorithms are not scalable for analyzing large number of retinal images. This MDD (Minimum Distance Discriminant) classifier uses a simple but effective method, based on statistical classification to identify lesions in retinal images[8].

Objects in an image usually can be described in terms of some features f_1, f_2… f_k such as color, size, shape, texture and other more complex characteristics. These features, f_1, f_2….f_k form a k-dimensional feature space, F. ideally, we have to find a space F such that different objects map to different, non-intersecting clusters in this feature space. If this condition is satisfied, we can easily identify different objects and classify them into corresponding classes by certain rules. Suppose we have N different objects to be identified in an image. Let $C_i(f_{i1},f_{i2},…..,f_{ik})$ denote the center of class i in the k-dimensional feature space F, where i=1,2,….N. let $X(x_1,x_2,….x_k)$ be the unknown object's feature measurement values in F. Let $D_i(X)$, i=1, 2…N, be the discriminant function that is used to determine whether X should be classified as belonging to class i. Given a specified pixel x with feature vector X, we classify pixel x as belonging to class i if $D_i(X)$ is the maximum along all $D_j(X)$, where j=1, 2,….N and j not equal to i.

The color features are taken as the feature space, F. The color fundus retinal image consists of three planes-red, green and blue, each plane with 256 levels of intensity denoted as (R, G and B). Color can be also represented by θ, φ, and L in the spherical co-ordinates. The relation between the two color spaces is expressed as:

$$L = (R^2+G^2+B^2)^{1/2} \quad (1)$$

$$\Theta = \text{Arctan}(G/R) \quad (2)$$

$$\Phi = \text{Arccos}(B/L) \quad (3)$$

L denotes the exposure or brightness of an image, whereas θ, φ emphasize the differences or changes of colors. When L is held constant, θ and φ describe the chromaticity is an illuminant surface. Since our focus is to differentiate between yellowish lesions and other darker objects in the color retinal images, we need to include both the brightness of the image as well as the changes of color information. Hence, we have selected L, θ, φ as our feature space, F (f_L, fθ, fφ). Then we need to derive an appropriate discriminant function. Our discriminant D(X) is derived from Bayes rule which is given as,

$$D_i(X) = (X-C_i)^T(X-C_i). \quad (4)$$

This is also called a minimum distance discriminant (MDD).

Applying $D_i(X)$ as defined above to the problem of detecting presence of exudates in retinal images, we define only two classes-yellow patches (lesions) and dark reddish background. The feature centers of lesions and background, $C_{lesion}(f_L,f_\theta,f_\varphi)$ and $C_{bkgnd}(f_L,f_\theta,f_\varphi)$, can be obtained and trained by selecting small windows inside exudates patches and background regions respectively in a set of typical sample images.

The means of exudates and background are then computed and stored as feature centers for the two classes respectively. For each pixel X (x_L, xθ, xφ) from the retinal image, the discriminant D_{lesion} and $D_{bkgnd}(X)$ are calculated. If $D_{lesion}(X)$ is less than $D_{bkgnd}(X)$, then pixel X is classified as lesion otherwise it is being classified as background. In this way, exudates or other yellowish lesions can be quickly detected. This simple and fast algorithm is able to achieve good accuracy in the detection of exudates in color fundus images. The results are shown in figures 6 to 11

Figure 6. TRAINING IMAGE FOR EXUDATES

Figure7. TRAINING IMAGE FOR BACK GROUND

Figure 8. INPUT IMAGE WITH OPTIC DISC CIRCLED

Figure 9. OPTIC DISC EXTRACTED IMAGE

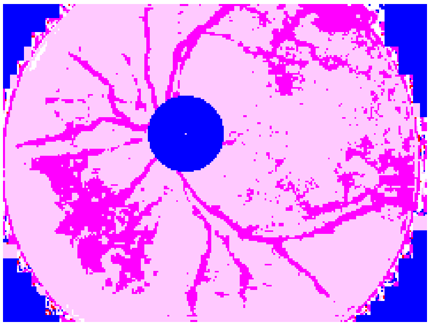

Figure 10. IMAGE CONVERTED TO SPHERICAL COORDINATES

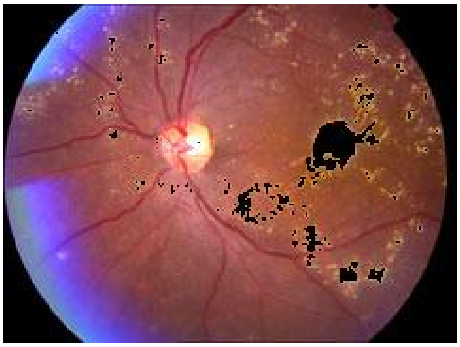

Figure 11. OUTPUT IMAGE WITH EXUDATES MARKED AS BLACK

2.4 Enhanced MDD Classifier

This image works on the RGB co-ordinates rather than spherical co-ordinates. In the Minimum Distance Discriminant (MDD) Classifier method, the centre of class is found using a training set and hence remains fixed. But this may cause problem because of difference in image illumination and their average intensity. So a method is employed such that the centre of class (C_{yell} and C_{bgnd}) varies dynamically depending on the image.

From previous Optic Disc detection method we know the position of the optic disc for the image. Using this knowledge we select a group of pixels that surrounds the Optic Disc and the mean of these pixels form the C_{bgnd}. Optic Disc usually has the same color and intensity as that of exudates. So the pixels that belong to the OD are used for calculation for C_{yell}.

$$C_{yell} = 1/m \sum_{i=1}^{m} Y_i \qquad (5)$$

$$C_{bgnd} = 1/n \sum_{i=1}^{n} B_i \qquad (6)$$

Where m & n are number of pixels in yellowish and background region respectively, that are used to calculate these centers and Yi and Bi are the vectors of the 3 color features in the different region of Optic disc and background.

The method attempts to detect exudates by using the two important features of exudates, its color and its sharp edges. It is carried out in the following steps.

- Detection of Optic Disc.
- Detection of yellowish objects in the image.
- Detection of objects in the image with sharp edges.
- Combination of the previous steps to detect yellowish objects with sharp edges.

2.5 Detection of Optic Disk

Principal Component Analysis between clusters and propagation through radii are used to detect Optic Disk. The area enclosing the Optic Disk is traced out and removed from the retinal image.

Figure 12 INPUT IMAGE WITH OPTIC DISK CIRCLED

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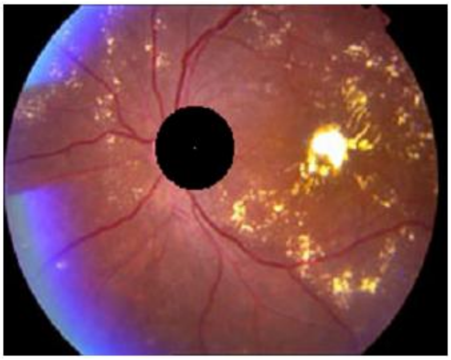

Figure 13 OPTIC DISC EXTRACTED IMAGE

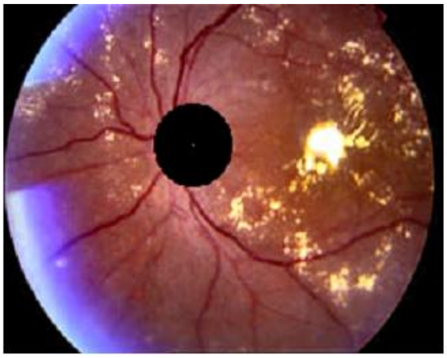

Figure 14 CONTRAST ENHANCED IMAGE

2.6 DETECTION OF YELLOWISH OBJECTS

The detection of yellowish objects is carried out performing color segmentation based on statistical classification method. It is based on the fact that if a group of features can be defined, so that the objects in an image map to non intersecting classes in feature space, then we can easily identify different objects classifying them into corresponding classes. We define two classes yellowish objects and background which are characterized using only three color features(R, G, and B).

Using Baye's theory the Minimum Distance Discriminant (MDD) is found as,

$$D_i(x) = -(x-C_i)^T(x-C_i) \quad (7)$$

Where i=1 ….N, N is the number of classes, here N=2.

So for each pixel X (x_R, x_G, x_B) the distances $D_{yell}(X)$ and $D_{bgnd}(X)$ are calculated. If $D_{yell}(X)$ is less than $D_{bgnd}(X)$, then the pixel X is classified as yellowish lesion, otherwise it is classified as background.

Next we performed an adjustment for non-uniformity of illumination, because of lighting variation, decreasing color saturation, skin pigmentation etc… the color of lesions in some regions of an image may appear dimmer than the background color that is located in another region and would be wrongly classified. We used a new color image; this image is obtained performing an operation of channels (N1, N2, N3) of the NTSC color space,

$$N1' = 1.5N1 - N2 - N3 \quad (8)$$

And then converting the image obtained (N1, N2, and N3) into the RGB color space again. We improve both contrasting attributes of lesions and overall color saturation in image making Optic disc and exudates to appear with same color independent of their location. Minimum Distance Discriminant (MDD) is applied to all pixels and the exudates are identified. While converting the ntsc image to rgb the color map is scaled to value '1'.Hence in mathematical computation the contrast improved image's value has to be multiplied by 255 since both the centre of class were obtained from the original RGB image where maximum intensity value is represented by 255. Along with exudates, other lesions like drusens, artifacts, Optic disc are also identified and the exudates are shown in figure 15 as black color.

Figure 15. DETECTION OF YELLOW OBJECTS FROM THE IMAGE

2.7 DETECTION OF YELLOWISH OBJECTS

There are various algorithms to find the edges of an image like sobel, canny etc…In our case we used sobel operator to find the sharp edges. We have a binary image with edges being shown white. This image contains the edges of optic disc, blood vessels, exudates and also the image boundary. So this cannot be independently used to determine the exudates.

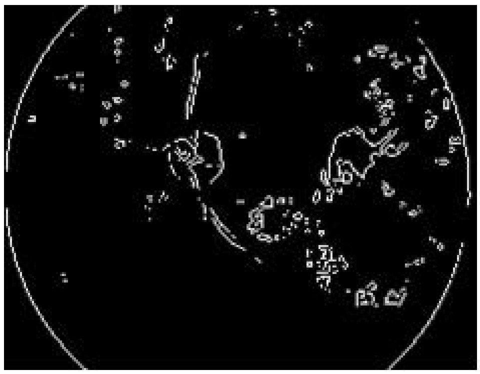

Figure 16. DETECTION OF SHARP OBJECTS FROM THE IMAGE

2.8 COIMBINATION OF TWO IMAGES

To detect only exudates and to remove all the false detections in the previous stages, we combined the two images obtained using Minimum Distance Discriminant (MDD) and edge detecting method through a Boolean operation, feature based AND. In feature based AND, ON pixels in one binary image are used to select object in another image. We used the image with objects having sharp edges to select objects in the image with yellowish elements, because in the last one the lesions are detected completely, not only their contours. Thus we obtain lesions characterized by two desired features-yellowish color and sharp edge. The boundary region encloses the exudates and is shown in figure17.

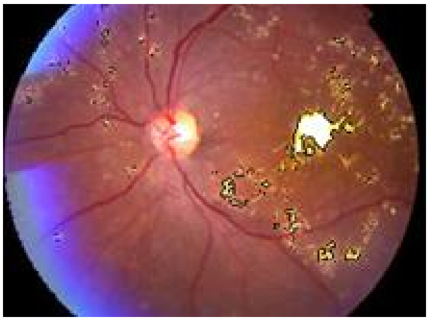

Figure 17. OUTPUT IMAGE GIVING BOUNDARY OF EXUDATES

3 CONCLUSION

The feature extraction again needs the proper thresholding values. The basic requirement in template matching is that we need both normal and abnormal images. The orientation, angle , lighting of both reference and the abnormal image should be same otherwise it would give wrong identification of the presence of exudates. Minimum distance discriminant (mdd) classifier is based on statistical recognition technique and this gives better result. But this works on spherical coordinates and the center is found using a training set and hence remain fixed. This may cause problem and employed such that the centre of class varies dynamically, depending on the image. Enhanced minimum distance discriminant (mdd) classifier uses rgb values of the image and the abnormality is characterized by the features yellowish color and sharp edges.

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