# Review on Image Analysis of Retinal Blood Vessel Images for Diagnosis of Diabetic Retinopathy

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## ABSTRACT
Diabetic Retinopathy (DR) is commonly occurring difficulty in Diabetes Mellitus (DM) patients. And therefore early detection of DR is effectively beneficial for the patient for further treatment of the disease. Appearance of the retinal blood vessel is a significant sign of diabetes. Out of many methods for detecting DR, segmentation of retinal vessels is currently found automated method for observing the state of retinal vessels. This paper reviews segmentation of retinal vessels by the application of various filters like High Pass filters, Laplacian filter, Sobel filter, Laplacian of Gaussian filter, Gaussian match filter, Binary Matched filter and Kirsch filter. It also reviews the results of segmentation by applying the above filters to retinal fundus image from STARE database.

### Keywords
Diabetic Retinopathy (DR), Diabetes Mellitus (DM),Non-Proliferative Diabetic Retinopathy (NPDR), Proliferative Diabetic Retinopathy (PDR), Segmentation of retinal image, Image Filters.

## 1. INTRODUCTION
Diabetes mellitus (DM), commonly referred to as diabetes, is a group of metabolic diseases in which there are high blood sugar levels over a prolonged period. This high blood sugar level can cause enormous problems which affect the end organs of the body including kidney, liver, heart, eyes and also limbs. Diabetic retinopathy is a condition occurring in persons with diabetes that occurs when the retina blood vessels are damaged which causes progressive damage to the retina [1].These complications, if ignored, can lead to serious damage to the patients. The number of diabetic patients is increasing day by day and the number of ophthalmologists is comparatively less as compared to the number of patients. Hence there is a need to develop an automated diagnostic system to expedite the work of the practitioner and reduce morbidity of the patients [2]. The diagnosis of diabetic retinopathy is carried out by using colour fundus images. Many methods are employed to obtain these images, such as wavelength transform, hybrid filtering, radon transform and morphological reconstruction [2]. This paper reviews the method of using image segmentation for the diagnosis of DR. Many methods have been discovered for segmentation of retinal vessels and they are divided into rule based methods and supervised methods. This paper reviews rule based method of segmentation using filters. The main idea is to use image filtering to extract blood vessels from retinal images. The method uses various types of filters-High pass filter, Laplacian filter, Sobel filter and Laplacian of Gaussian filter, Gaussian match filter, Binary Matched filter and Kirsch filter.

## 2. DIABETIC RETINOPATHY
Diabetic Retinopathy is a common condition that is usually seen in diabetic patients causing damage to the retina. DR occurs due to damage to the tiny vessels that nourish the retina. This results in thickening of retina. Based on the type of damage to the vessels, DR can be of two types, i.e., Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). [3]
In NPDR, which is early state, the blood vessels in the retina are weakened causing tiny bulges called micro-aneurysms to protrude from their walls. Whereas in PDR is advanced form of the disease in which new fragile blood vessels can begin to grow in the retina and into the vitreous, the gel-like fluid that fills the back of the eye. These new blood vessels may leak blood into vitreous that results in cloudy vision [3].

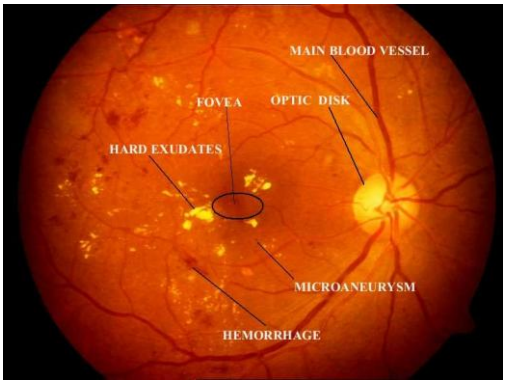


**Fig. 1 various affected areas [1]**

Diabetic Retinopathy lesions vary from micro-aneurysm and haemorrhages to exudates-soft cotton wool spots and hard exudates. Fig.1 shows various affected areas. In order to extract the abnormal lesion first the normal physiological components resembling the lesion in pixel intensity have to be extracted e.g. optic disc in case of exudates detection and fovea and blood vessels in case of haemorrhages and micro-aneurysms [1].

## 3. PROCESSING STEPS
### 3.1 Pre-processing:
The RGB image is converted to monochromatic image. The monochromatic image is enhanced in contrast by process of contrast enhancement. Thresholding can be done for converting image into binary image that lessens computational time. Threshold value for contrast enhancement can be taken as 33% of the highest grey level of the image.
Noise may be introduced in the image due to digitization process. Pre-processing also includes reduction of noise. Noise can be minimized by 5x5 mean filter. It is found that retinal vessels appear darker in grey images. Application of green filter to the image enhances the contrast between the retinal vessels and background [4].

### 3.2 Image Segmentation
The blood vessel can be viewed as a thread like structure in the retinal image. This can be done by image segmentation techniques mentioned in this article such as Laplacian filtering,

Laplacian of Gaussian, Gaussian matched filter, Binary matched, Kirsch matched filtering enhances the edges of the vessels [5].

## 3.3 Post Processing

After detection of edges, there might be a possibility that the edges of the vessel are not continuous. Edge linking process can be used for filling pixel gaps. And post processing is also required to remove falsely detected pixels of the retinal image [5].

# 4. STARE Database

The STARE (STructured Analysis of the Retina) Project was conceived and initiated in 1975 by Michael Goldbaum, M.D., at the University of California, San Diego. It was funded by the U.S. National Institutes of Health. The database contains 40 blood vessel segmentation images. Of these, this paper uses few images for obtaining results [6].

**Fig. 2 STARE database images [6]**

# 5. METHODS

### 5.1 High Pass Filter:

High pass filter removes the low frequency component from the image and enhances the edges. Thus, in segmentation of retinal vessels, high pass filter enhances the walls of vessels which act as high frequency components. Mask used for high pass filtering is given by

$$H=\begin{bmatrix}0 & -1 & 0\\ -1 & 4 & -1\\ 0 & -1 & 0\end{bmatrix}$$

Rotating the filter many times and applying the mask to the image, sharper images can be obtained.

### 5.2 Laplacian Filter:

Mask of Laplacian filter is somewhat similar to a high pass filter in a sense that the sum of all the elements of the mask is zero and replacing the central positive element with -1.

$$H=\begin{bmatrix}-1 & -1 & -1\\ 8 & -1 & -1\\ -1 & -1 & -1\end{bmatrix}$$

### 5.3 Sobel Filter:

Sobel filter is an edge detection filter in which two masks are applied simultaneously. Second mask is obtained from rotation.

$$H1=\begin{bmatrix}1 & 0 & -1\\ 2 & 0 & -2\\ 1 & 0 & -1\end{bmatrix};\ H2=\begin{bmatrix}1 & 2 & 1\\ 0 & 0 & 0\\ -1 & -2 & -1\end{bmatrix}$$

### 5.4 Laplacian of Gaussian Filter:

This is derivative of Gaussian filter which is used to find areas of high special frequencies, i.e., edges of blood vessels. Because of the negative central peak, it is also called as negative Laplacian.

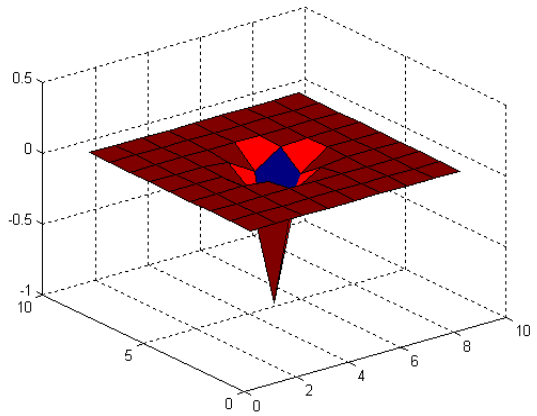


**Fig. 3: Laplacian of Gaussian filter representation in three dimensions [2]**

### 5.5 Gaussian Matched Filter:

Retinal Blood vessels do not have step edges. A Gaussian matched filter approximates the edges. The equation for Gaussian filter is as follows:

$$F(x,y)=A\{1-k\exp\left(-\frac{d^2}{2\sigma^2}\right)\}$$

Where d-the perpendicular distance between point (x,y) and the straight line passing through centre of blood vessel along with its length.$\boldsymbol{\sigma}$- the spread of intensity profile, k-the measure of reflectance of the blood vessel relative to its neighbour [4].

### 5.6 Binary Matched Filter:

Since binary matched filters uses only ones and zeros, the computation time of the Gaussian matched filter is significantly reduced. As discussed earlier, image is converted into binary image by thresholding.

### 5.7 Kirsch Matched Filter:

Kirsch's non-linear edge detector is used to search the maximum edge in a few determined directions. A single mask after rotating it to 8 major compass orientations (East, West, North, South, South-East, South-West, North-West and North-East) helps find the edge direction based on the maximum magnitude produced [5].

Masks are as shown below:

$$K1=\begin{bmatrix}5 & -3 & -3\\ 5 & 0 & -3\\ 5 & -3 & -3\end{bmatrix};\quad K2=\begin{bmatrix}-3 & -3 & 5\\ -3 & 0 & 5\\ -3 & -3 & 5\end{bmatrix};\quad K3=\begin{bmatrix}-3 & -3 & -3\\ -3 & 0 & -3\\ 5 & 5 & 5\end{bmatrix};$$

$$K4=\begin{bmatrix}5 & 5 & 5\\ -3 & 0 & -3\\ -3 & -3 & -3\end{bmatrix};K5=\begin{bmatrix}5 & 5 & -3\\ 5 & 0 & -3\\ -3 & -3 & -3\end{bmatrix};\quad K6=\begin{bmatrix}-3 & 5 & 5\\ -3 & 0 & 5\\ -3 & -3 & -3\end{bmatrix};$$

$$K7=\begin{bmatrix}-3 & -3 & -3\\ -3 & 0 & 5\\ -3 & 5 & 5\end{bmatrix};K8=\begin{bmatrix}-3 & -3 & -3\\ 5 & 0 & -3\\ 5 & 5 & -3\end{bmatrix}$$

# 6. RESULTS

The output is obtained by performing few processing steps on STARE database images.

## 6.1 Thresholding

Thresholding of STARE database image performed in MATLAB 7.10.0.

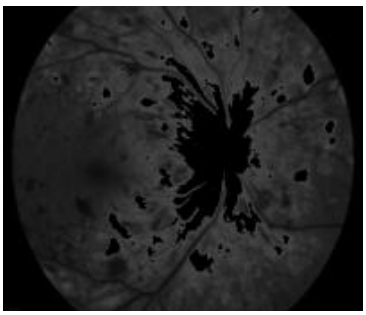

**Fig.4: Output of Thresholding**

## 6.2 High pass filter result

Output of rotated high pass filter on the image is shown in Fig.5. [2].

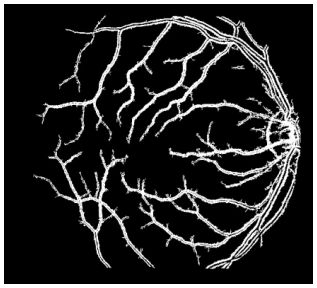

**Fig.5 Output of High Pass Filter**

## 6.3 Laplacian filter result

Output of rotated Laplacian filter on the image is shown in Fig.5. [2].

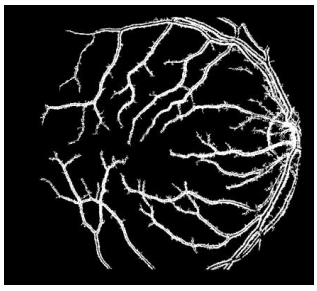

**Fig.6 Output of Laplacian filter**

## 6.4 Sobel filter result

Output of Sobel filter on the image is shown in Fig.7 [2].

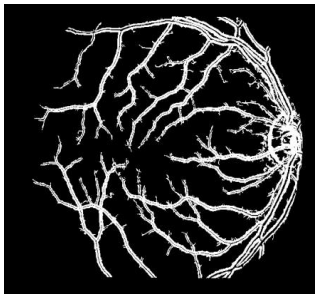

**Fig.7 Output of Sobel Filter**

### 6.5 Laplacian of Gaussian filter result

Output of rotated Laplacian of Gaussian filter on the image is shown in Fig.8 [2].

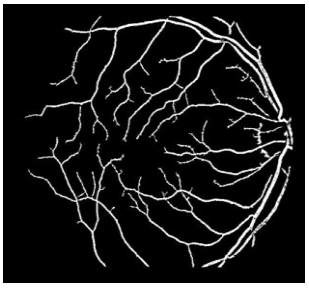

Fig.8 Output of Laplacian of Gaussian Filter

# 7 CONCLUSION AND FUTURE SCOPE

This paper reviews automated technique for detecting the blood vessels from colour fundus images. The segmentation of blood vessels is achieved by applying filters. Image segmentation involves using various types of filters such as high pass filter, Laplacian filter, Sobel filter, Laplacian of Gaussian filter,Gaussian match filter, Binary Matched filter and Kirsch filterto obtain high resolution images. Better results can be obtained by rotating the filters mentioned above. These results can then be used to view retinal blood vessels from the retinal images. The STARE database can be further used to detect hard exudates, soft exudates, micro aneurism and haemorrhages. The severity of DR can be efficiently predicted by analysing all these parameters, thus, widening the future scope of the method discussed in this paper.

# 8 REFERENCES

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