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Segmentation and Classification of Retinal Image Features

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***Abstract*—Retinal image analysis is becoming an important screening tool for the early revealing of certain risks and diseases such as Diabetic Retinopathy (DR). The main aim of this paper is to detect Diabetic Retinopathy. DR, also known as diabetic eye disease, is when damage occurs to the retina due to diabetes. It can eventually lead to blindness so it becomes necessary to develop a novel solution for easy detection of DR. It occurs when small blood vessels get damaged in the retina, due to the high glucose level. Exudates are the major sign of DR and the detection of exudates is the fundamental requirement to diagnose the progress of DR. Direct inspection of retinal image is not sufficient for the detection of DR and also requires periodic screening which is a time-consuming so this paper presents an automated process to detect DR through detecting exudate in fundus images. First, the image is converted into a grey scale which is followed by Adaptive histogram technique after preprocessing edge detection is done to detect exudates and then relevant features are extracted and finally, classification of DR is done using SVM classifier.**

Keywords—Diabetic Retinopathy, Exudates, Fundus images, Support Vector Machine Classifier.

I. INTRODUCTION

Diabetic Retinopathy (DR), the most common eye disease in the diabetic patients, occurs when small blood vessels get damaged in the retina, due to the high glucose level. It affects 80% of all patients who have had diabetes for 10 years or more, which can also lead to vision loss. Detection of diabetic retinopathy in advance protects patients from vision loss. The major symptom of diabetic retinopathy is the exudates. Exudate is a fluid that filters from the circulatory system into lesions or area of inflammation.

At first, diabetic retinopathy may cause no symptoms or only mild vision problems. Eventually, it can cause blindness. The condition can develop in anyone who has diabetes. The longer you have diabetes and the less controlled your blood sugar is, the more likely you are to develop this eye complication. Over time, too much sugar in your blood can lead to the blockage of the tiny blood vessels that nourish the retina, cutting off its blood supply. As a result, the eye attempts to grow new blood vessels. But these new blood vessels don't develop properly and can leak easily.This paper focuses on exudates because it provides Information about diabetic retinopathy. Exudates are largely made up of extracellular lipid which has leaked from abnormal retinal capillaries, hence there is often associated retinal oedema (which is not visible using direct ophthalmoscopy). So, an automated method is presented in this paper for detection of exudates from the colour fundus retinal images. The image containing exudates are shown in Figure 1.

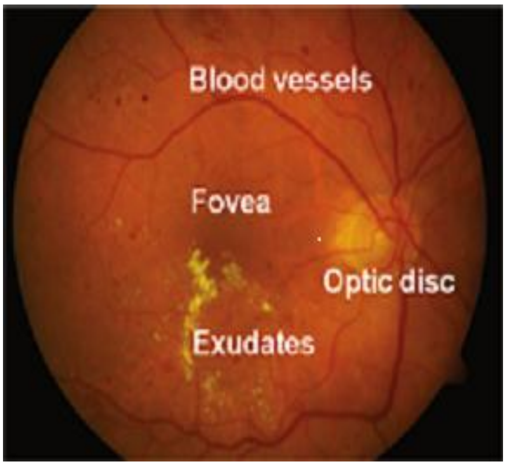

Figure 1. A retinal image containing exudates

Elbalaoui, M. Fakir, and A. Merbouha [1] proposed an automated method for the detection of exudates in retinal color fundus images. First, the image is converted to HSI model, after pre-processing possible regions containing exudate, the optic disk is detected using Hough transform. Graph cuts algorithm used for segmentation. Finally, the neural network was used which gives better results with a feature extraction of images. Ali Shojaeipour, Md.Jan Nordin and Nooshin Hadavi [2] suggested CAD system, that is created by the integration of computers and medical science for analyzing data. Features extraction and selection can be done using wavelets transform and the image was classified with a boosting classifier.

Kevin Noronha, Jagadish Nayak, and S.N. Bhat [3] describes the methods to detect main features of fundus images such as an optic disk, fovea, and exudates and blood vessels. The morphological techniques were applied in order to find the exact contours and the blood vessels were highlighted using bottom hat transform and morphological dilation after edge detection. V. Vijaya Kumari, N. Suriyanarayanan, and C.Thanka Saranya [4] used a robust and computationally efficient approach for localization of different features and lesions in retinal images. The green channel can use to detect the blood vessel and exudates, they both are separated by morphological operations. The optic disk is extracted by subtracting the blood vessel extracted an image from the exudate detected image.

Md. Jahiruzzaman, A. B. M. Aowlad Hossain [5] proposed an approach for detecting and classifying the High-Resolution Fundus (HRF) diabetic retinopathy image effectively. A k-means color compression technique was used to cluster the fundus image in the different region of interest reducing color dimension. Finally, the recognition of diabetic retinopathy was done by the knowledge-based fuzzy inference system (FIS). Prof B. Venkatalakshmi, V.Saravanan, and G.Jenny Niveditha [6] developed a novel solution for easy diagnosis of Diabetic Retinopathy. The hard exudates can be detected based on two features of this lesion such as the color and the sharp edges. Finally, each process involved in detecting hard exudates take up an icon in a single window called Graphical User Interface (GUI) window.

Syna Sreng, Noppadol Maneerat, Don Isarakorn, Jun-ichi Takada, and Ronakorn Panjaphongse M.D [7] proposed a method to extract OD and exudates. Blob boundary detection is used to find the most circular region by using the compactness measurement and morphological reconstruction. Finally, exudates are extracted by applying the maximum entropy thresholding. Morium Akter, Mohammad Shorif Uddin, and Mahmudul Hasan Khan [8] developed an automated system for the detection of exudates. Morphology-based methods are used for the detection of diabetic retinopathy through exudates from color fundus images.

Gowsalya P, Member IEEE, Mrs.S.Vasanthi [9] proposed segmentation of retinal for screening the eye diseases. Feature extraction of retinal blood vessels was obtained using Gradient Orientation Analysis followed by Morphological Operation. The line strength features use a line operator which aids to determine the linear structures in the retinal images. With the help of ensemble classifier normal and abnormal blood vessels was obtained separately. Similarly, fast localization with directional matched filtering is used to localize the exact OD location and the OD segmentation is done using the level set method.

II. METHODOLOGY

The automatic screening methodology for the proposed system is shown in Figure 2.The flow diagram depicts pre-processing of the input image, edge detection and then mathematical morphological operations are applied to the preprocessed images to detect the exudates. Then the image is assessed for the degree of abnormality of an image as moderate or severe risk using SVM classifier. In this paper, the evaluation of the automated screening system of diabetic retinopathy has been performed by using 90 different images which were taken from the database. The images are stored in a PNG image format (.png) files.

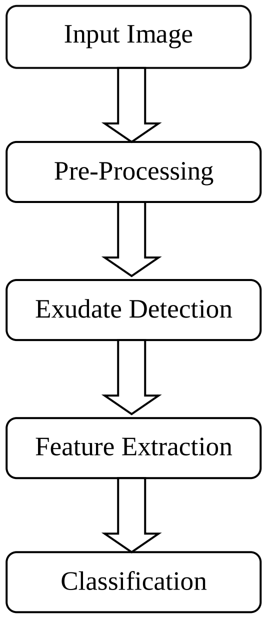

Figure 2. Flow Diagram of Proposed System

A. Pre-processing

Preprocessing is the first step for automatic diagnosis of retinal diseases. The problem with the retinal image is that the quality of the acquired images is usually not good. So, it is necessary to improve the quality of the retinal image. The purpose of pre-processing is to remove the noise from the retinal image as well as to enhance image contrast and image quality. This stage consists of color space conversion and image enhancement. In color space conversion, the color image is converted into gray scale model for the reason that working with gray scale image is more comfortable and easy than the color images.

The converted images quality is enhanced using contrast-limited adaptive histogram equalization (CLAHE). Adaptive histogram equalization (AHE) is a computer image processing technique used to improve contrast in images. It is different from ordinary histogram equalization by means that the adaptive method computes various histograms, each corresponding to a distinct section of the image, and utilizes them to redistribute the lightness values of the image. It is, therefore, suitable for improving the local contrast and enhancing the definitions of edges in each region of an image.

However, AHE has a tendency to over amplify noise in relatively homogeneous regions of an image. A variant of adaptive histogram equalization called (CLAHE) prevents this by limiting the amplification. In the case of CLAHE, the contrast limiting procedure has to be applied for each neighborhood from which a transformation function is derived. Image before pre-processing is shown in Figure 3 and the Image after pre-processing stages is shown in Figure 4.

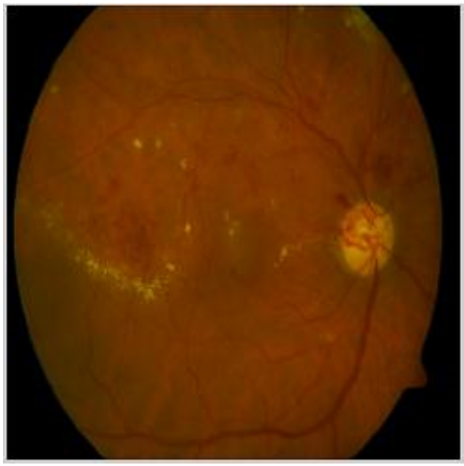

Figure 3. Original image

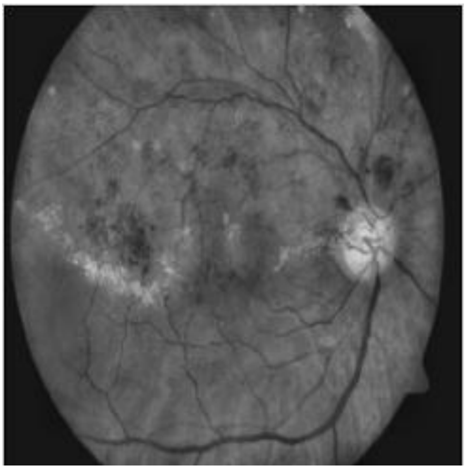

Figure 4. Image after Pre-processing

B. Detection of Exudates

1) Optic Disc detection:

The Optic Disc (OD) is the point in the eye where the optic nerve fibers leave the retina. Due to the absence of light-sensitive rods and cones of the retina at this point, it is not sensitive to light and thus is also known as "The Blind Spot" or "Anatomical Blind Spot". The optic disc in a normal human eye carries about 1 million neurons from the eye towards the brain. OD is the bright region within the retinal image and it has approximately a slightly oval (elliptical) shape. Exudates have similar intensity values as of OD. So it is necessary to detect and apply mask on the optic disc from the retinal image.

The circle Hough Transform (CHT) is a basic technique used in Digital Image Processing. It is a specialization of Hough Transform. The purpose of the technique is to find circles in imperfect image inputs. Objects of geometric shapes can be detected by converting the equation of the object into a Hough space parameter equation. For example, in a two-dimensional space, a circle can be described by:

$$(x-a)^2 + (y-b)^2 = r^2$$

The circle has three parameters in Hough space, the center (a,b) and the radius r of the circle. The optic disc is of elliptical shape which is approximately equal to circle, therefore the Hough transform is be used to detect the optic disc. This method finds the circular shape with fixed radius in a thresholded edge image of the fundus. Once the circle has been detected it becomes important to reduce the intensity of OD and this can be achieved by applying mask, hence a mask is created and applied on the detected circle.

2)Edge Detection:

Edge detection algorithm is applied to the masked image to make it suitable for identifying exudates. Canny edge detector is employed for the contour detection. This algorithm finds the edges where the grayscale intensity of the image changes and this variation can be found by determining gradients of the image. It enhances the blurred edges by preserving all local maxima in the gradient image. It can detect the boundaries optimally.

The Canny edge detection algorithm is known to many as the optimal edge detector. Canny's intentions were to enhance the many edge detectors already out at the time he started his work. He was very successful in achieving his goal and his ideas and methods can be found in his paper, "A Computational Approach to Edge Detection". In his paper, he followed a list of criteria to improve current methods of edge detection. The first and most obvious is low error rate. It is important that edges occurring in images should not be missed and that there be NO responses to non-edges. The second criterion is that the edge points be well localized. In other words, the distance between the edge pixels as found by the detector and the actual edge is to be at a minimum. A third criterion is to have only one response to a single edge. This was implemented because the first 2 were not substantial enough to completely eliminate the possibility of multiple responses to an edge.

Figure 5. Edge detected Image

Based on these criteria, the canny edge detector first smoothens the image to eliminate the noise. It then finds the image gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum (non-maximum suppression). The gradient array is now further reduced by hysteresis. Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a non-edge). If the magnitude is above the high threshold, it is made an edge. And if the magnitude is between the 2 thresholds, then it is set to zero. The edge detected image is shown in Figure 5.

3)Blood Vessel Removal:
Blood vessels have to be removed from the retinal image for identifying exudates. Ophthalmologist may mistaken blood vessels as exudates because the concentration level of both (blood vessels and exudates) are similar. High contrast vessels can be eliminated using dilation operator on the intensity image. Dilation is one of the basic operators in the area of mathematical morphology. The basic effect of the operator on a binary image is to gradually enlarge the boundaries of regions of foreground pixels (*i.e.* white pixels, typically). The dilation operation usually uses a structuring element (SE) for probing and expanding the shapes contained in the input image. One of the uses of dilation is to fill in small background color holes in images Blood vessels can be expanded using dilation by potentially filling in small holes (structuring element) and connecting disjoint pixels. It can be performed by laying structuring element on that image and sliding over the image. Structuring element is a shape, used to probe or interact with a given image, with the purpose of drawing conclusions on how this shape fits or misses the shapes in the image. A flat disc shaped structure described by structuring element, is used for removing the vessels that remain in the optic disc region. If the SE starts from brighter pixel, there will be no change then it will move to next pixel. If the SE starts from dark pixel, make all the pixels black from the image covered by the SE.

After applying dilation on edge detected image erosion operator is used to erode away the boundaries of regions of foreground pixels (*i.e.* white pixels, typically). Blood vessels are completely removed from the retinal image by using erosion operator on the dilated image.

4)Identifying the Exudates:
After detecting the optic disc and removing blood vessels from an image, closing operator can be used to detect exudates. Closing operator is defined simply as a dilation followed by an erosion using the same structuring element for both operation. Hence closing operator can distinguish the exudates portion from the non-exudates pixels.

C. Feature Extraction

After segmenting exudates regions in retinal images, the relevant features of an image should be extracted and it can be done using Gray Level Co-occurrence Matrix (GLCM). A co-occurrence matrix, also referred as a occurrence distribution, is defined over an image to be the distribution of co-occurring values at a given offset.

The gray-level co-occurrence matrix is represented as g[i,j], and it calculates how often a pixel with gray-level (grayscale intensity or Tone) value i occurs either horizontally, vertically, or diagonally to adjacent pixels with the value j. Texture is one of the important characteristics used in identifying objects or regions of interest in an image and contains important information about the structural arrangement of surfaces. The textural features based on gray-tone spatial dependencies have a general applicability in image classification. Based on the analyzed matrix and the texture information, the following features like autocorrelation, contrast, correlation, cluster prominence, correlation matlab inbuilt, energy and homogeneity were obtained.

1) Contrast

$$\text{Contrast} = \sum_i \sum_j (i-j)^2 g(i,j)$$

2) Correlation

$$\text{Correlation} = \frac{\sum_i \sum_j (i,j) g(i,j) - \mu_x \mu_y}{\sigma_x \sigma_y}$$

3) Cluster Prominence

$$\text{Cluster Prominence} = \sum_i \sum_j \{i + j - \mu x - \mu y\}^4 \, g(i,j)$$

4) Energy

$$\text{Energy} = \sum_i \sum_j (g(i,j))^2$$

5) Homogeneity

$$\text{Homogeneity} = \sum_i \sum_j \frac{1}{1+(i-j)^2} g(i,j)$$

The feature selection process can also reduce noise and enhance the classification accuracy. The TABLE I. below shows extracted features for the images shown in Figure 7 and 8.

TABLE I. Extrected Features

Parameters	Severe DR Image	Moderate DR Image
Autocorrelation	8.16666	4.08333
Contrast	1.16667	0.58333
Correlation	0.70833	0.84370
Cluster Prominence	6.20077	3.58488
Correlation matlab inbuilt	3.17593	2.18345
Energy	0.56609	0.34460
Homogeneity	0.83333	0.91666

D. Classification

After feature extraction of retinal images, the obtained image is applied to Support vector machine classifier. “Support Vector Machine” (SVM) is a supervised machine learning algorithm which can be used for classification purpose. Given a set of training examples, each marked as belonging to multiple categories, an SVM training algorithm builds a model that assigns new examples to one category or the other, making it a non-probabilistic binary linear classifier. SVM is a classification tool that uses machine learning theory to maximize predictive accuracy while automatically avoiding over-fit to the data, this classification task usually involves training and testing data which consist of some data instances . Each instance in the training set contains one target values and several attributes. The goal of SVM is to produce a model which predicts target value of data instances in the testing set which are given only the attributes.

Classification in SVM is an example of Supervised Learning. Known labels help indicate whether the system is performing in a right way or not. This information points to a desired response, validating the accuracy of the system, or be used to help the system learn to act correctly. A step in SVM classification involves identification as which are intimately connected to the known classes. This is called feature selection or feature extraction. They can be used to identify key sets which are involved in whatever processes distinguish the classes. Hence this classifier is used to evaluate training data to find a best way to classify images into different cases like normal, moderate or severe.

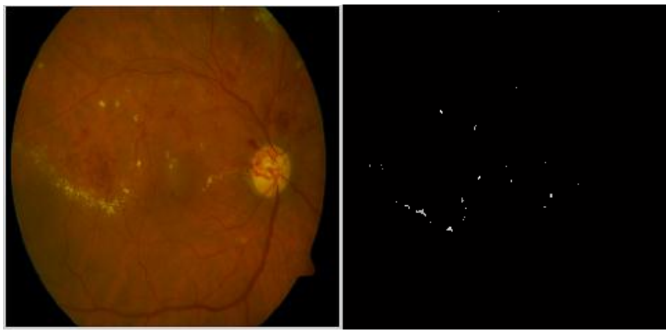

Figure 7. (a) Original image (b) Severe DR

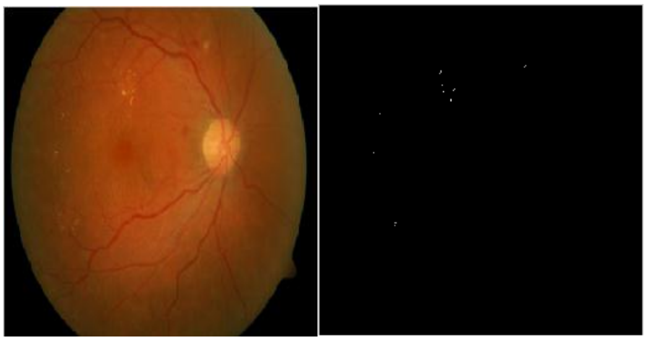

Figure 8. (a) Original image (b) Moderate DR

The results of classifier are shown in the figure 7 and figure 8. Figure 7. (a) shows the original image of severe stage of DR and its corresponding result is shown in Figure 7. (b). Figure 8. (a) shows the original image of moderate stage of DR and its corresponding result is shown in Figure 8. (b).

III. CONCLUSION

In this paper, the exudates were clearly diffentiatiated from optic disc and blood vessels. As the optic disc have similar intensity level of exudates, hough transform is used to detect circular shape then mask is applied on optic disc later blood vessels were completely removed beacause it also has similar intensity level of exudates. Thus the morphological operation were used to detect the presence and location of exudates. After detection of optic disc and removal of blood vessels the obtained image shows the location of exudates confirming the disease diabetic retinopathy. The proposed method not only detect the disease but also shows the severity level of the disease. The SVM classifier is used to assess the severity of this disease whether the patient is moderately affected or severely affected. This information will aid the physicians in quick examination of patients.

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