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Analogization of Algorithms for Effective Extraction of Blood Vessels in Retinal Images

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Abstract – This paper presents comparison of two methods for effective extraction of blood vessels. The purpose of detecting blood vessels is to identify diabetic retinopathy diseases such as exudates, micro-aneurysms. Diabetic retinopathy is a malicious disease that will occur due to severe diabetics. It is essential to diagnose it earlier. This research work has been carried out in two different methods. The first method comprises the following steps: Image pre-processing, contrast enhancements, background homogenization, segmentation and post-processing. The second method incorporates following steps: Image pre-processing, CLAHE, background exclusion, segmentation and post-processing. Other things such as edge detection method, resultant image, manually segmented image (Ground truth image) were involved in this work for comparison two methods. The effectiveness of two proposed methods has been calculated based on statistical analysis and execution time calculation. The comparative results reveal that the proposed methods developed in this work are efficient with respect to its accuracy and simplicity.

Index Terms – Diabetic Retinopathy, Blood vessel, Line Detection algorithm, Adaptive threshold technique, Enhancement, Filtering, Segmentation.

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1. INTRODUCTION

Diabetic Retinopathy (DR) is the most unexceptional diabetic eye disease, occurs when some transformation happen in blood vessels. It causes the growth of abnormal vessels on retinal surface. Occasionally these vessels can lead to swelling in the retinal surface and burst fluid. The retina is the layer of tissue at the back of the inner eye. The visuals that are entering into the eyes are sent to the brain through retinal optic nerves. Encompassing severe diabetics for a long duration of time will increase the possibilities of getting retinopathy.

In the first stage which is called non-proliferative diabetic retinopathy (NPDR) there are no symptoms, the signs are not visible to the eye and patients will have 20/20 vision. The only way to detect NPDR is by fundus photography, in which micro-aneurysms can be seen. In the second stage, abnormal new blood vessels (neovascularisation) form at the back of the eye as part of proliferative diabetic retinopathy (PDR), these can burst and bleed (vitreous haemorrhage) and blur the vision, because these new blood vessels are fragile. Without timely treatment, these new blood vessels can bleed, cloud vision and destroy the retina. In this paper two methods are presented for blood vessel detection.

2. RELATED WORK

The related work done by other researchers were given below:

Sivakumar, chitra et al. [1] proposed segmentation of blood vessel in retinal images using local entropy thresholding. In this paper, blood vessels from the green channel of the fundus image are enhanced using a two dimensional matched filter which enhances the contrast of the blood vessel against the background. The contrast enhanced blood vessels are then segmented using line detection algorithms which uses four directional filters. The final segmented vasculature is obtained by integrating the outputs from the directional filters.

A. S. Jadhav and Pushpa B. Patil et al.[2] had proposed classification of diabetes retina images using blood vessel area. The algorithm developed uses morphological operation to extract blood vessels. Mainly two steps are used: firstly enhancement operation is applied to original retina image to remove noise and increase contrast of retinal blood vessels. Secondly morphology operations are used to take out blood vessels.

Razieh Akhavan, Karim Faez et al. [3] had proposed two novel retinal blood vessel segmentation algorithms. The first proposed algorithm starts with the extraction of blood vessel centerline pixels. The final segmentation is obtained using an iterative region growing method that merges the contents of several binary images resulting from vessel width dependent modified morphological filters on normalized retinal images. In the second proposed algorithm the blood vessel is segmented using normalized modified morphological operations and neuro fuzzy classifier. Normalized morphological operations are used to enhance the vessels and neuro fuzzy classifier is used to segment retinal blood vessels.

Chandhani Nayak et al. [4] proposed the work retinal blood vessel segmentation algorithm for diabetic retinopathy using wavelet: a survey. . Retinal angiography images are mainly used in the diagnosis of diseases such as diabetic retinopathy. They presented a method that uses Gabor wavelet for vessel enhancement due to their ability to enhance directional structures and euclidean distance technique for accurate vessel segmentation. The proposed method enhances the vascular pattern using Gabor wavelet and then it uses Euclidean distance technique to generate gray level segmented image.

3. PROPOSED MODELLING

In this paper two methods have been proposed for effective extraction of blood vessels. The methods have been divided in to four parts. The output obtained from one part is taken as input to the next part.

3.1. First Method:

Line detection algorithm with Median filter and Histogram equalization

First proposed method comprises following steps:

- Preprocessing
- Background Homogenization
- Line Detection Method
- Post Processing

3.1.1. Preprocessing

Color images have lighting variations, poor contrast and noise. To reduce these imperfections the following preprocessing methods have been used.

1) Convert image in to green channel image. The green channel exhibits the best contrast between the vessels and background while the red and blue ones tend to be more noise.

2) Filtering: The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing.

3) Contrast Enhancement: It enhances the contrast of images by transforming the values in an intensity image so that the histogram of the output image approximately matches a specified histogram. Histogram equalization is a technique for adjusting image intensities to enhance contrast. Let f be a given image represented as a m×r by m×c matrix of integer pixel intensities ranging from 0 to L − 1. L is the number of possible intensity values, often 256. Let p denote the normalized histogram of f with a group of pixels for all possible intensity. So

$$p_n = \frac{number\ of\ pixels\ with\ intensity\ n}{total\ number\ of\ pixels}$$

$$n = 0, 1, \ldots, L - 1$$

The histogram equalized image will be defined by

$$g_{ij} = floor((L-1)\sum_{n=0}^{f_{ij}} p_n),$$

Where floor () down to the nearest integer. This is equivalent to transforming the pixel intensities, k of f by the function.

After pre-processing steps such as green channel conversion, filtering and contrast enhancement technique the output will be look like below fig 1.

Fig 1: (a) Original image (b) Preprocessed image

3.1.2. Background Homogenization

It is necessary to homogenize the background because it will lead us to easily identify the boundaries, lines and edges. The image contains some unwanted connected components that forms regions, which should get smoothed to avoid unnecessary components included in blood vessel area.

To remove the background lightening variations, a shade-corrected image is accomplished from a background estimate. First 3x3 mean filter is applied to smooth occasional salt-and-pepper noise. Further noise smoothing is performed by convolving the resultant image is performed by kernel of dimensions mxm=9x9 and mean=0 and sigma=1.79.Mean filtering is a simple, intuitive and easy to implement method of smoothing images, *i.e.* reducing the amount of intensity variation between one pixel and the next.

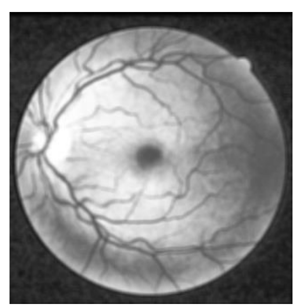

Fig 2: Background homogenized image

3.1.3. Segmentation Method

Here the segmentation process uses line detection algorithm. Line detection algorithm is based on edge detection, basically the process of finding all lines of interest in an image.

The masks shown below can be used to detect lines at various orientations.

−1	−1	−1
2	2	2
−1	−1	−1

−1	2	−1
−1	2	−1
−1	2	−1

−1	−1	2
−1	2	−1
2	−1	−1

2	−1	−1
−1	2	−1
−1	−1	2

Fig 3: Four line detection kernels which respond maximally to horizontal, vertical and oblique (+45 and - 45 degree) single pixel wide lines.

In fig 3, 0º shows horizontal line detection, 90º shows vertical line detection, 45º angle (i.e. acute) direction, and 135 º angle (obtuse) directions.

To cover all possible direction we use the method called Hough transform.

Connection between image (x,y) and Hough (m,b) spaces. A line in the image corresponds to a point in Hough space. To go from image space to Hough space:

- given a set of points (x,y), find all (m,b) such that $y = mx + b$
- the solutions of $b = -x_0 m + y_0$ this is a line in Hough space.

Typically Hough transform use a different parameterization

$$d = x cos\theta + y sin\theta$$

- d is the perpendicular distance from the line to the origin
- θ is the angle this perpendicular makes with the x axis

Basic Hough transform algorithm

Step 1: Initialize H[d, θ]=0

Step 2: for each edge point I[x,y] in the image

Step 3: for θ = 0 to 180

$$d = x cos\theta + y sin\theta$$

H[d, θ] += 1

Step 4: Find the value(s) of (d,θ) where H[d, θ] is maximum $d = x cos\theta + y sin\theta$.

The detected line in the image is given as follows

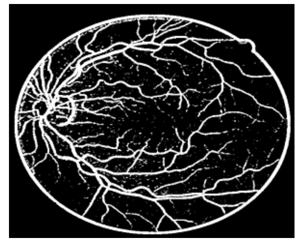

Fig 4: Resultant image

3.1.4. Post-Processing

The final image now contains pixels of the vessel as well some smaller disconnected regions are found in this image. In order to remove these smaller disconnected regions the final image needs to be processed. This is done in the post processing stage. For this morphological operation is performed on the final image. Morphological operator such as erosion, open, reconstruction of image also applied.

1) Apply open operator with five different angles using structure element as line.
2) Apply erode operator with three pixel diameter disk as structure element
3) Apply image reconstruction operation for the above two outcomes.

Now the outer circle is cleared. Next to remove the smaller disconnected region, for that pixels in each connected region is calculated. Then the region connected to an area which is below 40 pixels is reclassified as non-vessel. The final blood vessel segmented image after post-processing is shown in the fig.

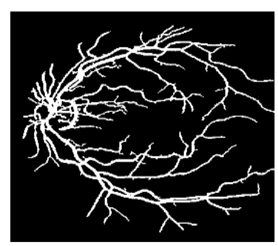

Fig 5: Final segmented image after Post-processing

3.2. SECOND METHOD: Adaptive Threshold Technique With Log Filter And CLAHE

This method comprises the following steps:

- Preprocessing
- Background Exclusion
- Adaptive thresholding technique
- Post Processing

3.2.1. Preprocessing

Color images have lighting variations, poor contrast and noise. To reduce these imperfections the following preprocessing methods have been used.

1) Convert RGB image in to green channel image.
2) Apply Laplacian of Gaussian filter (low pass filter) on green channel image to remove noise and smooth the retinal images.

$$\mathrm{L(x,y)} = \frac{\partial^2 \mathrm{I}}{\partial \mathrm{x}^2} + \frac{\partial^2 \mathrm{I}}{\partial \mathrm{y}^2}$$

3) Contrast Enhancement:

It is necessary to deepen the contrast of these images to provide a better performance of segmentation. The contrast stretching process applied to the gray-scale image. Techniques such as de-correlation stretch transform, unsharp mask, histogram equalization, adaptive histogram equalization (AHE), contrast-limited adaptive histogram equalization (CLAHE) are used for enhancing the image contrast. In the proposed algorithm, CLAHE technique is adopted to perform the contrast enhancement.

CLAHE is a widely used contrast enhancement technique which has proved it to be very effective for medical images. This technique enhances the contrast adaptively across the image by limiting the maximum slope in the transformation function.

Fig 6: (a) Original image (b) Preprocessed image

3.2.2. Background Exclusion

The main purpose of this step is eliminating background variations in illumination from an image so that the foreground objects may be more easily analyzed. In the proposed algorithm, the background exclusion is performed by subtracting the original intensity image from the average-filtered image.

Average filter is one of the simplest local operations over an image, which is also called as "neighborhood average method". The essential idea of a standard moving average filter is to replace the value of the center pixel $\hat{g}(x,y)$ by the average value of a predefined number of neighboring pixels $g_i(x, y)$ as shown in Eq.

$$\hat{g}(x,y) = \frac{1}{N \times M} \sum_{i=1}^{N \times M} g_i$$

In the proposed algorithm, a window size (M × N) of 9 × 9 pixels is used for implementing the average filter. Fig 7 shows the results of applying the average filter on the gray-scale images.

The original image g is subtracted from the average-filtered image $\hat{g}$. Mathematically, the difference image $h(x, y)$ between two images $\hat{g}$ and g, is generated by computing the difference 't' between all pairs of corresponding pixels in $\hat{g}(x, y)$ and $g(x, y)$ as shown in Eq.

$$h(x,y) = \begin{cases} t \text{ if } g(x,y) - g(x,y) > 0 \\ 0 \text{ otherwise} \end{cases} \quad 0 < t \leq 255$$

After background exclusion the image will be look like fig 7.

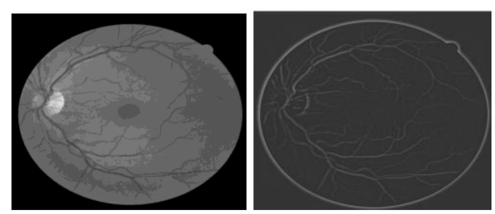

Fig 7. (a)Average filter (b) resultant image from background exclusion

3.2.3. Segmentation Method

The segmentation method uses adaptive thresholding technique. Adaptive thresholding typically takes a gray scale or color image as input, with simplest implementation and outputs a binary image representing the segmentation. For each pixel in the image, a threshold has to be calculated. If the pixel value is below the threshold it is set to the background value, otherwise it assumes the foreground value.

The adaptive threshold is to statistically examine the intensity values of the local neighborhood of each pixel.

The steps of applying adaptive thresholding are as follows:

Step 1: Calculate the threshold value from T for each pixel, mean of the local intensity distribution or median value

$$T = mean \quad or \quad T = median$$

Or the mean of the minimum and maximum values,

$$T = \frac{min + max}{2}$$

Step 2: Check if the pixel value is below the T it is treated as non-vessel otherwise it assumes as vessel.

Step 3: Repeat the steps until whole image is segmented

The following fig shows final result after applying the segmentation method.

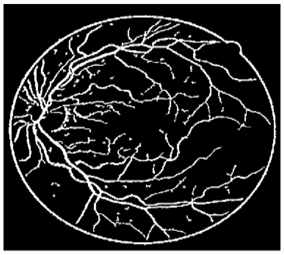

Fig 8. Resultant image after applying segmentation method

3.2.4. Post-Processing

This stage is absolutely replica to the first method done in the post-processing stage. So far we have discussed adequate details about the post-processing techniques and morphological operations. So that the result is shown in the figure.

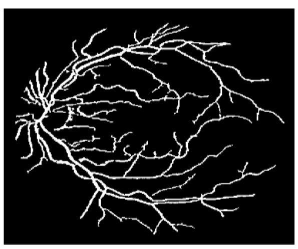

Fig 9: Final segmented image after Post-processing.

4. RESULTS AND DISCUSSIONS

Methods	Average Accuracy	Standard Deviation	Average time(sec)
Method1	95.49	3.950	6.51
Method2	95.67	3.953	2.16

Table 1: Experimented results obtain using statistical analysis such as mean & SD and average time.

For the performance evaluation of these proposed methods, the resultant image has been compared with publicly available databases such as DRIVE (Digital Retinal Images for Vessel Extraction) and Messidor. The DRIVE database contains 40 retinal images and Messidor contains 100 images.

DRIVE database contains 40 manually segmented images (ground truth image) for evaluating the performance of proposed methods. Statistical analysis has been made to prove the best method to extract the vessels. Execution time also calculated to prove the efficiency and simplicity of the algorithm.

5. CONCLUSION

In this paper, simple and computationally efficient algorithms for retinal blood vessel segmentation have been presented. The proposed methods have employed modules such as contrast enhancement, background illumination and segmentation. For segmentation an adaptive thresholding technique and line detection method have been employed. The performance of the proposed methods has been tested using DRIVE database images. From the experimental results, it is found that the proposed methods yield effective results with respect to the accuracy. Even though both methods are effective, the statistical analysis and average execution time of the methods prove that the adaptive threshold with LoG filter and CLAHE is the optimal method for vessel extraction. Also second method makes use of only simple and computationally less intensive processing steps, it is best suited for fast processing applications.

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