Retinal Blood Vessel Segmentation Using Fuzzy Logic

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Abstract – This paper presents a method to segments the retinal blood vessels using fuzzy logic. The proposed method is based on getting high pass filtered image at first and then applying different set of fuzzy rules on high pass filtered image to segment the retinal blood vessels. Different fuzzy rules were designed on the bases of some threshold values. Threshold values are intensity value of pixel and number of pixels in different cases. The proposed method is tested on publically available retinal images from DRIVE data set. The proposed segmentation results are compared with the manual results pixel by pixel and provide up to 95% accuracy. The proposed method is compared with previous methods. The proposed method segments the blood vessels in less interval of time than previous methods.

Index Terms – Diabetic Retinopathy, eye-fundus, cardiovascular, fuzzy rules, low pass filtering, blood vessel enhancement.

1. INTRODUCTION

Observation of retinal blood vessels from fundus images plays a very important role in diagnosing many eye related problems. Blood vessels are the one of the main part of the eye retina and can affected by many dieses. Dieses like hypertension, diabetic retinopathy, glaucoma, cardiovascular dieses, stork and arteriosclerosis etc can affect retinal blood vessels thus leads to eye-sight weakness [1]. Studies shows that common dieses like diabetic retinopathy and glaucoma are the main cause of eye blindness in many people these days [2].However early diagnosis of these dieses and early blood vessel observation can help to cure eye blindness. Blood vessels have many features like diameter, color, tortuosity, etc. the observation of these features can help to diagnose eye related problems [3]. But direct observation of retinal blood vessels from retinal images is very difficult to presence of noise and retinal background so best way of easy observation is to segment the retinal blood vessels from its background and other retinal regions. The task of segmenting blood vessels manually is complex and time consuming thus computer based automatic segmentation is the best solution and has been used from many years in segmenting blood vessels.

Many techniques has been proposed previously in past years. But not able to produce results with 100% accuracy. It is very difficult to attain 100% accuracy with automatic computer based approaches, but it's possible to produce results with accuracy close to 100% accuracy. So there is a good scope in blood vessel segmentation to improve the results and some other aspects like time, specificity, etc. Techniques proposed in previous years provide good results but can be improve by making some changes or by using new techniques.

This paper presents a method based on fuzzy rules to segment retinal blood vessels. The proposed method make use of different set of fuzzy rules to process retinal images taken from publically available DRIVE [20] data set. At first preprocessing operations were performed on color retinal images. After pre-processing a high pass filtered image of retinal images produced and then fuzzy rules were applied to segment the blood vessels. The proposed method does not need training rules. The proposed method is compared with existing method, providing better results in less time interval. The resultant images are also compared with the manually segmented results and provide 94-95% similarity.

Further this paper is organized in different sections. Section II describe the reviewed literature of existing methods of retinal blood vessel segmentation methods. The proposed method is described in section III and section IV include experimental results and final section V contains discussion and future scope. Introduce the problem that is going to be discussed in the entire article. Introduction section should motivate the readers to read the article further.

2. RELATED WORK

Automatic retinal blood vessel segmentation is under consideration from many years. Various techniques has been proposed till date and are able to get very good results. The literature has been performed through many techniques, few of them are discussed below.

In [2] they proposed a supervised method for Segmentation of retinal blood vessels. The proposed method is based on two approaches. (1) Neural-Network (NN) based pixel

classification (2) Moment invariant based feature for pixel representation. They perform their method on publically available data set of retinal images STARE dataset and DRIVE dataset. And in both case the proposed method performs efficiently they provide better results when comparing with previous techniques. The proposed method is fully dependent on the training set, so when this method is tested on same dataset they provide better results within less computational time than other methods, but when the data set is changes, then the proposed method does not provide better results.

In [4] presented a mathematical morphology and curvature evaluation method in this paper, the mathematical morphology method is used for detection of blood vessel in retinal images and the curvature evaluation method is used to differentiate the blood vessels from the retinal background that is not needed. The presented method is tested on different retinal images and is able to detect retinal blood vessel with better robustness and accuracy than the previous one. Still the presented approach has some flaws that can be overcome by making few changes. The results has shown that vessel like patterns are detected with good accuracy.

In [5] they proposed a method for retinal blood vessel segmentation using Cellular Neural Network (CNN). CNN is based on linear space invariant templates that is placed on retinal images to separate the pixels into vessels or non vessel pixels. The proposed method uses 3-by-3 template placed in different orientation from 0^o to 90^o to get all connected pixels. The proposed method takes less computational time then the previous methods. The accuracy is efficient but can be improve by making some changes in future. The results shows the effectiveness of the proposed technique.

In [1] they proposed an unsupervised algorithm to locating blood vessels in retinal images based on fuzzy. The proposed method solve the problem of initializing vessels and vessel structure as per literature. Also perform automatic tracking of retinal blood vessel. The method presented in paper uses the Fuzzy c-means clustering algorithm for detecting vessel and non vessel region in retinal images. The proposed method can handle the junctions and can also detect fork points. The proposed method is successful in tracking the blood vessel in retinal images automatically. The proposed method track the vessels successful, only vessel those are untracked are the vessels of very small diameter or having low contrast.

In [6] they presented a method based on ridge based Method. The ridge based method is used to detect the ridges those belongs to blood vessel centre line. The image is divided into patches using line elements and image pixels are assign to line elements. Feature vectors are discovered and KNN-classifier is use to classify the feature vectors for every pixels in the patches. The proposed method is based in training set and is trained using manual segmentation results. The proposed method is supervised method, thus having 2 different kind of errors in segmentation. One is over segmentation of blood vessel and second is missing of some blood vessel structure. The proposed algorithm is segmenting the blood vessel in efficient way but took long time for training KNN and in producing final results.

In [7] they proposed a method for segmentation of blood vessel based on 2-D Gabor wavelet and pixel classification methods. In the proposed method each pixels is classified as vessel pixel or non vessel pixel on the basis of pixel's feature vector. Feature vectors are generated by Gabor wavelet response and according to intensities of each pixel in the retinal images. The proposed method is a supervised method and is trained with the manual segmentation results available publically. For classification of pixels GMM classifier is used. The proposed method is dependent on the training set. The results shows the accuracy of blood vessel segmentation.

In [8] they presented a multi-concavity model based on Regularization to detect retinal blood vessels from pathologically effected and non effected retinal images. In proposed method blood vessels are detected when there is red lesions either bright or dark are present in retinal images. At first in proposed method a concavity measure is performed to detect and remove the bright lesions. To remove dark lesions a line shape based concavity measure is used, the detection of dark lesion is based on the difference in intensity structure in blood vessels and dark lesions. Then a normalized concavity measure is use to deal with irregularly spread noise in retinal images. Results from all three concavity measurement are combined to detect the blood vessel successfully. The proposed method provide efficient retinal blood vessel segmentation in both healthy and unhealthy retinal images in single experiment.

The literature discussed above provide enough information about previous methods and the areas to go through to make new changes and to enhance the performance new level. In next section the proposed method is discussed.

3. PORPOSED WORK

The proposed work presented in this paper is based on fuzzy logic or fuzzy rules. Each color eye fundus image passes through some pre-processing operations and then lead to further approaches. After pre-processing set fuzzy rules applied on the pre-processed image to get the final resultant image and then in post processing step each resultant image is compared with the manual segmentation results of that image to get the accuracy of the proposed work. Also the proposed approach is compared with some previous approaches. The proposed work is discussed as follows.

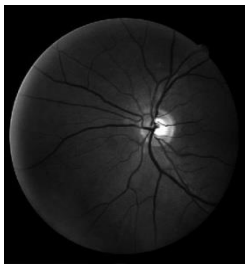
3.1. Data

The proposed work needs color eye-fundus images for processing. The required images are collected from DRIVE [20] data set that is available publically. This data set contains 20 to 30 color eye-fundus images captured through eye-fundus camera, mostly used for capturing fundus images. The data set also contains manual segmentation results for each color retinal image. The DRIVE data set contains all the desired data required to perform blood vessel segmentation operations. The next step is to perform pre-processing operations.

3.2. Pre-processing

The pre-processing stage include three steps. (a) Noise removal operation (b) green plane of the colored image and (c) blood vessel enhancement operations. At first a noise removal filter is use to remove noise from the color retinal image. Then an operation is performed to get the green plane of the color image. Basically a color image contains three planes red, blue and green. The green plane is preferred most in segmentation task because the blood vessels are dark in contrast and in green plane of the image blood vessels appears clearly in comparison to the other planes. Next step is blood vessel enhancement operation. In this operation each intensity value is multiplied with itself and the intensity value is replaced with resultant value. This operation will make dark region darker and the brighter region brighter. Thus blood vessels will become darker and the rest brighter region will become brighter. As shown below in images.

(a) (b)

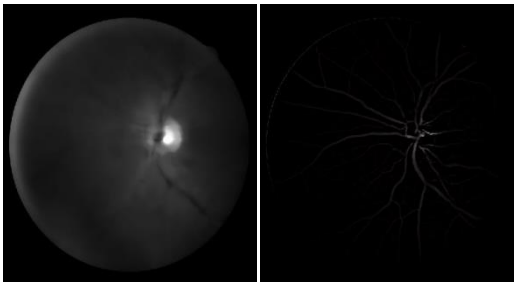


(c)

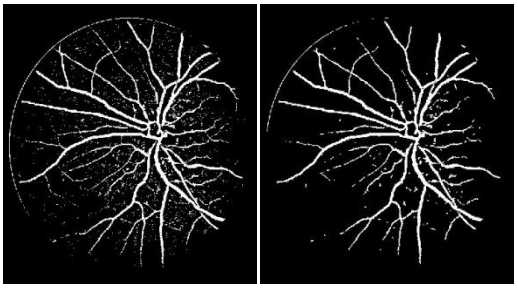
Fig 1. (a) Colored fundus image (b) Green plane of the color fundus image (c) Image after blood vessel enhancement.

3.3. Fuzzy-logic implementation

Before fuzzy rules implementation the resultant image of the blood vessel enhancement operation is passes through two more steps. 1). Low pass filtering operation, in this step low pass filter is applied to get the low pass filtered image. The low pass filter allows low intensity values to pass through it and block the values with high intensity values. In 2). Step resultant image of the blood vessel enhancement operation is subtracted from low pass filtered image this will result the image with high intensity values. And then fuzzy-logic is implemented on the resultant image to get the final blood vessel segmentation image. The fuzzy logic contains different set of fuzzy rules each fuzzy rule is having different threshold value. This threshold value helps in selecting and discarding the pixel values that leads to the selection of blood vessel pixels. This leads to the segmentation of retinal blood vessels. The experimental results will be discussed further in this paper.



(a) (b)



(c) (d)

Fig 1. (a) Low pass filtered image (b) High pass filtered image (c) (d) final blood vessel segmentation using fuzzy rules.

3.4. Post-processing

After successful segmentation of blood vessels from color retinal images the last step include the comparison operation. In this step the results of proposed work is compare pixel by pixel with manual segmentation results also computation time calculation operation is applied to get performance of the proposed work. Also the proposed work is compare with previous approaches.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

The performance of the proposed work is evaluated by comparing manual segmentation results with proposed work results. Manual segmentation takes more than 2 hours for segmentation on the other hand automatic computer based blood vessel segmentation takes only few seconds. Also the proposed work is compared with the previous methods. The results of the proposed work are shown below and the comparison results are discussed further in this section.

The proposed method is applied on 12 to 15 color retinal images and provide very good results. Results of this work is compared with manual segmentation results and able to get 93% to 95% similarity. The proposed work take very less interval of time for its completion. Segmentation results of some images are shown below

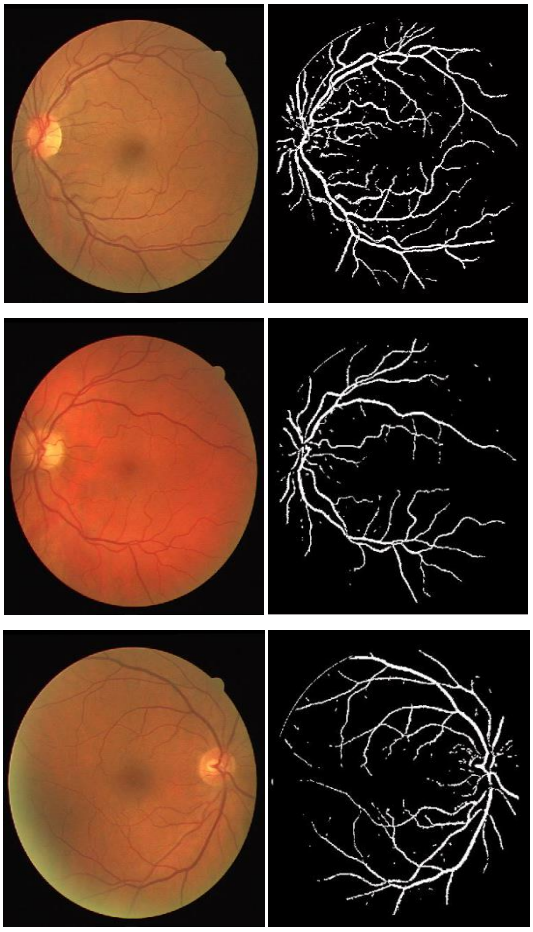


Fig 3. Retinal blood vessel segmentation results on different color retinal images.

This method is compared with previous methods on the bases of computational time and it takes less interval of time then previous one.

The proosed work has been aplied on many color retinal images, and the results of roosed method shown above in fig 3. The results shown in fig 3 bllod vessel segmentation is clearly visible. After segmentation all these results were comared with manual segmentation results of the same retinal image and method resented in this paper is able to get 94% to 95% similarity. Which is very good and close to other reviouse work. But the resented work took less comutational time to produce same results. Both comparison results with manula results and comutatinal time comarison result are shown below in tables. As shown below in tables the proposed method is compared with methods Miri [19], Mendonca [16], Joes staal [20], Soares [24] and Jiang [18].

Images	**Similarity**
Sample image_1	95.32 %
Sample image_2	94.85 %
Sample image_3	95. 21 %
Sample image_4	95. 04 %
Sample image_5	94.61 %

Table 1 Similarity index of proposed method segmentation results and manual segmentation results on 5 color retinal images.

Table 1 is showing the similarity between segmentation results proposed method and manual segmentation results on same color retinal images. as shown in table the similarity index is 94% to 95% that is very good.

Methods	**Execution Time**
Miri [9]	50 sec
Mendonca [10]	2.5 min
Joes staal [6]	15 min
Soares [7]	3 min
Jiang [11]	36 sec
Proposed	**11-15 sec**

Table 2 Computaional time comparison of proposed methods with previous methods..

As clearly shown in table 2 the computational time of proposed method is less as compare to previous methods mentioned in table. Results shows that the proposed method produce similar kind of results but with less computational time.

5. CONCLUSION AND F UTURE SCOPE

The proposed segmentation method is not dependent on training rules. Thus there is no time needed before to make training rules. The Proposed work is simply based on fuzzy rules. The segmentation task is performed on the bases of different set of fuzzy rules. Before applying fuzzy rules the color retinal images has to pass through different operations as discussed earlier. This method makes automatic retinal blood vessel segmentation little bit easier. Results shows that the proposed method performed well. The proposed method is able to segment the 94% to 95% blood vessels as discussed earlier in the paper. Also the proposed method produce results in less interval of time as compare to previous methods also mentioned in tabular results. The only drawback in the proposed work is that it misses to segment the very thin blood vessels. Blood vessels pixels with dark intensity values segmented easily but the blood vessel pixels with intensity values close to the intensity values of background pixels were missed. Zero dependence of the proposed method on training data and low computational time makes this method good for retinal blood vessel segmentation. The future work is directed toward further improvement in proposed method. In future changes will be made to segment the missed thin vessels and also to improve computational time. Also the proposed method will work on segmenting the blood vessels from the color retinal images in presence of red lesions and other pathological region.finds obtained from the proposed system. Conclusion should not be the same as abstract. Conclusion should be modelled efficiently.

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