Diabetic Retinopathy Detection using RGB Image Processing Techniques

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Abstract- In modern era diabetic eye disease comprises a group of eye conditions that affect people with diabetes, in which diabetic retinopathy (DR) has the potential to cause severe vision loss. This paper proposes a peculiar algorithm in MATLAB for automating the detection of DR using fundus image. Several morphological operations performed on fundus image to detect and extract the features like blood vessels, micro-aneurysms and exudates. Automatic detection of DR will determine to sort between normal or abnormal eye based on the features detection. As a result, an early detection of DR facilitates medication to prevent vision loss. Real-time image processing shows encouraging results in terms of validity and efficiency.

Keywords- Diabetic retinopathy, Morphological operations, Exudates, Micro aneurysms, Blood vessels.

I. INTRODUCTION

Diabetic Retinopathy is the most widely recognized diabetic eye illness in which veins in the retina changes. The main problem with this disease is that patients are unaware of this disease as ophthalmologists fail to recognize the disease at the earlier stages. It is based on the following features:

Exudates, which are yellowish spots, causes by the accumulations of lipoprotein spilling from retinal blood vessels. Micro Aneurysms (MA) known as bleeding. It is the break of debilitated capillaries appearing as little dabs or bigger blotches. Blood vessels leak fluids, swell, close off completely or anomalous develop on the surface of the retina.

The symptoms of DR on the retina can easily be detected by automated image processing techniques. As blood vessels serve as the main retinal milestone feature so their segmentation plays a vital role in the screening system. Macula centered fundus images are used for the examination and the treatment of the disease. The abnormal lesions caused by the DR are soft exudates, MA, hard exudates and hemorrhage etc. All these lesions have some special characteristics, which help in the clinical evaluation of the disease.

As recently, multiple image processing techniques are being used to detect different diseases [1-2]. In the same faction, several kinds of research are made on DR using different techniques. Recently, automation method using fundus images of DR is a useful method for detecting this disease. Ref [3] proposed an algorithm using fundus images for the extraction of blood vessels. The author used techniques like thresholding and matched filter based on Spatially Weighted Fuzzy C-Means Classifier (SWFCM) clustering algorithm.

Moreover, [4-5] presented the convolutional neural networks (NN) method for the diagnosis of disease from funds images. Deep convolutional neural networks for DR detection, coupled with hyper-parameter tuning and transfer learning is discussed in [6]. Modular feedforward NN to categorize retinal images as abnormal and normal to perceive DR is studied in [7]. Furthermore, automated classification and analysis of DR using two-field funds photography are discussed in [8-9]. Template matching, feature extraction and enhanced MDD classifiers comparison were used to detect exudates and optic disc was detected using propagation through radii method. Light based molecular imaging in rodents has been established in, ref [10], to exhibit changes in protein levels in the retinal microvessels as diagnostic biomarkers. Furthermore, [11] presented the web-based application for automatic detection of DR screening. The performance of the system was in accordance with the results obtained in the previous studies and comparable to that of human experts.

A combination of coarse segmentation based on a local variation operation to sketch the boundaries of candidates having perfect boarders and fine segmentation based on new split and merge technique and adaptive thresholding was used to detect the candidates. Based on mathematical morphology, candidates segmentation method is proposed in [12] where random forest method is utilized to detect the exudates in candidates.

This paper presents the automated detection of DR by using fundus image as input, different image processing techniques are then applied on it. The workflow for detection of diabetic retinopathy is shown in Fig.1.

The techniques used in this paper are dilation, erosion, opening, closing, inversion of an image, edge detection and boundary detection. The opening and closing operations are followed by disk shape elements for removing or adding pixels in the input image. After doing all the procedure, the required image of damaged areas is achieved with features e.g., blood vessels, exudates and micro-aneurysms. Simulation results will show the difference between normal and abnormal eye.

Section II provides is a brief literature review of corresponding image processing techniques. Feature extraction of blood vessels, MA and exudates are addressed in section III. Section IV is about results and discussion. Eventually, in Section V, the conclusion is made.

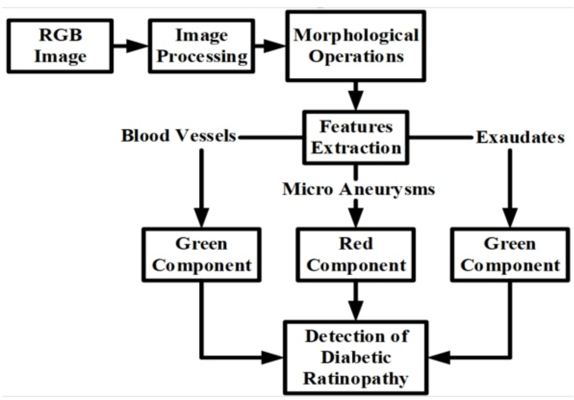


Fig.1. Workflow for detection of diabetic retinopathy

II. Image Processing Techniques

A. Morphological Operations

It is necessary to pre-process the fundus images to eliminate the non-uniform background. The uneven brightness and fluctuation in fundus image are main sources of non-uniformity. Hence Contrast-Limited Adaptive Histogram Equalization (CLAHE) is implemented to the image before employing any image processing techniques.

A structuring element (SE) is a morphology that is used to examine the image. The ball, disk, and octagon shaped SE are used more commonly among all other shape options.

A flat SE is a neighborhood of all binary values, either 2-dimensional or multidimensional, in which for morphological computation of a given radius only true pixels are included. The center pixel of the SE is called as origin, which identifies the pixel in the image being processed. Fig. 2 shows a disk-shaped SE and its center of origin with radius 3.

Moreover, morphological operations are used to recognize the form or structure of an image. This usually means classifying boundaries or objects within

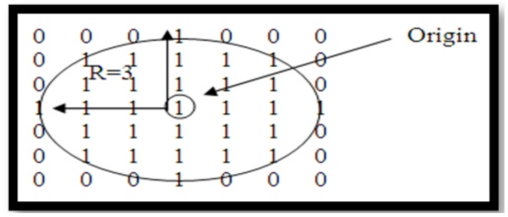


Fig. 2. Disk-shaped structuring element

an image. In a morphological operation, each pixel value in the output image is reliant on a comparison of the particular pixel in the input image with its neighborhood. A morphological process that is sensitive to specific shapes can be created in the input image by choosing the shape and size of the neighborhood. The various types of morphological operations include erosion, dilation, closing and opening[13].

Dilation thickens the vessels and then detraction of the eroded image from the dilated image gives the boundaries of the vessels, which are our requirement. Furthermore, binarization is preferred on the resultant image. After binarization, we get the boundaries of the blood vessels. Erosion deals with removing the unwanted pixels from the image with the help of a structuring element. The structuring element can be ball, disk and octagon shaped, it will have all ones in the shape suitable for desired factor removal and all zeros all around. Dilation, as well as erosion, is working on the principle of duality. Opening and closing are two basic operations derived from erosion and dilation. Opening is alike to erosion in which it retains the foreground area that is similar to SE and eliminates the rest of the area of the foreground. Likewise, closing is more like dilation that retains background area, which is similar to SE and removes the rest of the area of the background.

1) Thresholding

Thresholding is used to turn a gray sale or colored image into a single bit binary image. This is accomplished by making all pixels have only two colors i.e. black or white. The value limit that decides the ultimate 1 bit color of the image is called the threshold. In a fundus image, this helps to distinguish the blood vessels from the background by removing all grayscale information.

2) Edge Detection and Median Filtering

Edge detection is the procedure of locating and identifying the sharp cutoffs in an image. Edge detection can help to measure the size of objects within the image. Moreover, it isolates those objects from the background and recognizes particular objects for classification[14].

The six edge detection algorithms are as follows; Laplacian of Gaussian (LOG), Canny, Prewitt,

Roberts, zero-cross and Sobel. Out of these six methods, the canny method outperforms the others because it uses two thresholds for the detection of weak and strong edges.
A median filter is a non-linear filter that helps to reduce the "salt and pepper" noise in an image. It helps to reduce the noise as well as preserve the edges that are the requirement for edge detection; hence it makes it better than the other technique, i.e. convolution. In this method, a mean value is taken and the image is smoothed out by replacing the very small and very large values (Noisy Values) by their mean value.

III. FEATURES EXTRACTION

Features like blood vessels, micro-aneurysms and exudates are extracted by the following procedure.

A. Blood Vessels Detection

In the image pre-processing step, the green component of an image is extracted as it shows the best vessel-background contrast as compared to other colors [15]. After inverting the intensity of green component, the canny method is applied for edge detection. Furthermore, the detection of the border using the morphological opening operation, a disk-shaped SE with a radius of 8 is detected. The border of the boundary is then obtained by subtracting the eroded image from the original image.
CLAHE is then performed for improving the contrast of the image and for the correction of the uneven illumination. Opening operation is implemented again using a ball-shaped SE for smoothing out the background and highlighting the blood vessels. The image is then subtracted from the CLAHE. Resulting in an image that shows a higher intensity at the foreground (blood vessels) compared to the background contrast.
Thresholding with a median value of 0.1 is then performed on the grayscale image to make it binary; this removes any "salt and pepper" noise in the image. The median filtering is then used again to obtain the boundary by subtracting the border from the disk-shaped SE image. The border is finally removed by filling the separated holes (those that don't touch the edge), this gives us the final image that can be inverted to show blood vessels on a black background.

B. Micro-Aneurysms Detection

Micro-aneurysms appears as a point, slightly darker (red) than the neighboring of the fundus image, so red component from RBG is used to analyze micro-aneurysms [16]. Next, the severity is inverted for red component. Edge detection is performed using the canny method as in blood vessels. For boundary identification, opening operation is used by mixing holes using disk shape SE of radius 8. After that image obtained from the canny method and opening operation are subtracted to attain boundary-less image. The image obtained from opening operation in which holes were introduced, it was subtracted from the image without holes or gaps. The final image contains MA and other undesirable artifacts without the corners (edges).
The Canny method was used to detect the edges of blood vessels using the same procedure. The image obtained from canny detection is subtracted from the image after boundary removal image. Then again after introducing holes, the obtained image is subtracted from the image containing MA and undesirable artifacts results image contains only MA.

C. Exudate Detection

Exudates can be seen as yellow spots in the fundus images. They are easier to spot compared to the MA. For the detection of the exudates, the green colored element from the RGB image is extracted and a 9 octagonal SE is created. To make the exudates more prominent a morphological opening is performed. After this process, the residual optic disk is still present, as its gray levels are similar, but the exudates become visible. The image is then arranged into columns; here the parameter sliding indicates the usage of overlapping neighborhoods[17].
The unwanted artifacts are then removed leaving only the border, optic disk and the exudates. The thresholding is then performed with a threshold value of 0.7. Morphological closing is also performed, this gives a disk-shaped SE of 10 size by filling up the gaps and holes of the exudates. This disk has the highest pixel density in the image so canny method with Region of Interest (ROI) is used for detecting the edge and to remove the optic disk. First, a radius of 82 is defined as most of the optic disc is of size 80 x 80 pixels.
The optic disk and the border are then removed, followed by morphological erosion operation. This results in a 3 disk-shaped SE which constitutes entirely of the exudates.

IV. RESULTS AND DISCUSSION

All the results and their respective discussion for the detection of blood vessels, exudates and MA are discussed in the forthcoming subsections.

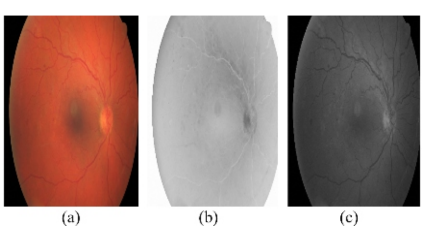
A. Results of Blood Vessels Detection

This section includes results of the operations discussed in the section above.
The first image shows the fundus image in the table. The image is an 8-bit image having 720 and 576 pixels. The image is a composition of red, green and blue components, from which we can extract the desired component. Here, the green component of the fundus RGB image is used for extracting the blood vessels that

are green in color. Most of the information lies in the green area of an image. The result shows in Fig. 3(b) after extracting component, invert the image and use the inverted image to detect the boundary and to detect the blood vessels separately shown in Fig. 3(c). In order to detect the boundary of the image Morphological Operations, Erosion and Dilation are performed as shown in Fig. 3(d, e). Erosion removes unwanted pixels from the image. It removes the noise to some extent and shrinks vessels too. SE of different shapes is used for the erosion process. It can be of different radius, the radiuses used here are 3,5,8,9 and 10, whereas the shape of the element depends on our requirement. Dilation adds pixels in the image and it thickens the vessels. Moreover, dilation is performed to detect boundaries. Multiplication with SE is performed for adding pixels.

The image achieved from erosion and dilation gives the blood vessels without boundaries. Subtraction of the eroded image Fig. 3(f) from the dilated image gives the boundaries of the vessels. After subtraction, the area having the blood vessels are detected. Binarization is preceded afterward to obtain a clear image of the desired area from eroded and dilated image shown in figure Fig. 3(g).

Now to detect the blood vessels, adaptive histogram equalization is performed in Fig. 3(h) on the inverted image which improves the image contrast as well as prevents the over-amplification of the noise. Calculating cumulative distribution functions (CDF), probability density functions (PDF) and shifting the pixels to a new point, which will have improved contrast and less noise, follow histogram equalization. A morphological opening is performed in Fig. 3(i) on the inverted image using the 'ball' structuring element. The 'ball' shaped structuring element gives the best results. Opening is done to highlight the blood vessels and to smooth on the background of the image. Contrast is resolved as the difference in color and brightness of the object in question and other objects within the same field of view. Subtract the image from the contrast image results in an image that shows higher intense values at the blood vessels than the background as shown in Fig. 3(j). After that, the binarization is performed in Fig. 3(k) on the image. The median filter is used to eliminate the noise, as the noise present in the image is just like salt and pepper noise. Finally, intense values of the image with the only periphery are subtracted from the transformed intense values of the image with blood vessels in order to eliminate the edges. The blood vessels are detected and shown in Fig. 3(l).



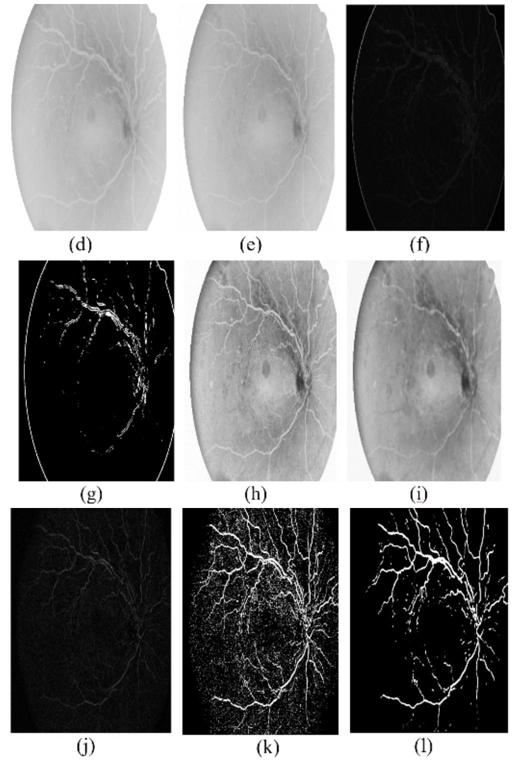
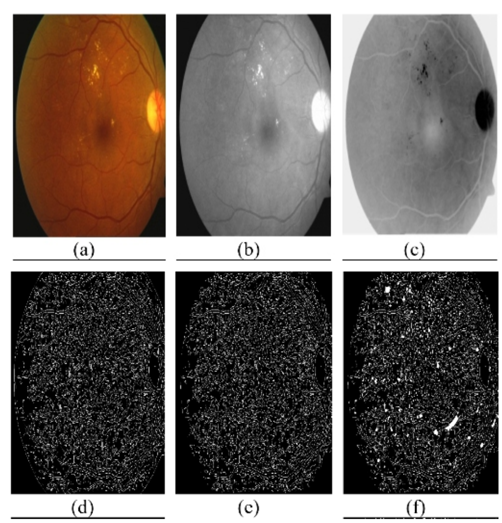


Fig. 3. Results of Blood vessels detection (a) Original image (b) Green component extraction (c) Inversion (d) Erosion (e) Dilation (f) Subtraction (g) Binarization (h) Histogram Equalization (i) Opening (j) Subtraction from contrast image (k) Binarization (l) Output image.

A. Results of Micro Aneurysms Detection

The fundus RGB image is shown in Fig. 4(a) is used for the detection of Micro Aneurysms (MA) in which only red component is used. After extracting red component as shown in Fig. 4(b), invert the image and use the inverted image to detect the boundary of the image as shown in Fig. 4(c).



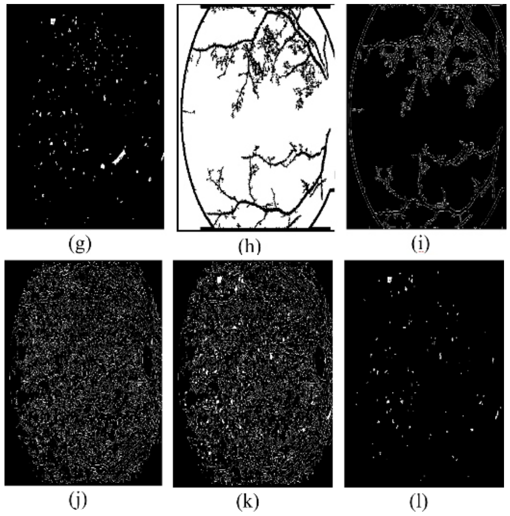


Fig. 4. Results of Micro Aneurysms Detection (a) Fundus image (b) Red component (c) Inverted red component (d) Canny edge detection (e) Subtraction (f) Filling holes or gaps (g) Subtraction (h) Blood vessels detection (i) Blood vessels after edge detection (j) Subtraction (k) Filling holes or gaps (l) Output image.

Filling up the holes performs detection of an edge. A disk-shaped SE created with erosion then dilation as shown in Fig. 4(d). Image Fig. 4(e) shows the image without boundary, which is obtained after subtracting canny edge image from the image with boundary. After filling holes, resulting MA with undesirable artifacts shown in Fig. 4(f), Furthermore after and before filled holes images are subtracted shown in Fig. 4(g). The image Fig. 4(h) contains MA and other undesirable artifacts without the corners (edges).

Blood vessels are identified using the same canny method to detect the edges of blood vessels shown in Fig. 4(i). The image obtained from canny detection is subtracted from the image after boundary removal image as shown in Fig. 4(j). Furthermore, after introducing holes the image is shown in Fig. 4(k), at last, the obtained image Fig. 4(l) is subtracted from the image containing MA and undesirable artifacts result image contains only MA. Finally, MA appears as tiny dots.

C. Results of Exudates Detection

The fundus image is shown in Fig. 5(a) is used for the detection of exudates. For detection of exudates, the green channel of RGB image is extracted in Fig. 5(b) as exudates are green in color and their information lies in the green channel.

Closing operation is performed in Fig. 5(c) on the SE results the exudates can be easily seen, although with the presence of the optic disk, as they have similar grey levels. SE is used for closing with disk, octagon and ball shapes of radius 8,9 and 10.

Image Fig. 5(d) shows the column-wise neighborhood operation, which is basically used to remove the undesirable artifacts left with border only.

Moreover, the thresholding operation is performed in Fig. 5(e) which basically takes color or grayscale image as input and output is 1- bit binary image either black or white depends on the threshold and pixel intensity.

The image after performing the morphological closing operation is shown in Fig. 5(f)

Result in Fig. 5(g) shows the detection of weak and fine blood vessels and removal of the optic disc after canny edge detection is shown in Fig. 5(h). Fig. 5(i) shows the image after removing borders.

Finally, in Fig. 5(j) erosion operation with disk-shaped SE of size 3 is performed to obtain the final image with only exudates. The exudates are detected having an area of 3190.

Exudates for the normal eye are not present and area for it is calculated to be 0.

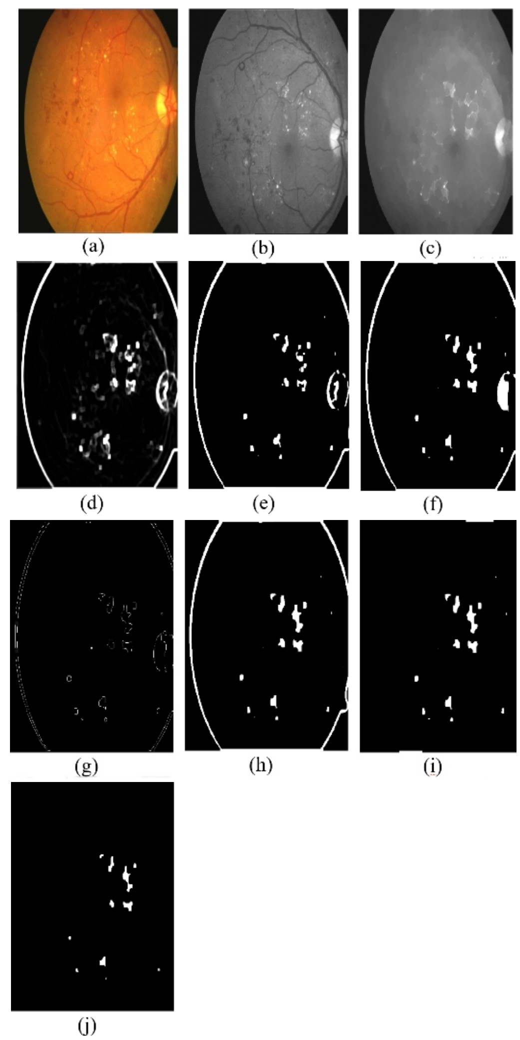


Fig. 5. Results of Exudates Detection (a) Input image (b) Component Extraction (c) Closing (d) Columnwise neighborhood Operation (e) Thresholding (f) Closing (g) Canny edge detection (h) Removing optic disc (i) Removing border (j) Output image.

V. Conclusion

Prolonged diabetes leads to diabetic retinopathy. If early-stage detection were not made, it could cause the severe vision loss. This paper proposed features detection to detect diabetic retinopathy using image-processing techniques. This method has great implication in saving time and burdensome work, which is an uncertain diagnosis. However, system can be improved further by using more input features and diverse data.

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