Detection of Vascular abnormalities of proliferative DR and non-proliferative DR

Sharath Kumar K T¹, Dr. H.V Kumaraswamy²
¹Student, M. Tech-LDC, RV College of Engineering, Bangalore
²Professor & HOD, Telecom Department, RV College of Engineering, Bangalore

Abstract
Diabetic Retinopathy is a common complication of diabetes that is caused by changes in the blood vessels of the retina. The symptoms can blur or distort the patient’s vision are a main cause of blindness. The blood vessels in the retina get altered. Exudates are secreted, microaneurysms and haemorrhages occur in the retina. The appearance of these features represents the degree of severity of the disease. Regular screening is essential in order detect the early stages of diabetic retinopathy for timely treatment to prevent further deterioration of vision. However, a significant shortage of professional observers has prompted computer assisted monitoring. This project detects the presence of abnormalities in the retina using image processing techniques by applying morphological processing to the fundus images to extract features such as blood vessels, micro aneurysms, haemorrhages, exudates and neo vascularization and perform different edge detection like canny, Robert, Prewitt and Sobel for feature like blood vessel for earlier detection. Then depending on the Area of these features are used for the detection of severity of Diabetic Retinopathy. Since an early detection and diagnosis will aid in prompt treatment and a reduction in the percentage of visual impairment due to these conditions, it will aid for a better treatment plan and to improve the vision related quality of life. It can quickly process a large number of fundus images obtained from mass screening to help reduce the cost, increase productivity and efficiency for ophthalmologists.

Keywords— Diabetic Retinopathy (DR), Blood Vessels, Exudates, Micro Aneurysms, Haemorrhages, Image Processing, Morphological Processing, Top Hat, Optic Disc, Disease Severity, Median Filter

1. Introduction
Diabetic retinopathy occurs in patients suffering from diabetes, which causes damage to the retina of the eye. This eventually leads to total vision loss. Diabetes is caused due to the body’s inability to store and make use of the sugar level in the blood. Usually there are no early visible symptoms of the disease and as the disease progresses the presence of micro aneurysms, exudates, haemorrhages new blood
vessels and neovascularisation can be observed. Diabetic retinopathy is of two types, namely non-proliferative and proliferative type. Non-proliferative is the early stage of the disease characterized by the presence of micro aneurysms, haemorrhages and exudates. Micro aneurysms are noticed in the eye. Proliferative diabetic retinopathy is the later stage. Circulation problems cause areas of the retina to become oxygen-deprived or ischemic. New fragile, vessels develop as the circulatory system attempts to maintain adequate oxygen levels within the retina. This phenomenon is called neo-vascularization. These new blood vessels have weaker walls and may break and bleed, or cause scar tissue to grow that can pull the retina away from the back of the eye. When the retina is pulled away it is called a retinal detachment and if left untreated, can cause severe vision loss, including blindness.

1.1 Retinal Imaging for Screening of Diabetic Retinopathy

Digital imaging technology has developed into a versatile non-invasive measurement tool which enables a wealth of applications in medical sciences. Since the retina is vulnerable to micro-vascular changes of diabetes and diabetic retinopathy is the most common complication of diabetes, eye fundus imaging is considered a non-invasive and painless way to screen and monitor such diabetic eyes. The manual analysis of retinal photographs is time consuming, expensive and requires trained ophthalmologists and specialized equipment. To cope with these challenges, digital imaging of the eye fundus, and automatic or semi-automatic image analysis algorithms based on image processing and computer vision techniques provide a great potential. By automating the analysis process, more patients can be screened and referred for further examinations, and the ophthalmologists have more time for patients that require their attention. Imaging the eye fundus with modern techniques is a current practice in many eye clinics, and it is becoming even more important as the expected lifetime and the costs of health care increase.

Diabetic retinopathy is the most common complication of diabetes and the primary cause for visual impairment and blindness in adults. Retinopathy is often asymptomatic and the patient is unaware of retinopathy until the eyes are routinely examined or until visual impairment is detected. It is important to note that it is not possible to diagnose diabetic retinopathy using laboratory tests. Therefore, diabetics’ eyes should be regularly checked. Alternate modalities such as fluoresce in angiography and optical coherence tomography, are typically utilized to reinforce the eye examination. If the retina is unreachable and light cannot traverse in the eye, the condition of the retina can be inspected using ophthalmic ultrasound. The ultrasound cannot directly detect diabetic retinopathy, but it can detect if retinal detachment is present due to proliferative retinopathy and non-proliferative retinopathy.

Figure 1: Features in the retina
In the screening of diabetic retinopathy, the primary health care doctor use either retinal fundus photograph evaluation or direct ophthalmoscope to investigate the state of the retina. Patients having either no or mild changes are monitored in the primary health care. If the symptoms are in the more advanced stage or the eye fundus images are upgradeable, the patient is referred to an ophthalmologist, preferably specialized in diabetic retinopathy. The ophthalmologist re-evaluates or takes new eye fundus images, or conduct clinical examinations to diagnose the severity of the disease. Depending on the diagnosis, the patients are appointed for further examinations or treatment.

2. System Methodology

Anatomical Structure Extraction

The detection of optic disk is a very important task because of it’s similarly in brightness and contrast to the exudates. The Border Formation needs to be performed only on the region of interest (ROI).

Feature Extraction

3. Detection of Blood Vessels

The fundus image is first pre-processed to standardize its size to576x720. The intensity of the green channel is then inversed before adaptive histogram equalization is applied. The optical disk is a black patch in the image shown at Fig 3.2 (b). Morphological opening which consists of erode followed by
Dilate is applied. Erode function protects the small blood vessels by reducing their sizes while dilate function blows up the larger remaining details which are intended to be removed.

The optical disk is then removed. The image is then converted to a binary image using the function “im2bw”. The pixels of the input image are converted to binary 1 (white) for values greater than the selected threshold and to binary 0 (black) if otherwise. The converted binary image at this point is still noisy and function “bwareaopen” is applied remove the small area of pixels considered to be noise.
The green component image 3.2(a) is also applied with adaptive histogram equalization and image segmentation to select the blood vessels area. Small pixels which are considered as noise are also removed. Some blood vessels are lost at the optical disk region after applying image segmentation. Hence, a mask is created to retain those blood vessels located when AND logic is applied. The image is combined with the mask and compared with the earlier blood vessel image using AND logic. The similar pixels are output as binary 1 (white) and represent the blood vessels.

![Figure 3.4 (a) Mask at the optical disk area, (b) Blood vessel image with noise](image)

### 3.1 Border Formation

**Method 1**
Grayscale image is used in the border detection. The first method uses canny edge detection to detect the edges before enclosing the circular region with a top and bottom bar. Function “imfill” is then applied to fill the region. The circular border is obtained after subtracting the dilated image with the eroded image.

**Method 2**
Method 2 is activated when a noisy image is obtained from method 1 instead of a circular border. This method inverses the intensity of the image first before image segmentation is applied with the function “im2bw”. The circular region is filled as a result and the circular border is obtained after subtracting the dilated image with the eroded image.

![Figure 3.5 Circular border](image)

### 3.2 Mask Creation For Optical Disk

As the optical disk is made up of a group of bright spots, it is not suitable to use loops and locate the largest value. This would only point to one spot and most likely to be on the side of the optical disk. The mask required to cover the optical disk would be inefficient as it would be much larger and covers more details. Mask creation is used in the detection of blood vessels, exudates and microaneurysms and haemorrhages. The grayscale image is used. The brightest pixel is first found in the image. The coordinates of all brightest points are then determined and the median is found. With this
3.3 Results of Final Blood Vessel
The area of the blood vessels is obtained by using two loops to count the number of pixels with binary 1 (white) in the final blood vessel image.

![Figure 3.6(a) Original fundus image, (b) Blood vessels image](image)

4. Detection of Exudates
Exudates appeared as bright yellowish deposits on the retina due to the leakage of plasma containing lipids from abnormal vessels. Their shape and size will vary with the different retinopathy stages.

![Figure 4.1: Block Diagram for Exudates Detection](image)

The fundus image is first pre-processed to standardize its size to 576x720 and the intensity of the grayscale image is then adjusted. Morphological closing which consists of dilate followed by erode is applied to remove the blood vessels. The dilate function expands the exudates area while erode function removes the blood vessels. The image (Fig 4.2 (a)) is then converted to double-precision value for function “colfilt” to mark the exudates (Fig 4.2(b)). This 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 points 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 function is then applied to fill the exudates.

Non-exudates (dark features) are extracted from the grayscale image using function “im2bw” and are represented as binary 1 (white) after intensity inversion. AND logic is then applied to the images {Fig 4.4 (a) and Fig4.4(b)} to detect the exudates {Fig 4.5}

4.1 Result of Final Exudates
The area of the exudates is obtained by two loops to count the number of pixels with binary 1 (white) in the final exudates image.
5. Detection of Microaneurysms

Micro aneurysms appeared as small dark round dots (~15 to 60 microns in diameter) on the fundus images. They are small bulges developed from the weak blood vessels. Hence, it is essential to detect them during the mild stage.

The fundus image is first pre-processed to standardize its size to 576x720 and the intensity of the grayscale image is then adjusted. The image’s contrast is stretched by applying adaptive histogram equalization before using edge detection (Canny, Robert, Prewitt, Sobel method) to detect the outlines of the image. Canny is the best edge detection for the earlier detection of DR.
The circular border is then removed before applying the function “imfill” to fill up the enclosed area {Fig5.3 (b)}. The holes (micro aneurysms and noise) image is obtained by subtracting away the edges image and removing the larger area using function “bwareaopen”. However, the image would still contain noise like blood vessels and exudates.

The exudates are first obtained using the original gray scale image and subtracted from the image in {Fig5.3 (b)} to remove the exudates which are present. The image {Fig 5.3} still contains the blood vessels in it. The blood vessels are obtained after applying adaptive histogram equalization and segmentation to the gray scale image. The final Micro aneurysms image is obtained after removing the optical disk area.

The exudates are first obtained using the original gray scale image and subtracted from the image in {Fig5.3 (b)} to remove the exudates which are present. The image {Fig 5.3} still contains the blood vessels in it. The blood vessels are obtained after applying adaptive histogram equalization and segmentation to the gray scale image. The final Micro aneurysms image is obtained after removing the optical disk area.

5.1 Result of Final Micro Aneurysms
The area of the micro aneurysms is obtained by using two loops to count the number of pixels with binary 1 (white) in the micro aneurysms image.

6. Detection of Hemorrhages
A retinal haemorrhages can be caused by hypertension, retinal vein blockage of the retinal vein) or diabetes mellitus (which causes small fragile blood vessels to form, which is easily damaged). It take place outside of the macula can undetected for many years. The white patch indicates the haemorrhages detection in the image.
There are two parts in detection.

1) Detection of Blood Vessels.

2) Detection of Blood Vessels with Haemorrhages.

Gray conversion helps identify all the exudates, optic disc Blood vessel and hemorrhages clearly. The green channel will clearly exhibit the red colour feature of both Blood Vessel and hemorrhages compared to other channels in original image. The extracted green channel image now displays the hemorrhages and Blood vessels in dark colour in the gray scale image. After that, Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied to the image to increase its contrast. It is transform which is used to extract small objects from an image. It is divided into two techniques:

1) White Top Hat

2) Black Top Hat.

White Top Hat is the difference between the image and the opening of image while Black Top Hat can be described as the difference between the image and the closing of the image. The White top hat operation aims to obtain the resulting image which contains bright and thin features with the size smaller that the structuring element. Morphological opening itself is an operation in which the Dilation and Erosion is applied to the Image. Morphological top hat is applied to the pre-processed image Firstly; opening is used on the image to obtain the filtered using ball shape structuring element. Then the filtered background is subtracted from the image. After that the image is binarized. The outputs of the binary image with the retinal vessels and hemorrhage candidates in white and the background in black. These white objects are called binary large objects or blobs. Here Median filter is used to remove the Noise.

Figure 6. (a) After Top hat and  (b) Blood vessel with noise

Figure 6.(c) Hemorrhage candid
6.1 Result of Final Hemorrhages
The area of the hemorrhages is obtained by using two loops to count the number of pixels with binary 1 (white) in hemorrhages image.

![Original fundus image](image1.png) ![Hemorrhages image](image2.png)

**Figure 6.4** (a) Original fundus image, (b) hemorrhages image

7. Comparison Of Different Edge Detection Technique
Canny algorithm depends heavily on the adjustable parameter symbol row which is the standard deviation for the Gaussian filter, and the threshold values, ‘T1’ and ‘T2’. Symbol row controls size of the Gaussian filter. The bigger the value of row, the larger the size of the Gaussian filter becomes. This implies more blurring, necessary for noisy images as well as detecting larger edges. Smaller the values of row imply a smaller Gaussian filter which limits the amount of blurring, maintaining finer edges in the image. Cannys edge detection algorithm is computationally more expensive compared to Sobel, Prewitt, and Roberts’s operator. However, the Cannys edge detection algorithm performs better than these entire operators under almost all scenarios. The main advantage of using canny is using probability for finding error rate, Localization and response, Improving signal to noise ratio, Better detection specially in noise conditions, accurate the disadvantage is Complex computations, False zero crossing, Time consuming. In the above fig here using a canny. The above fig shows canny is the best for the earlier detection proliferative diabetic retinopathy and non-proliferative diabetic retinopathy.

![Canny edge detection](image3.png)

**Figure 7.1** After Canny edge detection of blood vessel
Table I. The Following Tables shows Extracted Features and Disease Severity Classification

<table>
<thead>
<tr>
<th>INPUT FUNDUS IMAGE</th>
<th>BLOOD VESSELS</th>
<th>MICRO ANEURYSMS</th>
<th>EXUDATES</th>
<th>HEMORRHAGES</th>
<th>CLASSIFICATION/AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
<td>NORMAL BV-17352 MIC-0 EXU-0 HEM-0</td>
</tr>
<tr>
<td><img src="image6" alt="Image" /></td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
<td><img src="image9" alt="Image" /></td>
<td><img src="image10" alt="Image" /></td>
<td>MILDE BV-19503 MIC-388 EXU-0 HEM-0</td>
</tr>
<tr>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
<td><img src="image13" alt="Image" /></td>
<td><img src="image14" alt="Image" /></td>
<td><img src="image15" alt="Image" /></td>
<td>SEVERE BV-38660 MIC-482 EXU-616 HEM-199</td>
</tr>
</tbody>
</table>

8. Results

Depending of area of the feature disease are classified in to normal, mild and sever for non-proliferative diabetic retinopathy features like blood vessel, microanerysm , exudates and hemorrhages and proliferative diabetic retinopathy that is neo vascularisation.

9. Conclusion

In this paper, a system for the routine analysis for the initial signs of Diabetic Retinopathy (DR) has been developed by applying effective image processing techniques on the fundus images. By using MATLAB, the features such as blood vessels, micro-aneurysms hemorrhages exudates and neo-vascularization are detected. And performs different edge detection technique and canny is the best In order to detect the severity of DR the area of these features is calculated. Based on the results of area computation, the system uses the classification as normal, mild, severe to identify the stages of non-proliferative DR and proliferative DR. In the normal stage, there are no micro aneurysms hemorrhages and exudates. The mild stages are characterized by the presence of micro aneurysms. Since the blood vessels are weakened, we find the presence of micro aneurysms which are swellings in the small blood vessels called capillaries. In the severe stage, the weakened blood vessels are damaged and let fluids like plasma and lipids into the retina. Thus it shows the presence of exudates, hemorrhages and micro aneurysms. This image analysis will play an ever greater role in clinical ophthalmology fluids like plasma and lipids into the retina. Thus it shows the presence of exudates, hemorrhages and micro aneurysms. This image analysis will play an ever greater role in clinical ophthalmology.

10. References


