Blood Vessel Extraction From Retinal Fundus Images Using Dip Techniques

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Abstract — *The segmentation of blood vessels present in the retinal fundus image has become one of the important parameter for determining the type of disease that have affected the human eye. The process of segmenting the retinal blood vessel is considered as tricky since it forms a complex network structure. This work presents a double threshold and non-maximum suppression based system for segmenting the blood vessels. This work was proposed for the DRIVE database. The pre-processing technique used in this work includes Butterworth filter for removing noise and histogram equalization for contrast enhancement. The performance of this algorithm is analyzed by calculating its sensitivity, specificity, and accuracy. The average accuracy obtained in this algorithm is 0.964745 and the average time taken for execution is 3.448s.*

Keywords — *Double Thresholding, Non-Maximum Suppression, Retinal Blood Vessels*

I. INTRODUCTION

The analysis of the retinal fundus image is becoming an important diagnosing procedure in analyzing the disease affected and to identify its stages. Since the retinal image contains many anatomical features such as the optic disc, optic cup, fovea, blood vessels and in some serious cases of disease exudates will also be present. The segmentation of the vessel is a difficult work because by nature it is a complex form of network. So, segmenting the minute structure of the vessel is very difficult and the blood vessels are present in the foreground of the retinal image. Many algorithms were proposed to overcome this complexity in the segmentation of the blood vessels. The segmented structure using the proposed algorithm is shown Fig. 1. The proposed algorithm uses histogram equalization based contrast enhancement and double threshold along with non-maxima suppression for segmenting the vessels.

Fig. 1 Segmented blood vessels

II. REVIEW OF LITERATURE

Blood vessels localization from the retinal fundus image using centerline detection and bit planes [1] was proposed for automatic blood vessels segmentation. The orientation and shape of the blood vessels are acquired by using the multidirectional algorithm of morphological top-hat followed by slicing of the blood vessels using bit planes after the enhancement of the gray image. The first order Gaussian filter is applied. The morphological operator is used for contrasting the blood vessel from the background with structuring elements in a particular direction and important information of the vessels by considering its structure is obtained by the usage of bit planes. DRIVE, STARE and MESSIDOR datasets are used. The detection of the blood vessel using an improved matched filter in the retinal fundus image [2] was suggested to improve the filtering process in the detection of the blood vessel. This work has improved Gaussian matched filter to make the algorithm efficient. The efficiency of the filter mainly depends on the length of the segmented vessels having the same orientation and intensity of the profile spread. By optimizing these values better outcomes are obtained. The output of this algorithm is continuous so thresholding technique is carried out for segmentation of the blood vessels in the eye. Multi-scale line based detection and segmentation of retinal blood vessel [3] was proposed to detect the blood vessels present in the eye in the retinal colour image. The basic form of the line detector by varying the length is used to the green channel after carrying the inversion process. The inversion of the green channel is performed to make the vessels to appear brighter than the background. Shorter vessel lengths are taken to avoid the inclusion of the neighboring pixels of the vessel. In this work, it is observed that the algorithm work perfectly only on the healthy retinal image. An unsupervised method for the segmentation of the blood vessels using coarse to fine algorithm [4] was proposed to evaluate the blood vessels accurately. In this work the smoothing process is done by the means of Gaussian filter, the morphological operation is done using top-hat operator and contrast operation is performed to brighten the blood vessels than the background. The contrast enhancement process is carried out using the coarse algorithm, the output has a high contrast variation between the vessel in the retinal image and its background. The coarse algorithm is a type of thresholding process which is based on the cumulative distributive function of the probability of intensity of the pixel, unlike histogram intensity. This algorithm also segments thin and wide blood vessels and later it also differentiates between the true and blood vessel-like structure. By this way, the false positive value is reduced so the accuracy of this algorithm is increased. This testing is conducted on STARE and DRIVE dataset. Kernel fuzzy c- means and curvelet transform based blood vessel extraction [5] was proposed to extract the blood vessels automatically. The curvelet transform is employed since it can represent the curves, the lines, and the edges very well by using less number of coefficients compared to other techniques that use multiresolution. In this work, the curvelet transform is employed for retinal vessel enhancement. The matched filter is used to increase the intensity of the blood vessel and this is followed by the use of Kernel fuzzy c mean used employed to extract the silhouette of vessels from the background using non-linear mapping. The datasets used are DRIVE and STARE. Neovascular detection using mutual information maximization in the retinal image [6] was proposed to develop an automatic Computer Aided Diagnosis system and to achieve high accuracy. Curvelet transform is employed to increase the minute details of the vessels present in the retinal image and the thin and thick vessels are segregated by performing maximization of mutual information on the matched filter image. In this research work the green channel is extracted since the contrast between the region of interest and background are high this is followed by the enhancement of the edges by the means of curvelet transform. The matching filter is carried by employing the Gaussian filter in all possible angles. The Neovascular is detected using iterative threshold technique. The retinal vessel segmentation using an accurate, fast and robust system [7] was suggested to minimize the complexity of computation and to execute multiple independent procedures in parallel. In this work, the dark black curvature background is removed and the eyeball image is placed on the background with an average level colour of the fundus image. The extraction of the blood vessels in the retinal image was done by implementing global thresholding based on morphology. This type of segmentation is carried out to draw the vessel network structure present in the retinal image. The detection of capillaries will be simultaneously running on the same input image but here black and white reverse image are used. This system is considered as ideal for real-time diagnosis. The vessel detection in a retinal image using the Fourier cross-section profile [8] was put forward to detect the vessels automatically where optimization of the profile model is considered to be difficult. In this work by varying the sharpness of the boundaries the cross-sectional profile of the upward and downward vessels are represented. Symmetry and asymmetry in the Fourier domain are used for the detection of the vessels in the retinal image. The two-step approach is used to detect the vessel the detection features include vessel boundary and vessel center, and the next is detecting the linear feature. For feature identification log-Gabor filter is used. The main advantage of this algorithm is that it is found to be effective even in the presence of thin and thick vessels. The combined algorithm of fuzzy entropy, skeletonization and adaptive filtering based retinal blood vessel segmentation [9] was proposed to make an efficient system in the detection of different stages of progression of the disease more accurately. This work is using the skeletonization for segmentation at a greater ability. The fuzzy entropy is used for threshold selection. Designed Weiner's filter is used to remove the colour photography imageries. The adaptive filtering is used for identifying the blood vessel.

III. METHODOLOGY

A. BLOCK DIAGRAM

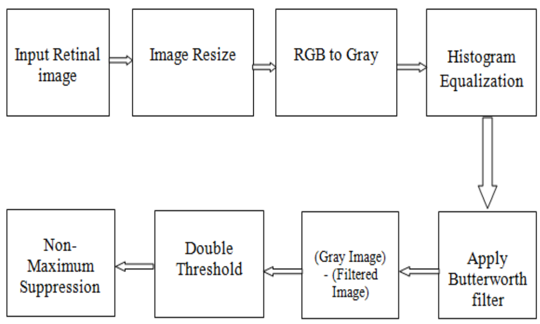

Fig. 2 Block diagram for the Blood Vessel Segmentation algorithm.

The Fig. 2. shows the entire techniques carried out in this work for segmenting the blood vessels. The retinal fundus image from the open access DRIVE datasets is used in this work. The acquired fundus retinal image is then resized, this process is carried out because the different image has different size if they are not resized with a common size then processing the image takes additional time for execution. The image is resized into 564 x 584. The resized image is converted into a gray scale image to decrease the complexity of the process. Histogram equalization is performed on the grayscale image to increase the contrast between the vessels and the background. The Butterworth high pass filter is applied to the histogram equalized image because the Butterworth filter is said to be more efficient for the retinal image compared to other filters. The filtered image is then subtracted from the grayscale image to remove the background and the resultant image is said to have only the network of blood vessels. This is nothing but similar to the edge detection process. The obtained image is then double threshold to avoid the presence of high or low-intensity pixels. By doing this process only the Region of Interest is obtained and other regions are eliminated. Even after the double threshold process, some minimum pixels may be present in the image. To remove this minimum intensity pixel non-maximum suppression technique is adopted in this work. The final step in this technique is that merging the non-maximum suppressed image with the original image. Finally, the blood vessels are segmented from the retinal fundus image (DRIVE dataset).

B. Hardware and Software Requirements:

The Segmentation of blood vessels from the retinal fundus image is carried out in CPU Intel core i7 2600 processor 3.4 GHz 8MB Cache with MATLAB R2017b. The retinal fundus images are collected from the online available dataset called DRIVE.

C. Database:

The database used in this work is DRIVE (Digital Retinal Image for Vessel Extraction).As the name indicates this database is created especially for segmenting the blood vessel in the retinal image. This database was created by screening the eye of the public who are affected by Diabetic Retinopathy. In this work, 20 test images from the DRIVE database are used to analyze the performance of the proposed algorithm.

D. Processing:

Step 1: The input fundus image is denoted as I (m, n), which must not be null and must be finite and the value is given as $0 < I(m, n) < \infty$. The m and n are the row and the column of the input image.

Step 2: It is important that all the images used should be at the same size because the change in the size of the image will result in decreased accuracy. After this, the RGB coloured image is converted to a grayscale image. The grayscale image is represented as $I_g(m, n)$.

Step 3: The histogram equalization is a discrete function, which is used to enhance the contrast in the input image. It is defined as.

$$H(i_n) = N_n \qquad (1)$$

Where N_n represents the total number of pixels in the image with intensity value n and i_n is the n_{th} intensity value. The retinal image will be convoluted with the histogram equalization equation as follows,

$$I_h(m,n) = I_g(m,n) * H(i_n) \qquad (2)$$

The normal histogram is used because in this work detecting the blood vessel is our main for which this type of segmentation is considered more effective.

Step 4: For sharpening the image Butterworth filter is used. The transfer function of the n_{th} order Butterworth filter is given as

$$I_f(m,n) = \frac{1}{1 + \left({I_0}/{I(m,n)}\right)^{2n}} \qquad (3)$$

Here I_0 is the cut-off frequency I (m,n) with dimension m x n and $I_f(m, n)$ is the filtered image. Butterworth high pass filter is used because it is said to have high accuracy [10] than the corresponding low pass filter.

Step 5: The filtered image is subtracted from the grey image.

$$I_s(m,n) = I_g(m,n) - I_f(m,n) \qquad (4)$$

Here the $I_s(m, n)$ denotes the subtracted image

Step 6: Usually in single thresholding process only one value is being used the value less than the defined value is considered as black (0) and value that are equal or greater than the prescribed value is considered white (1). In this work double thresholding is used in which high limit and low limit values are given the intensity value that lies in this range are considered as 1 and the rest of the values taken as 0. Mathematically it is defined as

$$I_d(m,n) = \begin{cases} 0, & I_s(m,n) \le I_{dmin} \\ 1, & I_s(m,n) > I_{dmax} \end{cases} \qquad (5)$$

Here $I_d(m, n)$ is the double threshold image, I_{dmin} is the lower limit and I_{dmax} is the higher limit of the double threshold technique.

Step 7: The image $I_d(m, n)$ is arranged to have both maximum and non-maximum values of intensity. The unnecessary edges are considered as the noise. So, the noise (unwanted non-maximum values) should be eliminated for the noise-free edge detection process. It is also used to sharpening the edges (only maximum values). So, in this work to remove the unwanted edges from the double threshold image the non-maximum suppression technique is used.

E. Performance Analysis

The performance analysis of this algorithm is carried out to check sensitivity, specificity, and accuracy so that we can come to a conclusion that how effectively the blood vessel network is detected. The performance analysis of the algorithm is carried out based on a numerical formula such as

$$\text{Sensitivity} = \frac{TP}{TP+FN}$$

$$\text{Selectivity} = \frac{TN}{TN+FP}$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \qquad (6)$$

Here the TP represents True Positive, TN denotes True negative, FP is the False positive and FN is False Negative. In the detection of the vessel network, false positive should be high. Since, we are dealing with the blood vessel network which is present in the foreground of the retinal image.

IV. RESULTS AND DISCUSSIONS

This work provides the outcome of double threshold and non-maxima suppression, the extracted blood vessel network is established as follows in Fig.3, which represents input or original fundus image, filtered image, contrast-enhanced image, Edge detected image, Non-maximum suppressed image and blood vessel segmented image. These images are plotted in MATLAB Figure window.

From Fig.3. Input retinal fundus image is converted into a grayscale image. The gray scale image undergoes contrast enhancement process done using histogram equalization is shown in Fig.3. (b). The noises present in the image are removed using Butterworth high-pass filter and this filtered image is subtracted from the gray scale image, which is shown in Fig.3. (c) and (d) respectively.

These preprocessing steps play critical and their outputs are comparatively accurate than other filters and enhancement techniques. The blood vessels in the retinal image are extracted by the use of proposed Double threshold and Non- maximum suppression technique shown in Fig. 3. (e). The final step of the process is that merging Fig. 3. (e) With the input image and the output appears as in Fig. 3. (f).

Fig.4 shows the outputs of the proposed algorithm for blood vessel extraction for the datasets available online. The histogram equalization based contrast enhancement is better than other techniques for extracting the blood vessel. High-pass Butterworth filter performs more accurate and consumes less time for execution compared to most of the other filters and the noise suppression technique present. In the last column of Fig.4. the blood vessels of testing images are successfully extracted in their places automaticall

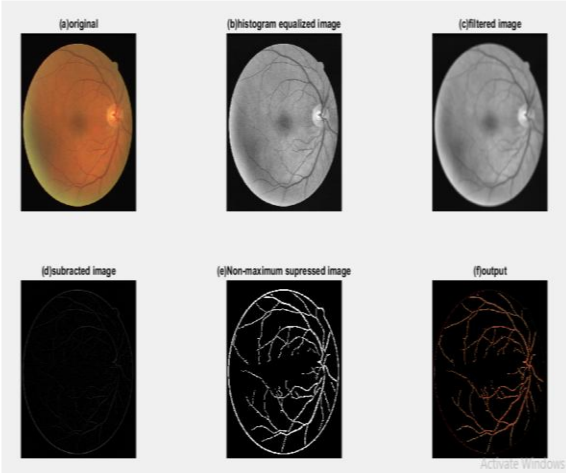

Fig.3 Results of the proposed algorithm

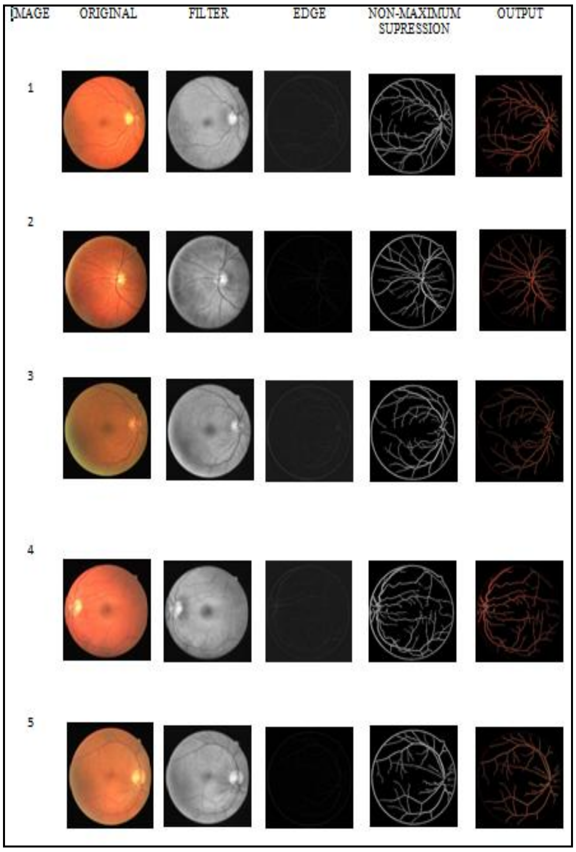

Fig.4 Result for DRIVE dataset

The performance analysis of the proposed method is tabulated in Table 1. The performance analysis includes the sensitivity, specificity, and accuracy. The execution time is also tabulated in Table 1. The average sensitivity and specificity values for 20 test image of DRIVE database for the proposed Double threshold and Non-maximum suppression based system are 0.85044 and 0.932315 respectively. This method has an average execution time of 3.448, the seconds range from 3.37 s to 3.53 s. Which is proven to be rapid when compared with most of the existing systems.

From Fig.5, the average accuracy value of the proposed method is compared with the existing methods. The maximum accuracy value is acquired is 0.9882 for the test image 6 of the DRIVE database. The average accuracy value of the proposed research work is 0.9647. This result shows our system is more accurate than [1], [2], [3], [4] and [7] lesser than [6]. From the fig.5, the proposed non-maxima suppression based blood vessel extraction method is more accurate. Further high accuracy value should be achieved than [7] and this system should be made even more a rapid one. Finally, the blood vessel network is segmented and localized in their place. The performance analysis indicates that it performs effectively compared to the existing systems.

Table.1 Performance analysis of the proposed algorithm

Sample Images	Sensitivity	Specificity	Accuracy	Execution Time (in Seconds)
Image_01	0.8263	0.9314	0.9793	3.42
Image_02	0.8415	0.9623	0.9631	3.48
Image_03	0.8823	0.9921	0.9327	3.51
Image_04	0.9356	0.9946	0.9586	3.49
Image_05	0.8873	0.9211	0.9824	3.40
Image_06	0.8356	0.9165	0.9882	3.39
Image_07	0.7318	0.8910	0.9735	3.41
Image_08	0.8126	0.9762	0.9615	3.47
Image_09	0.8513	0.9767	0.9732	3.42
Image_10	0.9114	0.9615	0.9687	3.46
Image_11	0.8913	0.9274	0.9441	3.49
Image_12	0.8786	0.9161	0.9528	3.48
Image_13	0.8261	0.9067	0.9487	3.51
Image_14	0.8125	0.9002	0.9818	3.39
Image_15	0.8118	0.9089	0.9805	3.37
Image_16	0.8223	0.8727	0.9633	3.46
Image_17	0.8617	0.8986	0.9239	3.53
Image_18	0.8913	0.9472	0.9726	3.42
Image_19	0.8563	0.9267	0.9843	3.39
Image_20	0.8412	0.9184	0.9617	3.47
Average Value	**0.85044**	**0.932315**	**0.964745**	**3.448**

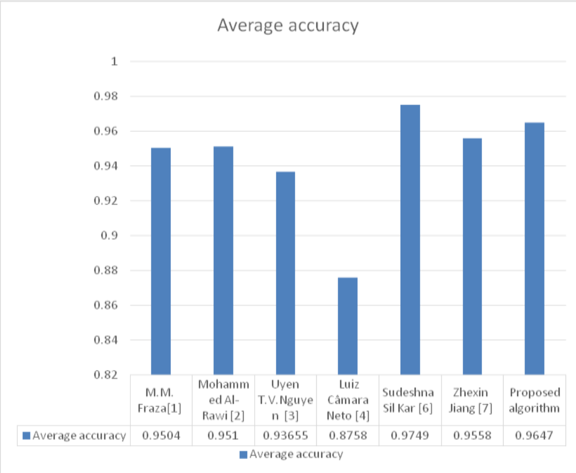

Fig. 5 Comparative analysis of the accuracy of the proposed system with existing systems

V. CONCLUSIONS

The segmentation of the vessel network is a necessary parameter in determining the type of disease that have affected the eye but the complexity of its position and network structure makes the extraction process difficult. This work assures the segmentation of blood vessels. The working of this algorithm is demonstrated. The performance of this algorithm is analyzed and tabulated with the average values of sensitivity, specificity, accuracy and execution time. This algorithm has resulted in better accuracy. But further work should be done to increase its accuracy and to make the system a rapid one.

REFERENCES

[1] M.M. Fraza, S.A. Barmana, P. Remagninoa, A. Hoppea, A. Basitb, B. Uyyanonvarac, A.R. Rudnickad and C.G. Owend, *An approach to localize the retinal blood vessels using bit planes and centerline detection*, computer methods and programs in biomedicine 108 (2012).

[2] Mohammed Al-Rawi, Munib Qutaishat and Mohammed Arrar, *An improved matched filter for blood vessel detection of digital retinal images*, Computers in Biology and Medicine 37 (2007).

[3] Uyen T.V.Nguyen, AlauddinBhuiyan, LaurenceA.F.Park, and KotagiriRamamohanarao, *An effective retinal blood vessel segmentation method using multi-scale line detection*, Pattern Recognition 46 (2013).

[4] Luiz Câmara Neto, Geraldo L.B. Ramalho, JeováF.S. Rocha Neto, Rodrigo M.S. Veras and Fátima N.S. Medeiros, *An unsupervised coarse-to-fine algorithm for blood vessel segmentation in fundus images*, Expert Systems with Applications 78 (2017).

[5] Sudeshna Sil Kar and Santi P. Maity, *Blood vessel extraction and optic disc removal using curvelet transform and kernel fuzzy c-means*, Computers in Biology and Medicine 70 (2016).

[6] Sudeshna Sil Kar and Santi P. Maity, *Detection of neovascularization in retinal images using mutual information maximization*, Computers and Electrical Engineering 62 (2017).

[7] Zhexin Jiang, Juan Yepez, Sen An and Seokbum Ko, *Fast accurate and robust retinal vessel segmentation system*, biocybernetics and biomedical engineering 37 (2017).

[8] Tao Zhu, *Fourier cross-sectional profile for vessel detection on retinal images*, Computerized Medical Imaging and Graphics 34 (2010).

[9] Khosro Rezaeea, Javad Haddadniaa and Ashkan Tashk, *optimized clinical segmentation of retinal blood vessels by using combination of adaptive filtering, fuzzy entropy and skeletonization*, Applied Soft Computing 52 (2017).

[10] Amit Shukla1, R.K. Singh, *Performance analysis of frequency domain filters for noise reduction*, e-Journal of Science & Technology (e-JST).