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AN ACCURATE LOCALIZATION AND SEGMENTATION OF BLOOD VESSELS AND OPTIC DISC REMOVAL IN RETINAL FUNDUS IMAGES

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ABSTRACT

Retinal blood vessels segmentation plays an important role for retinal image analysis. Diabetic retinopathy, Glaucoma is an eye disease which leads to blindness because of the pressure in blood vessels and finally damaging the vessels. Diabetic retinopathy affects the old people of age group above 50-60 who are the victims of diabetes. By analysing the vasculature structures in retinal images, we can detect the diabetes earlier in advanced stages. In this paper, an approach based on Fuzzy C- Means clustering algorithm and mathematical morphology is used to segment the blood vessels. To enhance the contrast of the image and to smoothen the image, adaptive histogram equalization and median filtering technique is carried out respectively. The proposed approach is tested on the DRIVE and STARE dataset and is compared with alternative approaches. These databases contain retinal images as well the ground truth images marked by the experts. Various metrics like sensitivity, specificity and accuracy are evaluated to justify the higher performance of the proposed method. Experimental results obtained by the proposed approach showed that it achieved an average accuracy of 96.97% and best accuracy of 98.06% on DRIVE dataset and an average accuracy of 95.06% and best accuracy of 97.33% on STARE dataset.

KEY WORDS: Retina, Diabetic Retinopathy, Optic disc, Blood vessels, Fuzzy C-Means, Mathematical morphology.

INTRODUCTION

Retinal blood vessels generally appear as a mesh like structure or tree like structure. Analysis of the blood vessels helps in diagnosing eye diseases such as diabetic retinopathy, glaucoma and hyper tension.

The analysis of retinal blood vessels becomes more and more important since they have a serious impact on human’s life.

Figure: 1 shows the retinal fundus image with main anatomical structures. The retina is an interior surface of eye which acts as the film of eye. It converts light rays into electrical signals and sends them to the brain through the optic nerve. Optic nerve is the cable connecting the eye to the brain. Optical disc is the bright region within the retinal image. It is the spot on the retina where the optic nerve and blood vessels enter the eye. Macula is responsible for our central vision and colour vision. The fovea is an indentation in the centre of the macula. This small part of our retina is responsible for our highest visual acuity. The vascular network is a network of vessels that supply oxygen, nutrients and blood to the retina.

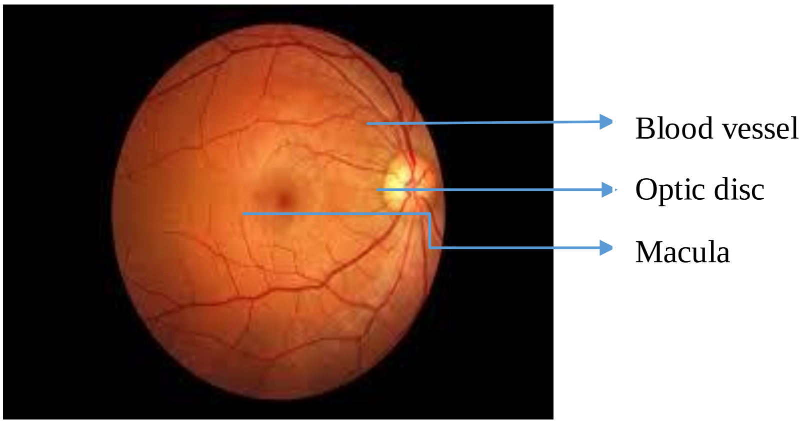


Figure 1: Retinal fundus image

Optic disc detection and removal is the main step while developing automated screening systems for diabetic retinopathy and glaucoma. Assessment of the retinal blood vessels diameter and tortuosity or the optic disc shape manually has many disadvantages such as, time consuming and prone with human error, especially with complicated vessel structure and a large number of images.

This paper presents some morphological operations and Fuzzy C- Means clustering algorithm for segmentation. Proposed work was implemented in MATLAB environment and various metrics were determined to analyse the performance.

RELATED WORKS

Many different algorithms were deployed for vessels segmentation, which achieved various results and performances.

Gehad Hassan et al., introduced an approach based on the mathematical morphological operations and K-Means clustering algorithm providing an accuracy of 96.25%.

R.Sai Prakash et al., proposed an approach to segment the blood vessels from the retinal fundus image based on the Otsu thresholding technique.

Sukanya et al., proposed an approach for the removal of optic disc from the fundus image. They carried out top hat transform to highlight the image from the background and optic disc is removed.

Shilpa Joshi and Karule extracted the blood vessels from the retinal image using the morphological operations and thresholding. They used the publicly available databases such DRIVE database and compared the results.

Marin performed a neural network scheme for pixel classification; 7-D vector was computed. For training and classification, they used multi-layer feed forward neural network. This method has average accuracy, sensitivity and specificity on the DRIVE database 0.9452, 0.7067 and 0.9801 respectively.

An automated enhancement and segmentation method for blood vessels is presented by Y. Hou . This method decreases the optic disc influence and emphasizes the vessels by applying a morphological multidirectional top-hat transform with rotating structuring elements to the background of the retinal image. This method has average accuracy, sensitivity and specificity on the DRIVE database 0.9420, 0.735, 0.969, respectively.

MATERIALS AND METHOD

Methodology of the proposed method is shown as architecture in the figure show below. The system architecture has three phases, first is the pre- processing phase and second is the segmentation phase and last one is the post processing phase.

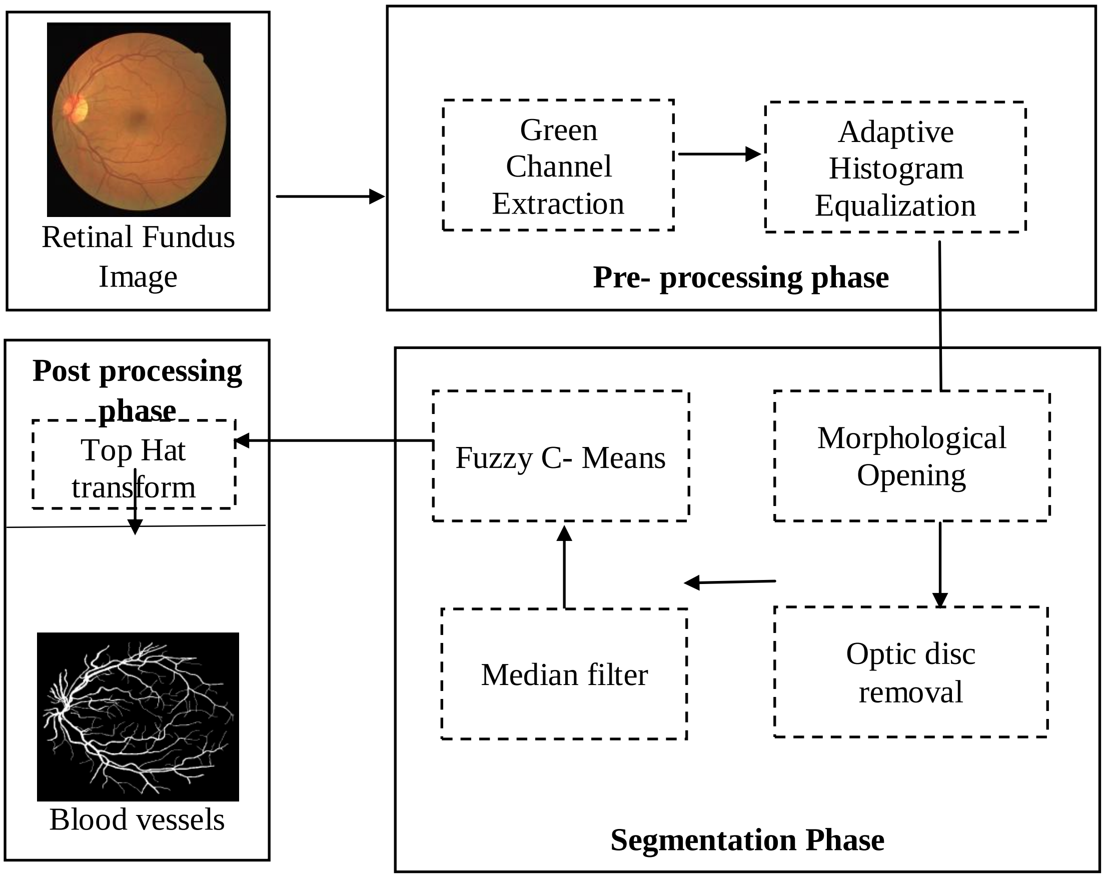


Figure 2: System architecture of the proposed method

INPUT DATA DESCRIPTION:

We evaluate the performance of proposed method using two public databases. One is the DRIVE(digital Retinal Images for Vessel Extraction) database, 20 images are employed for training and 20 images for testing. These images are captured by a CanonCR5 3CCD camera with a 45°FOV and size is 700 × 605 pixels per colour channel and has a FOV of approximately 540 pixels in diameter. The other database is STARE (Structured Analysis of the Retina). In this database, 20 raw retinal images are used for blood vessel segmentation and ten of them have pathologies. All images were captured by a TopCon TRV- 50 fundus camera at 35°field of view (FOV) and digitized to 700 × 605 pixels with 8 bits per color channel. The FOV for each image is approximately 650 × 550 pixels. There were two ground-truth image sets labelled by two observers. We use the first result as ground truth.

Pre- processing phase:

It is the process of converting an acquired image into useful format according to the user. In the pre-processing phase two steps are carried out.

a) Green channel Extraction:

Initially the RGB retinal fundus image is converted into Green channel image. Gray-scale image provides only the luminance information from the colour image after eliminating the hue and saturation, while the green-channel image provides maximum local contrast between the background and foreground [9, 10]. By converting the RGB image into Green image blood vessels can be easily segmented thus reducing the computational time. Then complement of the green channel image is taken and enhanced.

b) Contrast Enhancement:

The green image is a low contrast image. To make the blood vessel visible, contrast of the image has to be improved. In the proposed method Adaptive Histogram Equalization (AHE) is carried out. It differs from ordinary histogram equalization in respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness value of the image.

Segmentation Phase:

a) Morphological opening:

Erosion, dilation, closing and top- hat transformation are the basic morphological operations which are used to detect, modify and manipulate the features presented in the image based on their shapes [11].Structuring element (SE) is applied by morphological operators typically to binary images and sometimes can be extended to gray-level images. Selecting the proper structure element for the image results can be strengthen. A structuring element can be any size and take any shape and has origin point.

The opening of image A by structuring element B is denoted by is simply erosion followed by dilation as shown in (1).

$$A \circ B = (A \ominus B) \oplus B \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

b) Optic Disc removal:

Optic disc appears as a yellowish region in the fundus image. It typically occupied approximately one seventh of the entire image. Optic disc (OD) removal is an important task while segmenting the blood vessels from the retina. Several methods have been used for optic disc localization [12]. For optic disc removal the morphologically opened image is subtracted from the contrast enhanced image.

c) Filtering:

Speckle noise reduces the resolution and contrast of the image, thus reducing the diagnostic value of the imaging modality.Median filter is commonly used for reducing speckle noise due to their robustness against impulsive type noise and edge preserving characteristics [13].Median filter is used to smoothen the image after removal of the optic disc. Followed by filtering background removal is performed. Then the image is adjusted to improve the contrast thus making the blood vessel even brighter and visible.

d) Binarization:

Binarization is performed after adjusting the image. During binarization lighter region is converted to white and the darker area will be transformed to black pixel.

e) Segmentation:

In the proposed work, Fuzzy C-Means is used for the segmentation purpose. Fuzzy C-Means algorithm is an iterative clustering method that produces an optimal number of partitions, c by minimizing the weighted within group sum of squared error objective function.The main objective of Fuzzy C-Means algorithm is to minimize the objective function.

$$J(U,V) = \sum_{i=1}^{n} \sum_{j=1}^{c} M_{ij}^{m} \,||x_i - r_j||^{2} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,

$||x_i - r_j||$ is the Euclidean distance between i^{th} data and j^{th} cluster centre.

m is the Fuzziness index which is any real number greater than 1.

Let X = $\{x_1, x_2, x_3 \ldots, x_n\}$ be the set of n dimensional data points and R = $\{r_1, r_2, r_3 \ldots, r_c\}$ be the set of centers. The main objective of Fuzzy C-Means algorithm is to minimize the objective function.

The algorithm is given below.

1. Initialize Degree of membership matrix M= [Mij] matrix, M (0).
2. At k-step: calculate the cluster centre vectors R(k) =[Rj] with M(k).
3. Compute the fuzzy centres R_j,using equation given below:

$$R_j = \frac{\sum_{i=1}^{n} x_i M_{ij}^{m}}{\sum_{i=1}^{n} M_{ij}^{m}} \ldots\ldots\ldots\ldots\ldots (3)$$

4. R_j=∀j=1, 2...c, c is the cluster centers.
5. Update U(k), U(k+1) where U = $(M_{ij})_{n+c}$ is the fuzzy membership matrix.
6. Degree of membership of x_i to the cluster j is given as,

$$M_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{||x_i - c_j||}{||x_i - c_k||}\right)^{\frac{2}{m-1}}} \ldots\ldots\ldots\ldots\ldots (4)$$

7. The process stops if $max_{ij} ||M^{(k+1)} - M^{(k)}|| < \partial$ or minimum J is obtained, where ∂ is the termination criterion between [0, 1]
8. Otherwise go to step 3.

Post- processing phase:

In the post processing phase, top hat transform is applied to the image obtained in the previous step. The top-hat transformation has enhancement effect which is estimates the local background by a morphology opening operation, and then subtract it from the original image resulting and this operation have a good effect on vessels.The Top-hat of image A by structuring element B as shown in (5).

$$Tophat\ (A) = A - (A \circ B) \ .... (5)$$

The output thus obtained is the retinal blood vessels with high accuracy.

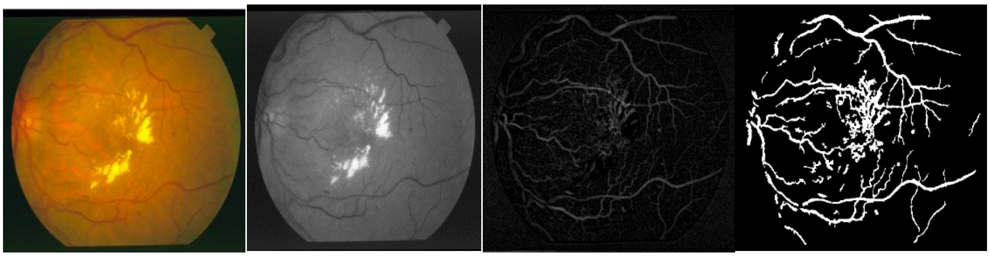
IV. EXPERIMENTAL RESULTS AND DISCUSSION

For the vessel segmentation approach, our algorithm was tested on the DRIVE and STARE public dataset. The performance of our approach is tested and validated against a number of alternative approaches.

DRIVE	40 images
STARE	20 images
Total	60 images

a) Retinal image b) Green image c) OD removed e) Segmented image

Figure 3: 01_test image in DRIVE dataset



a) Retinal image b) Green image c) OD removed e) Segmented image

Figure 4: im0001 image in STARE dataset

We use some parameters to facilitate the comparison in performance and accuracy, these parameters such as the accuracy rate (ACC), sensitivity and specificity.

(1) Sensitivity: It represents a measure of the possibility of the outcomes that are TP.

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

(2) Specificity: It is used to determine the possibility of the outcomes that are TN.

$$\text{Specificity} = \frac{TN}{TP+TN}$$

(3) Accuracy: It characterizes the overall performance of the algorithm.

$$\text{Accuracy} = \frac{TP+TN}{FP+FN}$$

Table 1: Experimental results of DRIVE database

Image	Sensitivity	Specificity	Accuracy
1.	0.6946	0.9861	0.9608
2.	0.6724	0.9934	0.9606
3.	0.7408	0.9636	0.9686
4.	0.5485	0.9967	0.9555
5.	0.5880	0.9945	0.9564
6.	0.6053	0.9910	0.9535
7.	0.6351	0.9835	0.9517
8.	0.7065	0.9668	0.9644
9.	0.6656	0.9795	0.9541
10.	0.5882	0.9936	0.9602

Table 2: Experimental results of STARE database

Image	Sensitivity	Specificity	Accuracy
1.	0.7018	0.9480	0.9283
2.	0.5594	0.9474	0.9216
3.	0.8096	0.8949	0.8895
4.	0.7827	0.8785	0.8714
5.	0.6838	0.9721	0.9461
6.	0.8028	0.9729	0.9610
7.	0.8235	0.9735	0.9617
8.	0.8227	0.9758	0.9643
9.	0.7954	0.9804	0.9658
10.	0.7805	0.9629	0.9482

Performance of this approach on DRIVE dataset is compared with alternative approaches such as Gehad Hassana [3], Marin [7], Hou[8], Martinez-Perez [14], Perez [15], Vlachos [16]. Performance comparison revealed that this approach produces an average accuracy of about 96.97% and best accuracy of about 98.06% on DRIVE dataset. Performance of this approach on STARE dataset is compared with alternative approaches such as Marin [7], Chang [17], Inkaew [18], Akram [19, 20]. Proposed approach yields an average accuracy of 95.06% and best accuracy of 97.33% on STARE dataset.

Table 3: Performance comparison on DRIVE dataset

Approach	Sensitivity	Specificity	Accuracy
Gehad Hassana [3]	0.8799	0.9799	0.9625
Marin [7]	0.7067	0.9801	0.9452
Hou[8]	0.7350	0.9690	0.9420
Martinez-Perez [14]	0.7246	0.9655	0.9344
Perez [15]	0.6600	0.9612	0.9220
Vlachos [16]	0.7470	0.9550	0.9290
Proposed	0.6603	0.9856	0.9697

Table 4: Performance comparison on STARE dataset

Approach	Sensitivity	Specificity	Accuracy
Marin [7]	0.6944	0.9819	0.9526
Chang[17]	0.7350	0.9690	0.9431
Inkaew [18]	0.8774	-	0.9423
Akram [19]	-	-	0.9439
Akram [20]	-	-	0.9502
Proposed	0.7387	0.9630	0.9506

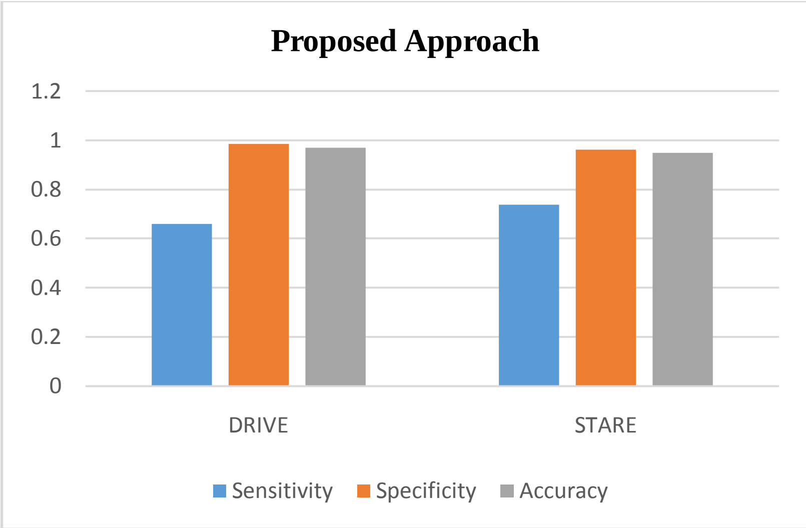


Figure 5: Graphical representation of proposed approach on DRIVE and STARE dataset

CONCLUSION

In this paper, an approach was introduced and implemented on the MATLAB environment for the extraction of blood vessels from the retinal fundus images. Various metrics were evaluated and compared with alternative approaches. Results shows that the proposed system produce identical results as theground truth and have a high accuracy ratio and low misclassification ratio comparing with the manual extraction This work produces an average accuracy of 96.97% and 95.06% accuracy on DRIVE and STARE datasets respectively.

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