Retinal Blood Vessel Segmentation and Optic Disc Detection Using Combination of Spatial Domain Techniques

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Abstract— ***Medical imaging is the process of creating visual representations of the interior portion of a human body for clinical analysis. Medical imaging reveals the internal structures hidden by the skin and bones, as well as to diagnose and treat disease. It also helps in identifying the abnormalities.***

Medical imaging technology helps doctors to see the interior portions of the human body and made easy for diagnosis. Segmentation of retinal blood vessels assists in identifying various diseases such as diabetes mellitus, hypertension, macular degeneration, glaucoma etc. The early detection of these diseases is important to prevent the patients from reaching severity. This method makes use of edge detection and morphological operators to segment the retinal blood vessels. Our method also consists of automatically detecting the position of the Optic Disc in digital retinal fundus images. Input images are obtained from DRIVE and STARE datasets.

Keywords- segmentation , Andy operator, mathematical top hat morphological operation

I. INTRODUCTION

Retinal blood vessels contribute as one of the main features of the retinal fundus image. Over the past few years several techniques are employed for blood vessel extraction. Images of retina help in identifying various diseases. Since the size of typical retinal vessel is only a few pixels wide, it is critical to obtain the vascular width. Segmentation of vessels is complicated due to various reasons. Accurate vessel segmentation plays a critical role. There are various problems associated with it. Presence of hemorrhages, exudates and cotton wool spots creates problem during extraction.

Segmentation subdivides an image into its constituent regions or object. The goal of segmentation is to simplify the representation of an image that is more meaningful and easier to analyze. Retinal image segmentation is typically used to locate blood vessels, optic disc, hemorrhages, exudates and cotton wool spots. The proposed method uses mathematical filters, edge detection operators and morphological operators to obtain the retinal blood vessels. Images are analyzed on DRIVE and STARE databases. Experimental results prove that the proposed method gives better accuracy and precision.

II. RELATED WORK

Several methods for detection of retinal blood vessels have been proposed. Wang et al.[11] proposed a fast method for automated blood vessel detection. Edges were extracted using sobel operator and to make the algorithm fast, edge thinning was employed to preserve the seed points followed by local windowing and thresholding. Edward Rajan et al proposed ANN techniques based on gabor and moment invariant features. Retinal blood vessels were identified by means of multilayer perceptron neural network [2]. Alonso et al proposed pixel parallel approach for retinal vessel segmentation. Pixel parallel processor array was used to test the retinal vessel tree [29].

S.A. Barman et al. [3] proposed an approach to localize the retinal blood vessels using bit planes and centerline detection. Mathematical morphology is used as a proficient technique for quantifying the blood vessels in the retina. Centerlines were extracted by using the first order derivative of a Gaussian filter in four orientations. The shape and orientation map of blood vessels were obtained by applying a top-hat operator followed by bit plane slicing of the vessel enhanced grayscale image. The centerlines are combined with these maps to obtain the segmented vessel tree.

Dua et al. [5] implemented a unique method for blood vessel detection. His method was based on the regional recursive hierarchical decomposition using Quad trees and post-filtration of edges. Staal et al. [4] used a ridge based approach for retinal vessel segmentation. The system is based on the extraction of image ridges, which coincide with vessel centerlines. With the line elements an image is partitioned into patches by assigning each pixel to the closest line element.

Soares et al. [16] proposed retinal vessel segmentation using the 2-D Morlet. Feature vectors are composed of the pixel's intensity and continuous two-dimensional Morlet wavelet transform responses taken at multiple scales. The Morlet wavelet allows noise filtering and vessel enhancement in a single step. Bayesian classifiers were used for classification.

Adaptive detection of blood vessels in retinal images was performed based on contrast enhancement, feature extraction and tracing . Feature extraction was done using gabor filter. Tracing of vessels was done using forward detection, backward detection and bifurcation identification [7].

III. PROPOSED METHOD

This paper presents an efficient method to segment the retinal images using a combination of edge detection operator, non linear filtering technique and mathematical morphological technique. The following sub sections give brief description of the techniques. Figure 1 shows the original input image.

A. Noise removal and edge detection

The median filter is a non linear spatial filtering technique applied to remove the noise. It considers the neighborhood pixels to decide whether or not it is representative of its surroundings. It replaces the pixel value with the median of neighboring pixel values. First sort all the pixel values from the surrounding neighborhood into numerical order and then calculate the median. The median filter allows high spatial frequency details to pass, while remaining very effective at eliminating noise from images where less than half of the pixels in a smoothing neighborhood have been affected. It is also better in sharp edge preserving.

The points at which image brightness changes sharply are organized as a set of curved line segments termed edges. Edge detection aims at identifying the points at which image brightness changes sharply. An edge is a set of connected components that lie on the boundary between two regions. The proposed method uses Andy operator for edge detection. This is shown in figure2.

The masks below will extract lines that are one pixel thick and running in a particular direction.

$$\begin{bmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{bmatrix}$$

Horizontal

$$\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$$

Vertical

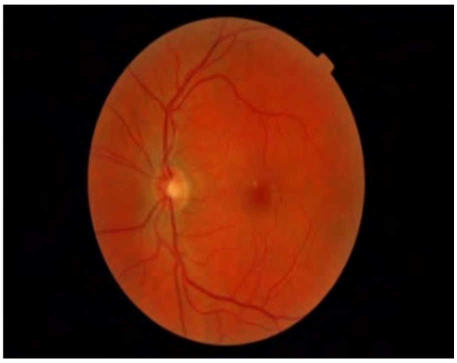

Figure 1. Original image

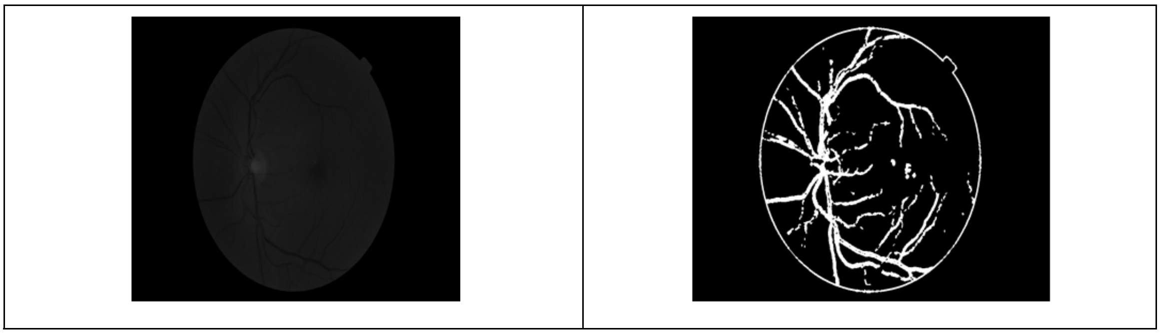

Figure 2. Noise removal and edge detection

B. Contrast ehanement and Extraction of minute(small) elements in the image.

Unsharp filter is used for contrast enhancement. Unsharp filter enhances the edges via a procedure which subtracts a smoothed version of an image from the original image and helps in removing the noise. Unsharp masking produces an edge image $g(x, y)$ from an input image $f(x, y)$ by

$$g(x, y) = f(x, y) - f_{smooth}(x, y) \qquad (1)$$

where $f_{smooth}(x, y)$ $f_{smooth}(x, y)$is a smoothed version of $f(x, y)$.

$f(x, y)$ is smoothened using Laplacian of Gaussian filter.

Laplacian of an image highlights regions of rapid intensity change and is often used for edge detection. Laplacian is often applied to an image that has first been smoothed with a Gaussian smoothing filter in order to reduce its sensitivity to noise. The 2-D LoG function centered on zero and with Gaussian standard deviation has the form:

$$\mathrm{Log}(x, y) = -1/\pi\sigma^4 \left[1 - \frac{x^2 + y^2}{2\sigma^2}\right] e^{-\frac{x^2+y^2}{2\sigma^2}}$$

using a larger σ for the Gaussian will reduce the noise.

Unsharp is usually implemented as a convolution kernel which detects edges. The result of this convolution is added back in to the original image to increase edge contrast which adds the illusion of additional "sharpness". The kernel used may vary but the general format is:

$$\text{Matrix m} \quad \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Given an input image I, the output is defined as: $output = I + c(I * m)$, where * is the 2D convolution operator and 'c' is some scaling constant, usually above 0.5 to 1.

Transformations are used to correct non uniform illumination .Uniform illumination plays an important role in segmentation. Watershed, top-hat and bottom-hat transformations are used in medical image segmentation. Combining image subtraction with openings and closings results in top-hat and bottom-hat transformations. Bottom-hat transformation is used for feature extraction. Bottom-hat transformation, extracts small elements and details from the given image. Bottom-hat filtering is subtracting the input image from the result of performing a morphological closing operation on the input image. The bottom hat filtering object uses flat structuring elements only. Bottom-hat preserves sharp bottoms of an image and improves the contrast. Top-hat transformation is subtracting the input image from the result of performing morphological opening operation on the input image.

Top-hat transform is used to enhance light objects on a dark background and similarly bottom hat transform is used to enhance dark objects on light background. Figure 3 shows the bottom hat result.

The bottom-hat and top-hat transformations of image f is defined as:

$$B_{hat}(f) = (f \cdot b) - f \quad (2)$$

$$T_{hat}(f) = f - (f \circ b) \quad (3)$$

where f is a grayscale image and b is the structuring element

These transformations are used to remove objects from an image using a structuring element in the opening or closing operation. The difference operator gives an image in which only the removed components remain. Reconstruction is done by subtraction operation on result images of median filter and bottom hat operator. This subtracted image is given as input to second bottom-hat transformation.

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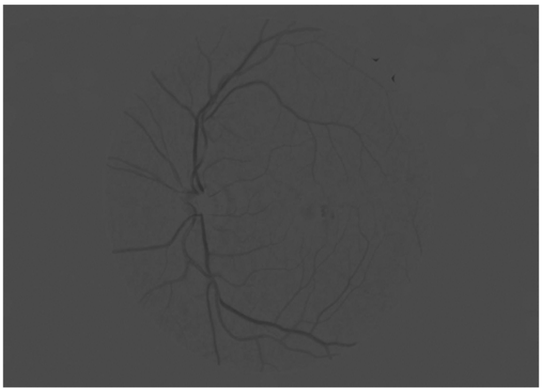


Figure 3. Result of bottomhat

C. Binarization and postprocessing

The binary image replaces all pixels in the input image with luminance greater than level, with the value 1 i.e white and replaces all other pixels with the value 0 i.e. black. The edges are enhanced using mathematical morphological operations like dilation and closing. Mathematical morphology is set theory concept. It is used as powerful approach to numerous image processing problems. Morphological operations are typically applied to remove imperfections introduced during segmentation. Morphological operators apply structuring elements (SE) to images. Structuring elements can be of any size. The structuring element is moved across every pixel in the original image to give a pixel in a new processed image. The value of this new pixel depends on the operation performed. Pixel group which are having smaller area than the vessel width is removed using morphological operations. This in turn also reduces the noise. The edges are enhanced using dilation and closing operations to obtain the final segmented image. Dilation, erosion, opening and closing are some the morphological operations. Dilation expands objects by a defined Structuring Element, filling holes, and connecting the disjoint regions.

Dilation of image f by structuring element b is given by $f \oplus b$. Closing operation is combination of dilation operation followed by an erosion operation. The closing operation of image f by structuring element b, denoted by

$f \bullet b$ is simply a dilation followed by an erosion.

$$f \cdot b = (f \oplus b) \ominus b \quad . \quad (4)$$

After performing the above steps, the final segmented image is obtained. After segmentation clustering algorithms can be employed for identifying vessel and non vessel part. Support vector machine, Bayesian classifier and KNN can be used. The resultant segmented image can be used in detection of the various diseases. Result of post processing is shown in figure4.

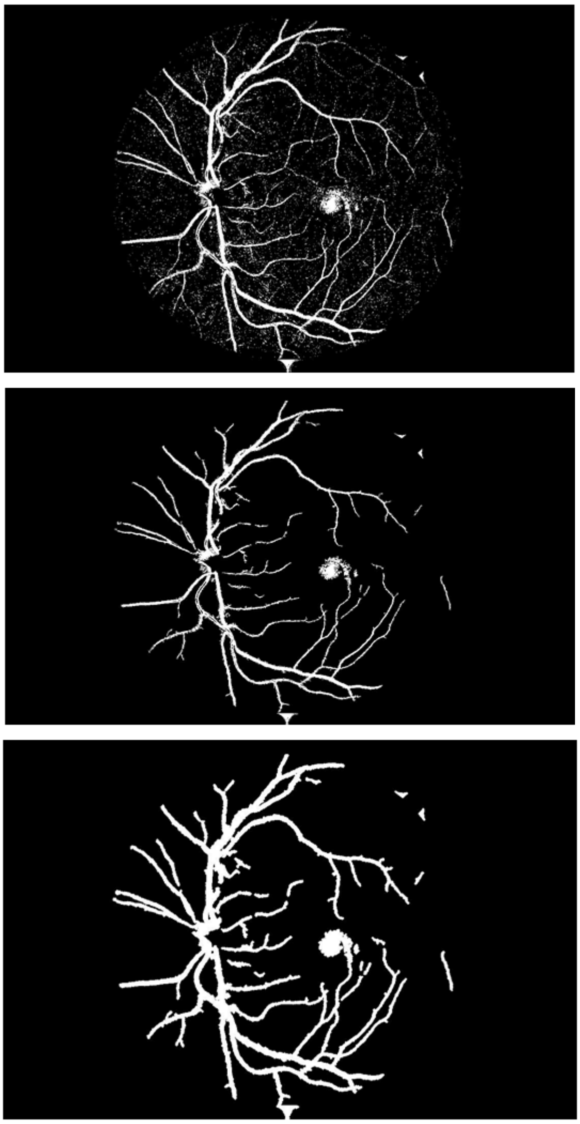


Figure 4. Post processing

Optic disc detection

The optic disc is one of the main features of the retina. All retinal vessels originate from the Optic Disc and follows a parabolic path in all images. It appears as a round region brighter than the surrounding. Locating the optic disc in fundus images is quite complicated because it can be confused with other lesions. The detection of Optic Disc position is a prerequisite for the computation of some important diagnostic indexes for hypertensive retinopathy based on vasculature, such as central retinal artery equivalent and central retinal vein equivalent.

Many techniques have been proposed to detect the Optic Disc, mainly based on its specific round shape and relatively high brightness .These techniques, often fail on pathological images, where other regions of fundus may be round shape and/or elevated brightness such as large exudative lesions. Our method to detect the position of the Optic Disc in digital retinal fundus images starts by converting the input image to grayscale, noise reduction using filtering techniques, binarization and obtaining the optic disc , finally highlight the optic disc by applying the bounding box around segmented optic disc. Figure 5 shows d result of optic disc detection.

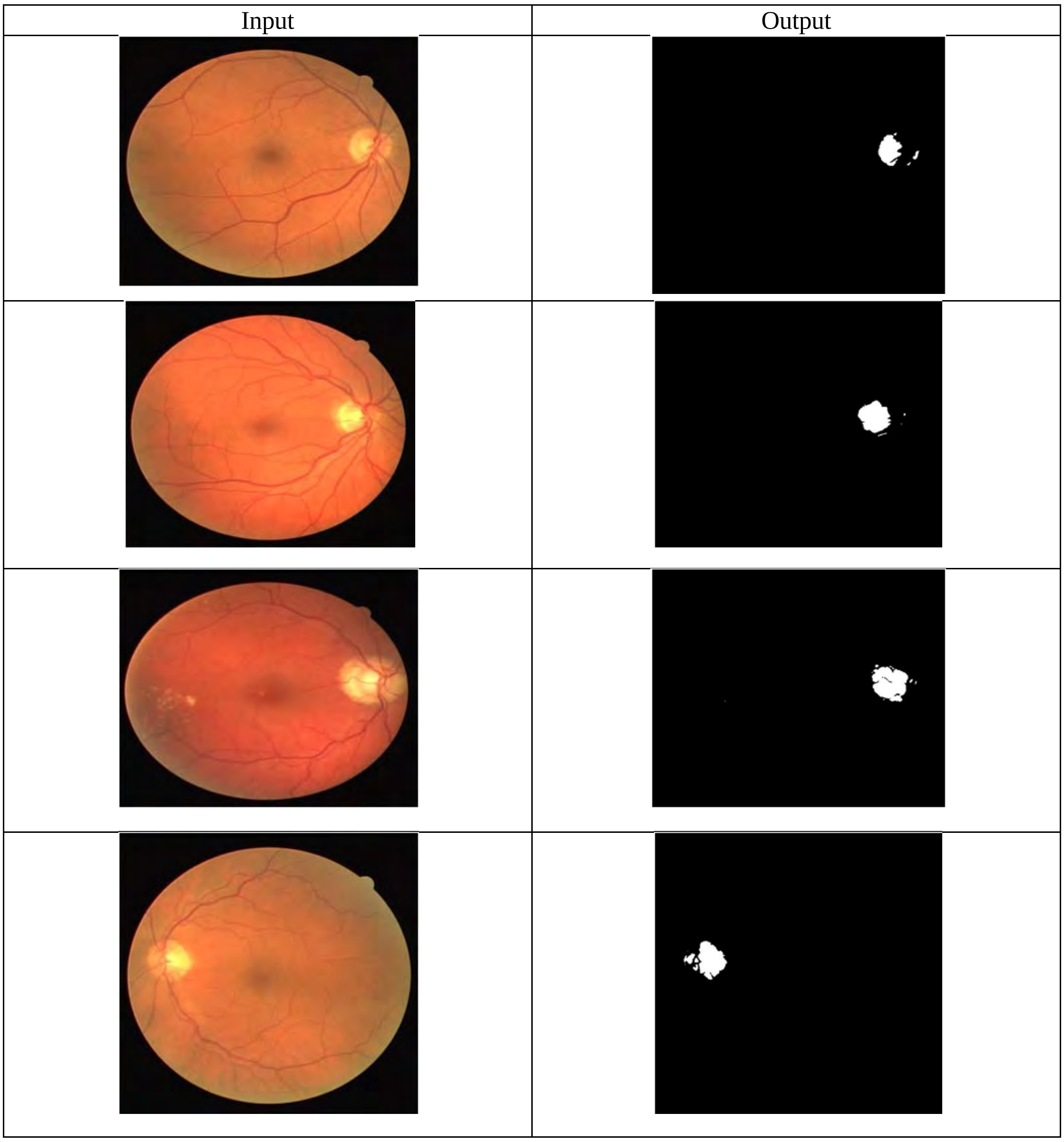


Figure 5. Results of optic disc detection

IV. RESULTS AND DISCUSSIONS

Experimentation has been done on more than 500 different images. Results have shown that the proposed method is well suited for segmentation of retinal blood vessels and optic disc detection. The proposed method works well for standard DRIVE and STARE dataset and results are shown below. Segmentation results were analysed from human perception. Figure6 shows the result of blood vessel segmentation.

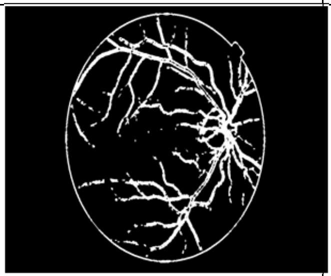
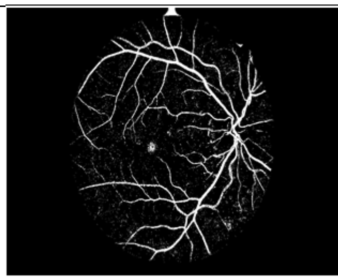
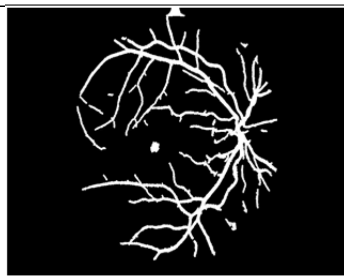
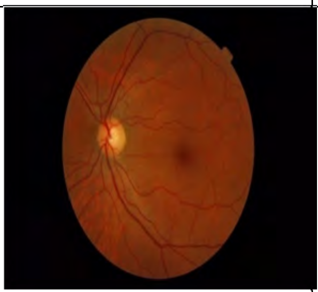
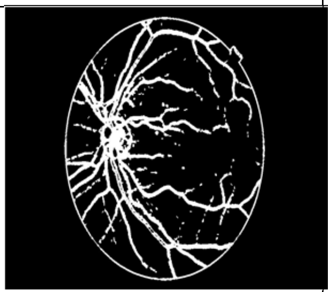
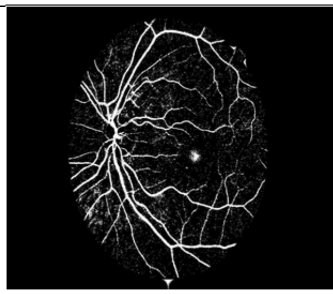
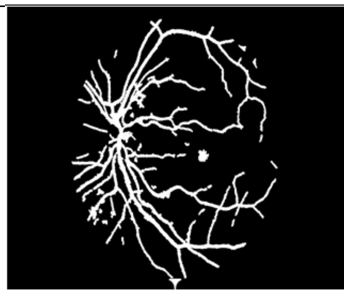
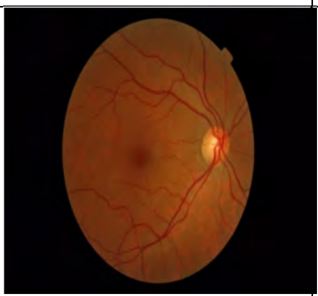
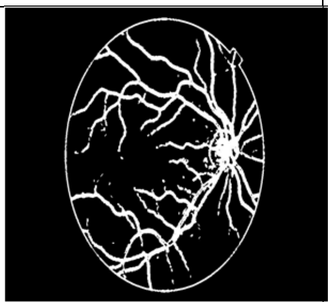
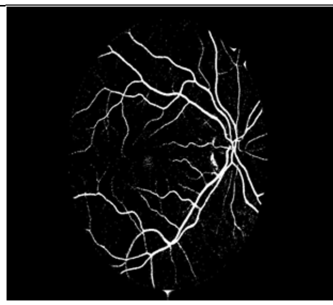
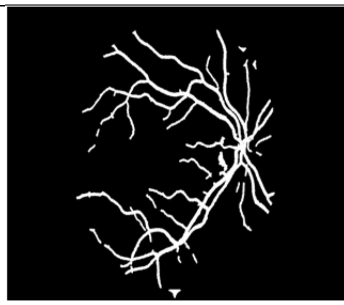
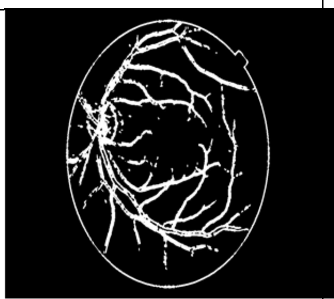
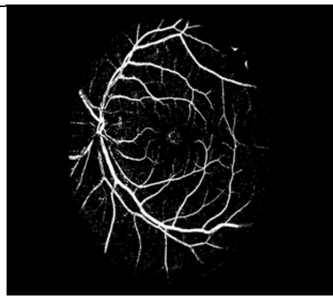
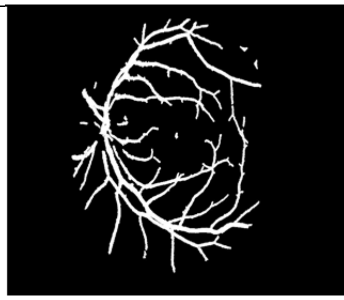
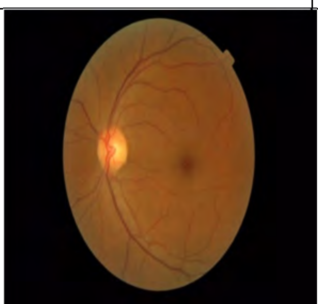
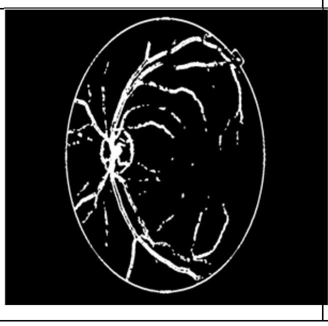
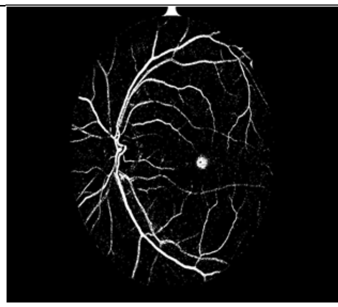
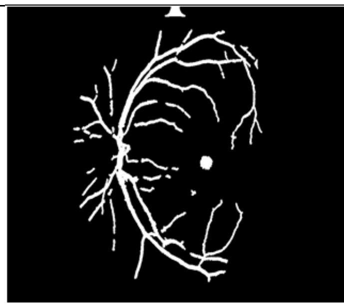
Input image	Noise removal and edge detection	Binarization	Post processing
			
			
			
			
			

Figure 6. Results of blood vessel segmentation

V. CONCLUSION

Due to the advancement in imaging system, high volume of Ophthalmic images are collected from patients. An efficient segmentation algorithm is required to process these images. Our Proposed method is efficient method for blood vessel extraction and detection of optic disc. It tracks and segments the retinal blood vessels. The steps include reading the input image, noise removal, edge detection, contrast enhancement, morphological operations, and post processing. The final segmented image is shown in figure4.The accuracy, specificity and sensitivity is high in our method. This method can be applied on the images of DRIVE and STARE databases

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