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GUI For Retinal Blood Vessel Articulation for Detection Of Diabetic Retinopathy.

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ABSTRACT

A GUI has been developed for a new technique of segmentation of retinal blood vessels proposed in this paper. It is observed that retinal blood vessels have low contrast with respect to their background in fundus images when the retina of the patients are scanned to diagnose retinal disease. The paper overcomes this issue in fundus images for the accurate diagnosis of disease & treatment of the patients by ophthalmologists. This GUI also provides a wide range of pre-processing techniques on the input image for the reduction of noise before performing segmentation on the image. MATLAB R2014a, version 8.3.0.532 was used to create this GUI. The input data consists of a retinal image from fundus camera. The GUI has the capability of performing extraction of complement of green channel, application of AHE, removal of optic disc using morphological operations by erosion and dilution, removal of salt pepper noise using median filter & adjustment of image intensity finally followed by vessel segmentation by Fuzzy C Means based on the proposed methodology. The output is the segmented image of retinal blood vessel. The interface was solely developed to be simple, convenient & user friendly. Following the segmentation of the retinal image, calculations of efficacy of the methodology measuring the accuracy and precision of the image can be illustrated.

Keywords: Fundus Images, Retinal blood vessel, Retinal vessel segmentation, Vessel detection, Morphological operation, Fuzzy logic, Clustering, Image Enhancement.

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INTRODUCTION

It is important to use the appropriate image segmentation technique for precise detection of retinal blood vessels. The main aim is to improve the detailed quality of the image of the patient's retina by enhancing and segmentation. Further, to examine the image and study it using the static parameters. On obtaining the results, the diagnosis is classified as- normal or abnormal based on which the problem in the abnormal eye can be detected.

Image Segmentation

In general terms of image processing, image segmentation is the process of dividing a digital image into multiple segments. The goal of segmentation is to simplify the representation of an image so that it is meaningful and easier to analyze. Image segmentation is often used to detect objects and boundaries in images.

The result of image segmentation is a set of contours extracted from the image covering the entire region. Each pixels in the region are identical with respect to characteristics like color, intensity, and texture.

This paper presents a GUI for the proposed methodology in which a retinal fundus image is taken as the input image and processed at two levels. In the first level, the original image is converted into complement of green channel. AHE is used to enhance this image. To remove the optical mask, morphological operations of erosion and dilution techniques are used, and to remove the salt-pepper noise, a 2D median filter is used. The image intensity is adjusted to form a new image in such a way that 1% of data is saturated. In the second level, the segmented image of the Blood vessels are obtained by using Fuzzy C Means algorithm.

Related Work

The paper was grounded by reviewing some previous works: Sudeshna Sil Kar et al. [1] proposed an automatic blood vessel extraction method on retinal images using matched filtering in an integrated system design platform that involved curvelet transform and kernel based fuzzy c means. Gyorgy Kovacs et al. [2] proposed a novel technique based on template matching and contour reconstruction for the segmentation of the vasculature. Eysteinn Mar Sigurdsson et al. [3] presented an unsupervised method based on the extraction of two vessel features vectors in order to detect the pixels belonging to the vessel tree. Argyrios Christodoulidis et al. [4] proposed a hybrid method for the segmentation of the smallest vessels where line detection and perceptual organization techniques were combined in a multi-scale scheme.

Chengzhang Zhu et al. [5] proposed a supervised method based on Extreme Learning Machine (ELM) to segment retinal vessel. Santi P. Maity et al. [6] worked to eliminate noise from the image under consideration through curvelet based denoising. The image was passed through a bank of sequential bandpass filter structure optimized for contrast enhancement to include the fine details and the relatively less thick vessel structures. G. Mahendran et al. [7] proposed a method to detect lesion exudates automatically with the aid of a non-dilated retinal fundus image to help ophthalmologists diagnose the disease.

Buket D. Barkana et al. [8] evaluated the performance of descriptive statistical features in retinal vessel segmentation by using fuzzy logic, an artificial neural network classifier (ANN), support vector machine (SVM), and classifier fusion. Aboul Ella Hassanien et al. [9] proposed an automated retinal blood vessels segmentation approach based on two levels optimization principles which made use of the artificial bee colony optimization in conjunction with fuzzy cluster compactness fitness function and pattern search. According to Istvan Lazar et al. [10] the directional responses of a pixel were considered as a vector. Lei Zhang et al. [11] presented a retinal vessel segmentation algorithm which used a texton dictionary to classify vessel/non-vessel pixels.

Khosro Rezaee et al. [12] proposed an efficient algorithm that introduced a higher ability of segmentation by employing Skeletonization and a threshold selection based on Fuzzy Entropy.

From the above surveyed works it can be possibly concluded that the accuracy of segmentation is lower due to the presence of different types of noises in image. Therefore, an improved technique was been proposed to overcome this issue. This paper is organized in the following manner: Section II gives an in-depth explanation of the proposed methodology. Section III shows the experimental results. Finally, Section IV concludes the paper.

PROPOSED SYSTEM

Graphical User Interface (GUI)

Graphical User Interface (GUI) is an analyzing system that was developed using MATLAB R2014a software. GUI acts as an interface between the user and the dataset of images for segmentation as shown in Fig. 2. In the real application, a given image is pre-processed and segmented to over the issue addressed in the paper and comparison between the test image and trained image is performed and computations of the efficacy is illustrated. The purpose of creating a GUI using MATLAB for blood Vessel Images is to make it easy, simple & user friendly. Finally, it has the ability to display the edges of the detected blood vessels on the given image.

An input retinal image from an existing dataset of your computer is chosen for segmentation as the first step. Fig. 3 shows the original image in the GUI. Upon clicking 'Segmentation', the complement of green channel of the original image is extracted. Then, AHE is applied on the extracted image to enhance the contrast of the image. Morphological operation using erosion & dilution is performed to remove the optical disc. To filter out the noise in the image, it is passed through 2D median filter and the intensity of the image is adjusted as in Fig. 4. Finally, fuzzy C Means segments the image based on iterations and updation of selected clusters. Hence, the image is displayed as the segmented image in Fig, 5. Select a trained sample from the dataset by pressing 'Performance', for the calculation of parameters like Sensitivity, Specificity, Accuracy and Positive Predictive Value. Fig. 5 shows that pushing of 'Show Edges' displays the retinal Blood Vessels on the original image. To close the program, click 'Exit'.

Proposed Methodology

The proposed system takes a retinal image of a fundus camera as the input as illustrated in Fig. 1. The input image is converted to complement of green channel. Now, the image is processed in two levels: In the first level, Adaptive Histogram Equalization (AHE) is used for band selection, brightness correction and to denoise the image. When a noiseless image is obtained, morphological operations for erosion and dilution is applied on the image to remove optical disc. Then, it is passed through 2D median filter to remove background and the image is adjusted. At the second level, the obtained image is taken as input for segmentation using unsupervised method of Fuzzy Cluster Means to find the coarse vessels. The resulting image is a segmented image which is further used as a statistical parameter to compare and set the status as - normal or abnormal based on which the problem in the abnormal eye can be detected.

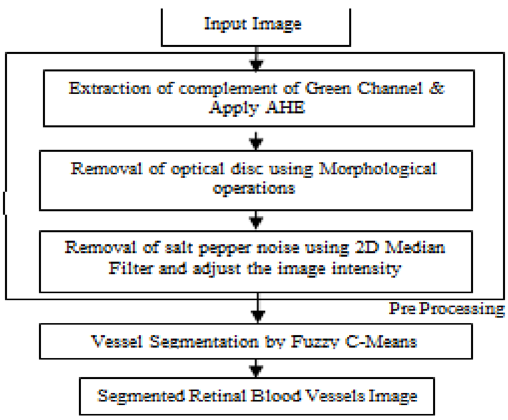


Fig. 1. Proposed Architecture

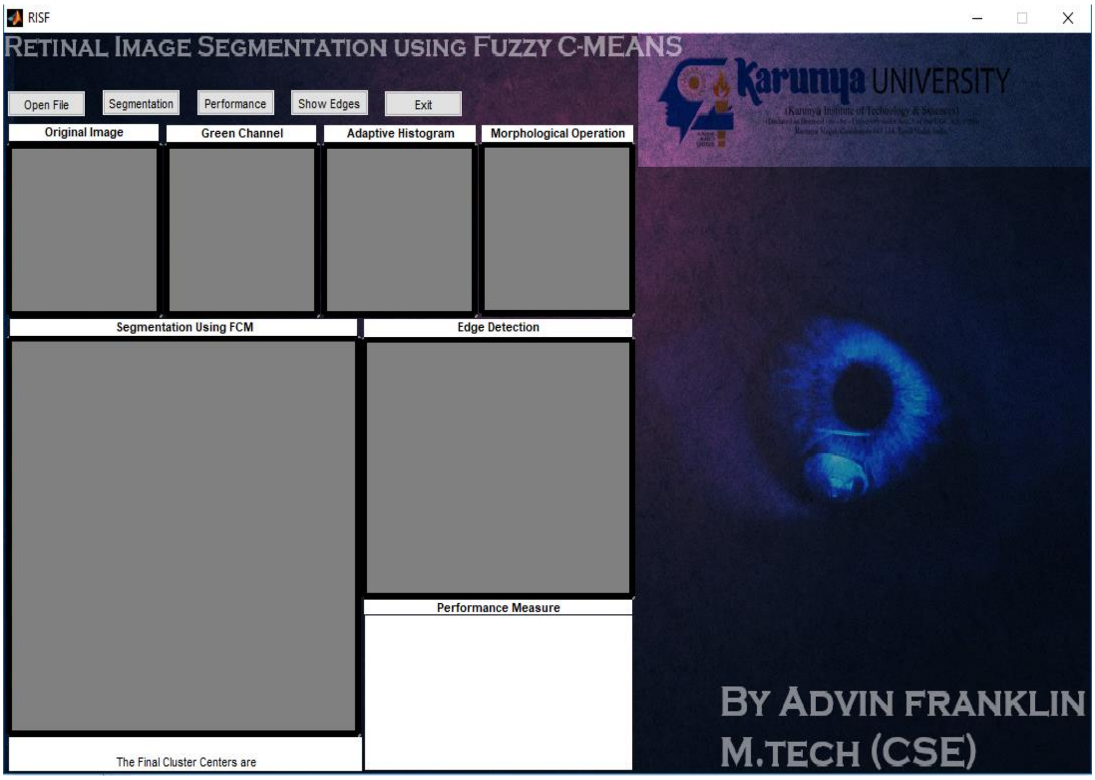


Fig. 2. Graphical User Interface for Retinal Image Segmentation.

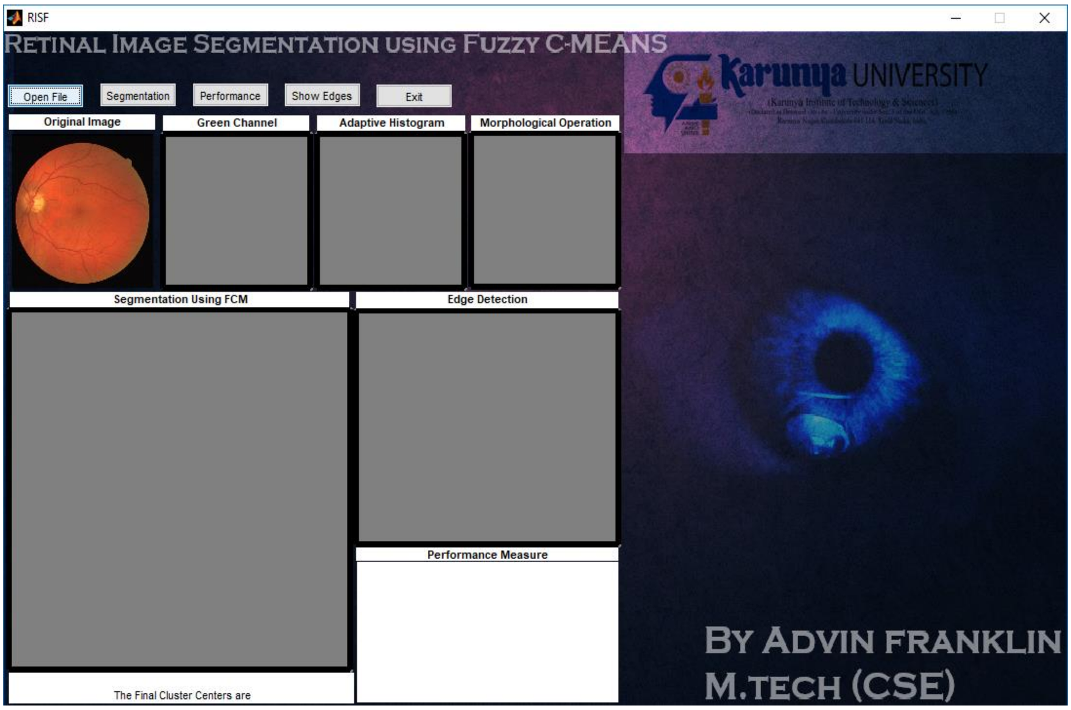


Fig. 3. Selecting Original Image

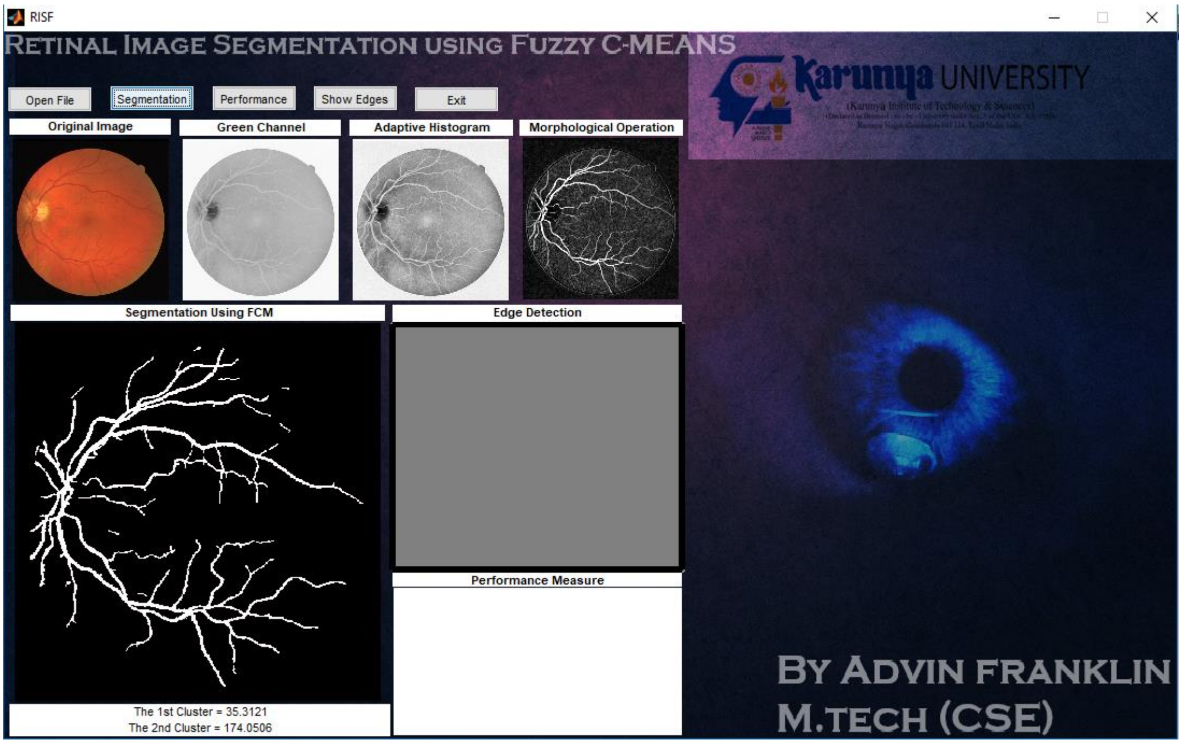


Fig. 4. Segmentation of the chosen image.

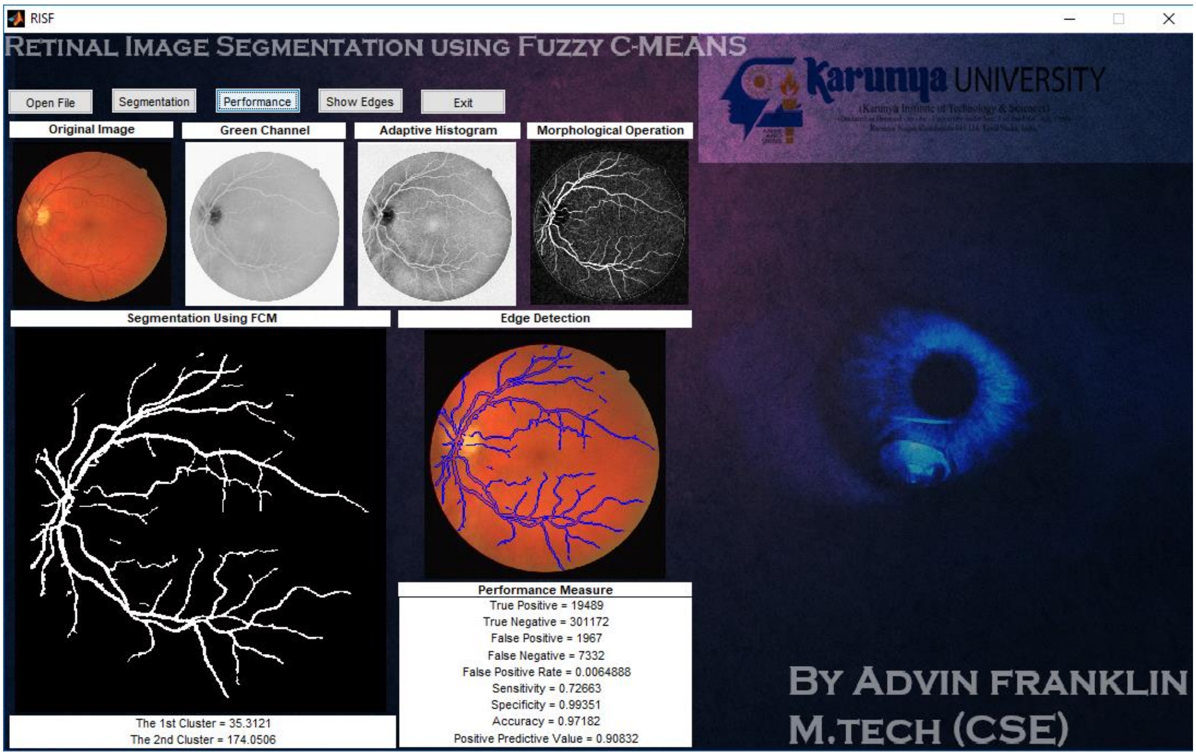


Fig. 5. Displaying Blood Vessels in Original Image.

Adaptive Histogram Equalization (AHE)

To improve the contrast of the image AHE is applied. AHE varies from the original histogram in such a fashion that it calculates many histograms that are corresponding to a selected region of the image and thereby using them renetwork the intensity value in the image. Thereby the contrast of the image is improved and enhanced in every part of the image.

Morphological Operations

Applying the grouping element to a given input image and then create the resultant image in the original size. The resemblance of the corresponding pixel with their adjacent pixels of the image gives the rate of the image by performing the mentioned operation. This operation is created in a way that it is conscious to the selected shape of the original image by taking into consideration the shape and size of the adjacent pixels. The operation is involved with the crevice of the original image with the grouping element. Erosion and dilution is operated on the original image by taking the grouping element.

The dilation of the erosion is called the crevice of the operation illustrated in Eq. (1).

$$X^{\circ}Y = (X \ominus Y) \oplus Y \qquad \text{(Eq. 1)}$$

where $X^{\circ}Y$ refers to the morphological crevice process of image X with a grouping element Y, $\ominus$ and $\oplus$ and refer to erosion and dilation, respectively. To produce a background image, I_{BK}, the blood vessels in the given image are restrained using crevice morphological operation with a non-flat and ball-shaped grouping element. The background image is removed from the resultant image of the adaptive histogram equalization, I_{AHE}, to obtain a normalized image, I_{NR}.

$$I_{NR} = masking\{I_{AHE}(i,j) - I_{BK}(i,j)\} \qquad \text{(Eq. 2)}$$

where i and j are pixel coordinates. The normalized image is generated by Eq. (2). Masking is applied to remove residual outside the fundus region of interest (ROI) in the entire normalized image.

2D Median Filter

To remove the noise present in the image is the purpose of the pre-processing technique. This noise is present in the form of fluky dissimilarity of color intensity and information while having other types of noises too. To remove this type of ‘salt and pepper noise’, median filtering is used. The fluky dissimilarity of the black and white pixel is referred to as ‘salt pepper noise’.

In the form of 2D, the filter performs the median filtering operation. The output pixel has the median value in 3 by 3 region adjacent to the pixels in the original image. The median values for points within half of the edges of the adjacent pixels are disoriented when the zeroes on them is padded.

Now, 1% of data is saturated at high and low intensity when the intensity values of the input image is mapped to new value to form a new image thereby increasing the contrast of the new image.

Fuzzy C-Means

FCM is an unsupervised clustering algorithm that finds its application to large series of problem which involves feature analysis, clustering and classifier design.

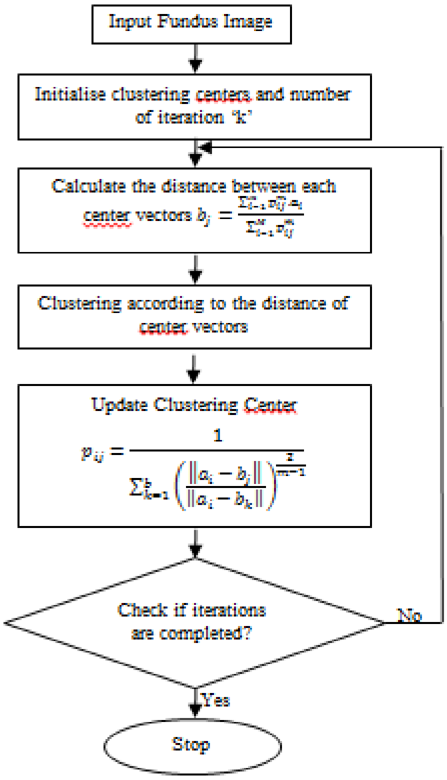


Fig. 6. Fuzzy C-means clustering Process

Fig. 6 shows the implementation of FCM algorithm that performs the classification of the image by clustering similar data points into clusters. Clustering by FCM is performed by reducing the cost function that is reliant on the area between the pixel and the center of the cluster. The pixels that are adjacent to other pixel in the region are associated with each other. So, image segmentation uses this spatial accordance of the adjacent pixels.

Fuzzy membership is used to allot pixels to their respective category. If A=(a1, a2,..am) are the pixels in a image with M pixels that must be divided into 'b' clusters, where 'ai' shows the multispectral data, the repetitive development that reduces the cost function is shown as:

$$J(V) = \sum_{i=1}^{b}\sum_{j=1}^{b_i}\left(\left\|a_i - t_j\right\|\right)^2 \quad \text{(Eq. 3)}$$

where '$\left\|a_i - t_j\right\|$' is the Euclidean distance between a_i and t_j and

$$p_{ij} = \frac{1}{\sum_{k=1}^{b}\left(\frac{\left\|a_i - b_j\right\|}{\left\|a_i - b_k\right\|}\right)^{\frac{2}{m-1}}} \quad \text{(Eq. 4)}$$

Where p_{ij} stands for the membership of pixel in the cluster, and m is a constant, 'b_i' is the number of data points in i^{th} cluster, 'b' is the number of cluster centers. The parameter m controls the fuzziness of the resulting partition.

$$b_j = \frac{\sum_{i=1}^{M} p_{ij}^{m} a_i}{\sum_{i=1}^{M} p_{ij}^{m}} \quad \text{(Eq. 5)}$$

Since the pixels that are adjacent to centroids of the respective cluster are allotted high membership values, the cost function is minimised. Meanwhile, pixels that are far from the centroid are allotted lox membership function. The membership function shows the possibility of a pixel belonging to the respective cluster.

RESULTS

Performance Measures

There are four measures used for the computation of segmentation performance of proposed novel algorithm: Sensitivity, Specificity, Accuracy and Positive Predictive Value. These measures are computed individually for each image and on average for the whole test images set.

$$Sensitivity = \frac{TP}{(TP+FN)} \quad \text{(Eq. 6)}$$

$$Specificity = \frac{TN}{(TN+FP)} \quad \text{(Eq. 7)}$$

$$Accuracy = \frac{(TP+TN)}{(TP+FN+TN+FP)} \quad \text{(Eq. 8)}$$

$$Positive\ Predictive\ Value = \frac{TP}{(TP+FP)} \quad \text{(Eq. 9)}$$

where the TP is True Positives, FN is False Negatives, TN is True Negatives, FP is False negatives of the pixels in the image. Therefore, the Sensitivity (Se) is the ratio of correctly classified vessels pixels while Specificity (Sp) is the ratio of correctly classified background pixels and Accuracy (Acc) is the ratio of correctly classified both the vessels and background pixels. Positive Predictive Value (Ppv) reveals the probability of a pixel that has been classified as a vessel is really a vessel as portrayed.

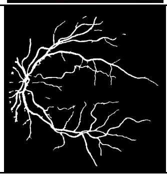
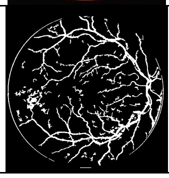
DRIVE Dataset	
Best Case	Worst Case
05_test	08_test
	
	

Fig. 7. Best & Worst case of DRIVE dataset.

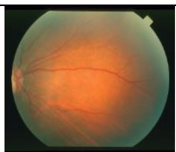
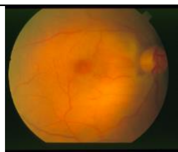
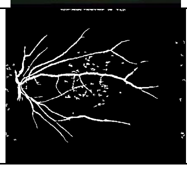
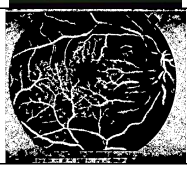
STARE Dataset	
Best Case	Worst Case
im0291	im0004
	
	

Fig. 8. Best & Worst case of STARE dataset.

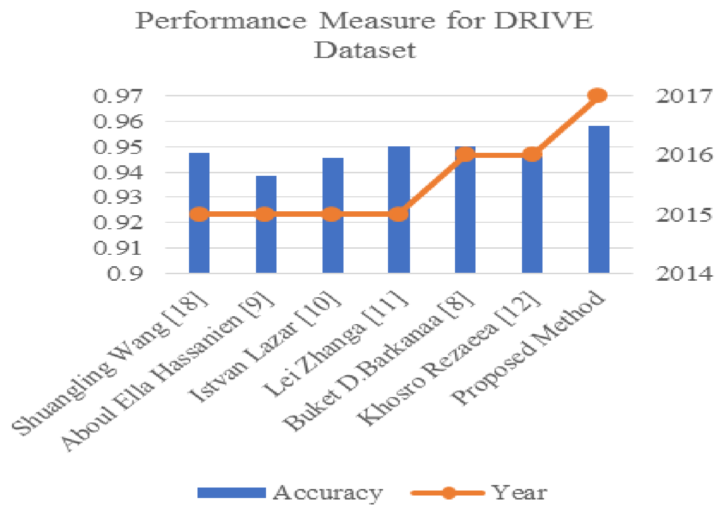


Fig. 9. Comparison chart for DRIVE dataset.

Table 1. Performance measures of the proposed methodology for DRIVE dataset.

Image ID	Acc (%)	Se (%)	Sp (%)	Ppv (%)
01_test	96.4	75.09	98.44	82.2
02_test	96.61	72.47	99.32	92.22
03_test	95.16	79.71	96.66	70
04_test	96.05	58.95	99.61	93.56
05_test	97.12	72.94	99.26	89.68
06_test	95.77	68.07	98.62	83.46
07_test	95.62	79.85	96.84	66.07
08_test	93.39	86.85	93.86	50.22
09_test	94.99	74.2	96.82	67.21
10_test	96.81	69.82	98.9	83.02
11_test	95.85	71.6	98.05	76.95
12_test	95.49	82.85	96.6	68
13_test	95.26	60.45	99.18	89.23
14_test	95.61	84.16	96.53	66.19
15_test	95.19	70.94	97.14	66.66
16_test	96.73	74.72	98.77	85.01
17_test	95.68	81.58	96.81	67.1
18_test	96.52	74.65	98.73	85.59
19_test	96.19	68.56	99.23	90.97
20_test	95.87	69.9	98.52	82.86
Average	**95.82**	**73.86**	**97.89**	**77.8**

Table 2. Performance comparison of vessel segmentation methods on DRIVE dataset.

No.	Methods	Year	Se	Sp	Acc
1.	Shuangling Wang [18]	2015	0.8173	0.9733	0.9475
2.	Aboul Ella Hassanien [9]	2015	0.721	0.971	0.9388
3.	Istvan Lazar [10]	2015	0.7646	0.9723	0.9458
4.	Lei Zhanga [11]	2015	0.7812	0.9668	0.9504
5.	Buket D.Barkanaa [8]	2016	0.7224	0.9840	0.9502
6.	Khosro Rezaeea [12]	2016	0.7189	0.9793	0.9463
7.	**Proposed Method**	**2017**	**0.7386**	**0.9789**	**0.9582**

Table 3. Performance of the proposed methodology for STARE dataset

Image ID	Acc (%)	Se (%)	Sp (%)	Ppv (%)
im0001	92.28	65.49	95.01	57.22
im0002	92.95	60.34	94.87	40.86
im0003	88.50	70.61	89.60	29.34
im0004	77.21	70.04	77.77	19.70
im0005	93.32	60.03	97.23	71.77
im0044	93.76	60.66	98.03	79.90
im0077	94.18	62.60	98.89	89.42
im0081	93.21	55.88	99.15	91.30
im0082	94.18	58.75	99.12	90.33
im0139	91.08	53.31	97.89	82.02
im0162	93.98	51.38	99.49	92.92
im0163	95.34	62.45	99.65	95.91
im0235	92.24	46.46	99.76	96.99
im0236	93.57	55.47	99.41	93.53
im0239	94.84	65.19	99.09	91.13
im0240	91.34	45.29	99.63	95.69
im0255	93.43	51.67	99.74	96.78
im0291	96.30	65.18	98.35	72.21
im0319	80.49	80.12	80.51	21.59
im0324	84.38	66.64	86.34	35.07
Average	**91.33**	**60.38**	**95.47**	**72.18**

Table 4. Performance comparison of vessel segmentation methods on STARE dataset.

No.	Methods	Year	Se	Sp	Acc
1.	Aboul Ella Hassanien [9]	2015	0.649	0.982	0.94677
2.	Istvan Lazar [10]	2015	0.7248	0.939	0.9351
3.	Buket D.Barkanaa [8]	2016	0.70.14	0.9846	0.9553
4.	Khosro Rezaeea [12]	2016	0.7202	0.9741	0.9257
5.	Nagendra Pratap Singh [13]	2016	0.7939	0.9376	0.9270
6.	**Proposed Method**	**2017**	**0.6038**	**0.9547**	**0.9133**

CONCLUSION

In this paper, a software GUI for the segmentation of retinal images was presented. This application was designed using MATLAB. The state-of-the-art was reviewed and a new technique of segmentation of images of eye from fundus image was proposed. Experimental results were computed:

The proposed technique outperforms the existing techniques by giving the following results: For DRIVE dataset by achieving an Accuracy of 95.82%, Sensitivity of 73.86%, Specificity of 97.89% and Positive Predictive Value of 77.8% and, For STARE dataset by achieving an Accuracy of 91.33%, Sensitivity of 60.38%, Specificity of 95.48% and Positive Predictive Value of 72.18% in the experimental setup.

Future works can be done on creating more functionality for calculation of diameter of vessel and label number of vessel in retinal image.

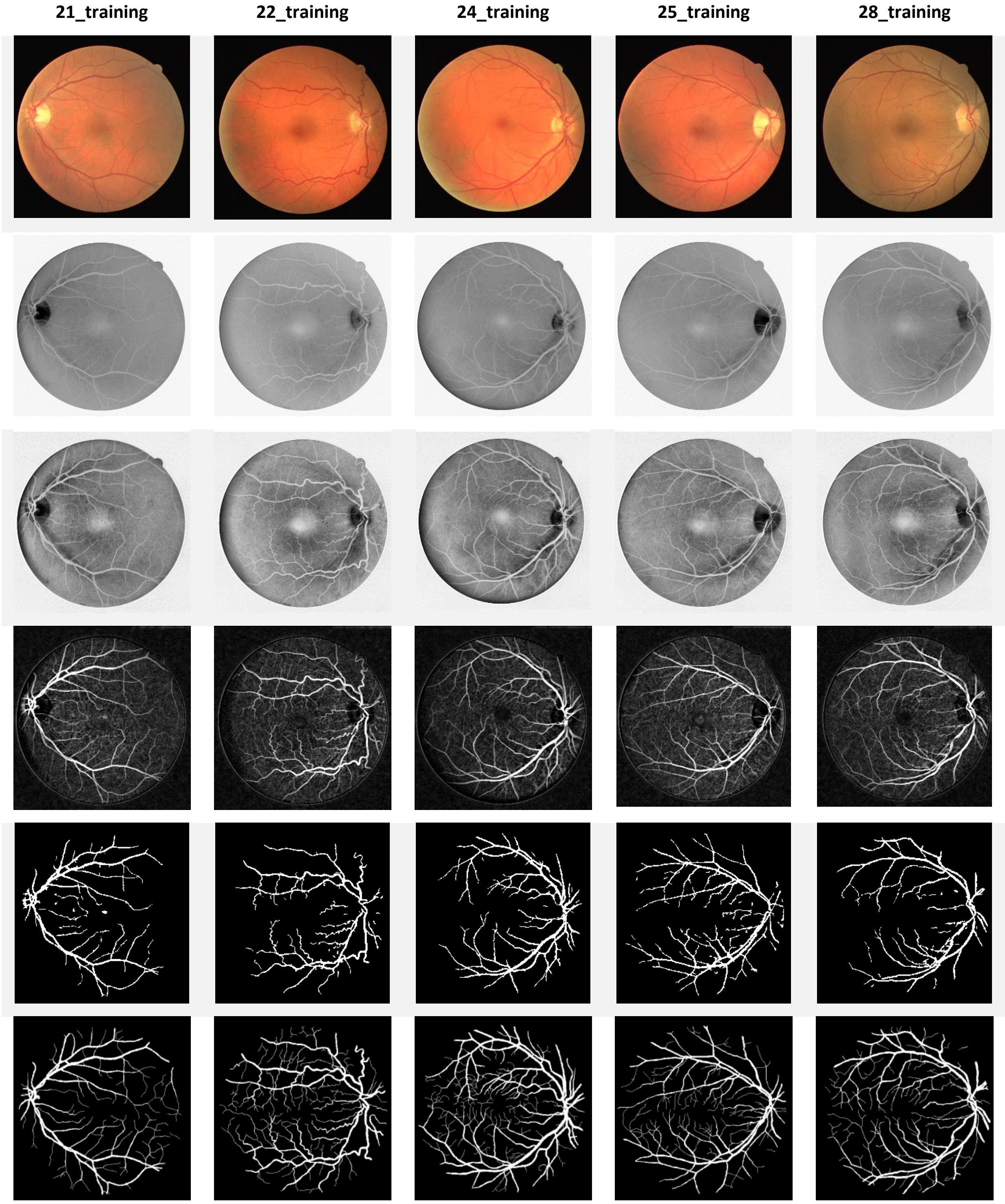


Fig. 6: 1st Row: Retinal image of DRIVE dataset, 2nd Row: Green channel image, 3rd Row: Adaptive Histogram Equalization (AHE) image, 4th Row: Morphological Operation & 2D Median Filter for removal of optical disc, 5th Row: Segmented retinal Image using Fuzzy C-Means, 6th Row: Vessel extraction results of Ground truth image.

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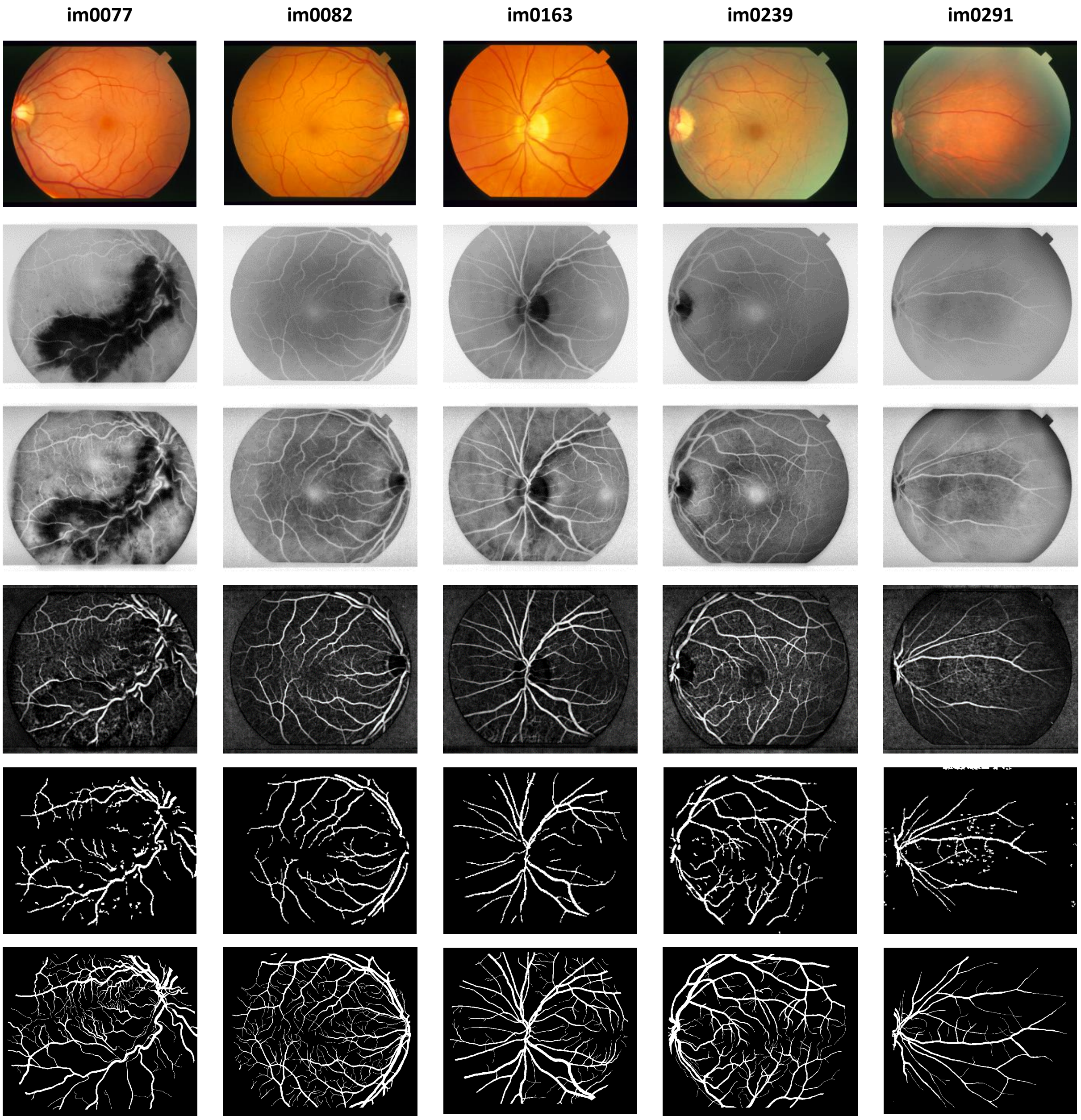
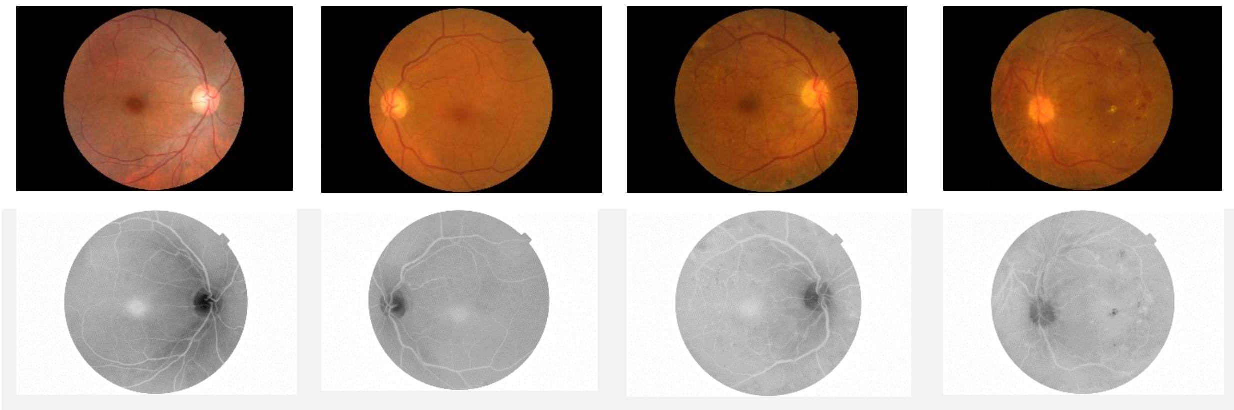


Fig. 7: 1st Row: Retinal image of STARE dataset, 2nd Row: Green channel image, 3rd Row: Adaptive Histogram Equalization (AHE) image, 4th Row: Morphological Operation & 2D Median Filter for removal of optical disc, 5th Row: Segmented retinal Image using Fuzzy C-Means, 6th Row: Vessel extraction results of Ground truth image.



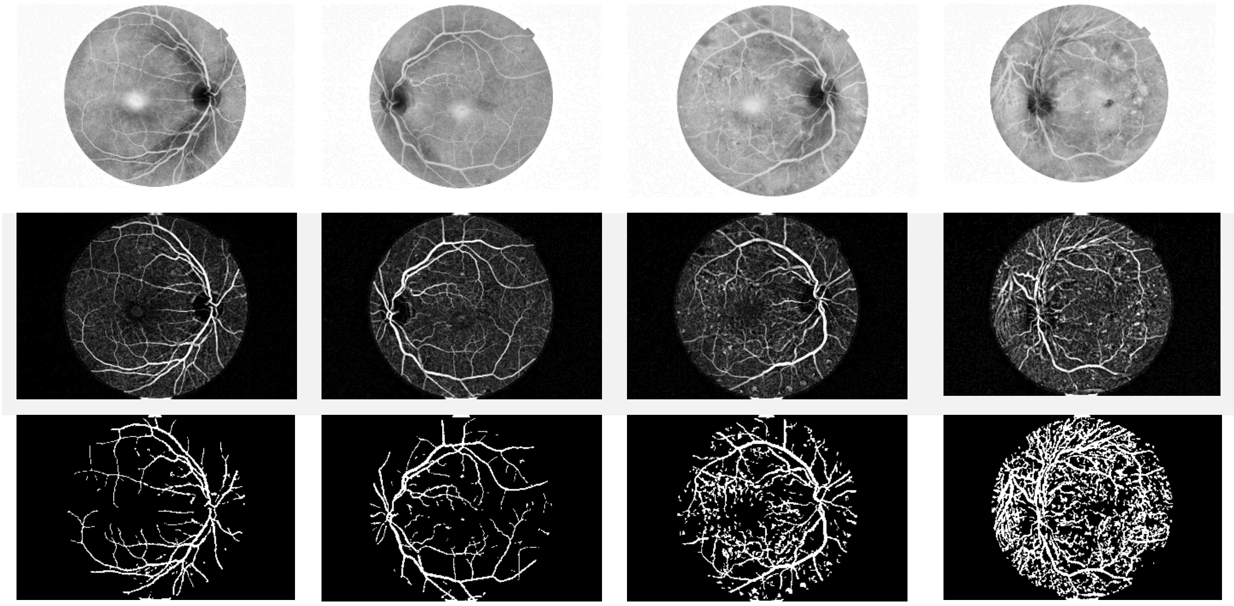


Fig. 8: 1st Row: Retinal image from Reputed Hospital in Coimbatore, 2nd Row: Green channel image, 3rd Row: Adaptive Histogram Equalization (AHE) image, 4th Row: Morphological Operation & 2D Median Filter for removal of optical disc, 5th Row: Segmented retunal Image using Fuzzy C-Means.

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