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Intelligent Diabetic Retinopathy Diagnosis in Retinal Images

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Abstract

Diabetic Retinopathy is one of the most important reasons of blindness which causes serious damage in the retina. The aim of this research is to detect one lesions of the retina, named Exudates automatically with Image processing techniques. Preprocessing is the first step of proposed algorithm. After preprocessing, the optic disc was detected and removed from the retinal image due to the same color of OD and the exudates. Next, the HSV format of image has been used where the H and V channels, standard deviation on green channel of retinal image and the background removal features were used as input of the system. The Fuzzy C-mean algorithm is used for classification. In this research the databases were Diaretdb0 and Diaretdb1. The results show 88.86% for Sensitivity and 99.98% for Specificity. Also, the result for PPV was 95.66% and the Accuracy was 99.90%.

Keywords: *Exudates, FCM clustering, Image processing, Morphological operations, Optic disk detection, Retinopathy diabetes*

1. Introduction

Mellitus diagnosis is one of the most important applications of image processing in medical field. Digitized data in ophthalmology is a focus for researchers to automatically detect and measure some important diseases like Diabetic Retinopathy (DR). Diabetes manifest in human body due to disordering in producing or using insulin, the hormone that converts glucose to energy. Diabetic retinopathy is the damage of the eye's retina that occurs with long term diabetes. Different parts of retina are optic disc, vessels and macula. This disease in developed stages can damage and block the retina's vessels which might lead to growth of new vessels that provide nourishment for the retina. These new vessels are very fragile and thick which bleed and leak fluid easily. Diabetic retinopathy is characterized by the development retinal micro aneurysms, hemorrhages and exudates on the retina. This work focuses on the exudates detection. It is necessary to say that if this mellitus doesn't diagnosis in early time and the symptoms will develop near the macula, vision loss can occur and lead to blindness. Automatic detection of diabetic retinopathy can prevent developing of diseases. The aim of this research is to intelligent diagnosis of manifested exudates on the retina by using image processing techniques. The patient with diabetes mellitus requires a permanent screening for early detection of DR. Retinal images have several parts like optic disc, vessels, macula and fovea. Two retinal images are shown in Figure 1.

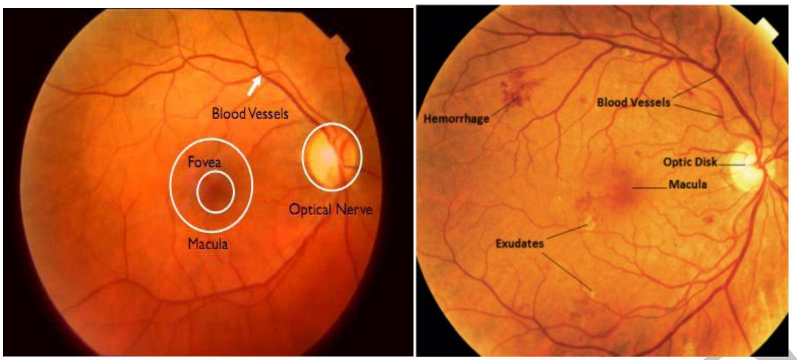


Figure 1. Retinal images

Early detection of DR helps in reducing the process of this disease and prevents visual loss. So, various methods have been proposed to automatically detect Diabetic Retinopathy in retinal fundus images and reduce the risk of blindness. There are a lot of works in blood vessel segmentation. Fraz planned a framework for the existing research and categorized the retinal vessel extraction algorithms [1]. Optic disc is a circular shaped structure with a bright appearance on the retina. The optic disc might diagnose as exudates area due to same color of it and the exudates, so we are supposed to remove the optic disc area from the retinal images. So, numerous techniques have been proposed to detect the optic disc. For instance Sinthanayothin assumed that the retinal lesions have a lower variance of intensity than that of the optic disc area, in which the optic disc is approximated by identifying the largest local variation with an 80*80 window size [2]. Lalonde proposed to locate the candidate OD regions by mean of pyramidal decomposition [3]. Sopharak presented the idea of detecting the optic disc by entropy filtering [4]. Ravishankar tried to track the optic disc by combining the convergence of the only thicker blood vessel initiating from it and high disk intensity properties in a cost function [5]. Niemeijer defined a set of features based on vessel map and image intensity, like number of vessels and average width of them, standard deviation, orientation and etc, measured under and around a circular template to determine the location of the optic disc [6]. Also an efficient combination of algorithms for automated localization of the optic disc and macula in the retinal fundus images was proposed by Qureshi [7]. There are various methods for automate detection of exudates that some of them are introduced here. For example Sopharak investigated and proposed a set of optimally adjusted morphological operators to be used for exudates detection on diabetic retinopathy patients [8]. An automatic method to detect exudates using a Fuzzy C-Means clustering proposed by Sopharak [9]. Kavitha proposed an automated classifier based on Adaptive Neuro-Fuzzy Interface System (ANFIS) [10]. Hard exudates were detected using CIE color channel transformation, Entropy thresholding, and Improved Connected Component Analysis from the fundus images. A comparison of various automated techniques for exudates detection like morphological approach, region growing approach, fuzzy C-mean Clustering techniques and k-means clustering techniques were done by Ramasway[11]. Kose developed an alternative simple approach by using the inverse segmentation method to detect retinapathy [12]. Garcia proposed an algorithm which includes a neural network (NN) classifier to detect hard exudates automatically [13]. In this work tree NN classifiers were investigated: Multilayer Perceptron (MLP), Radial Basis Function (RBF) and Support Vector Machine (SVM).

2. The Proposed Algorithm

Preprocessing, optic disc detection, background removal, FCM clustering, evaluation and comparing results are the steps of this algorithm. The block diagram of the steps of exudates detection process is illustrated in figure 2.

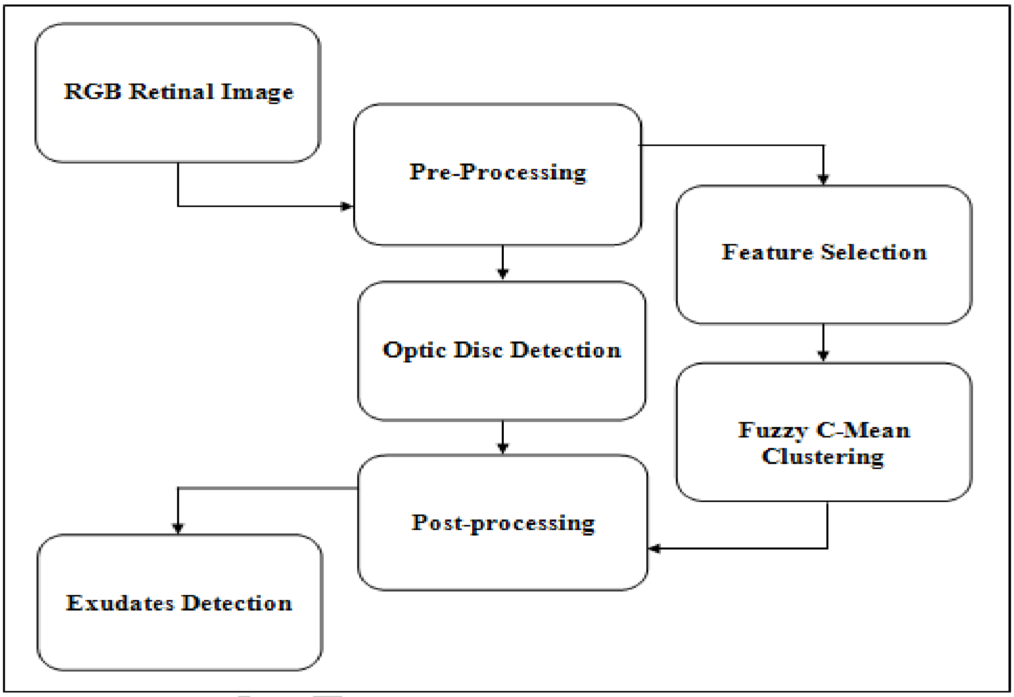


Figure 2. Block diagram of exudates detection algorithm

2.1 Pre-processing

The first step in automatic diagnosis of retinal diseases is preprocessing which is a crucial stage for preparing the fundus images. At first, color fundus images are resized to a size of 400*450 pixels. Next the green channel is extracted from the RGB image, because green channel provides maximum local contrast among pixels. The state of tree color channels is shown in Figure 3. The next step is applying a median filter of size 3*3 pixels. The resulting image after applying this filter is shown in Figure 5(c). This filter returns the median values of the elements along different dimensions of an array. At the next step, contrast equalization is applied on the image by using contrast-limited adaptive histogram equalization (CLAHE) which enhances the contrast of the image. CLAHE operates on small regions in the image, called tiles, rather than the entire image. The neighboring tiles are then combined using bilinear interpolation to eliminate induced boundaries artificially. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image. The median filter doesn't blur the borders of image. The resulting retinal image is shown in Figure 5(d).

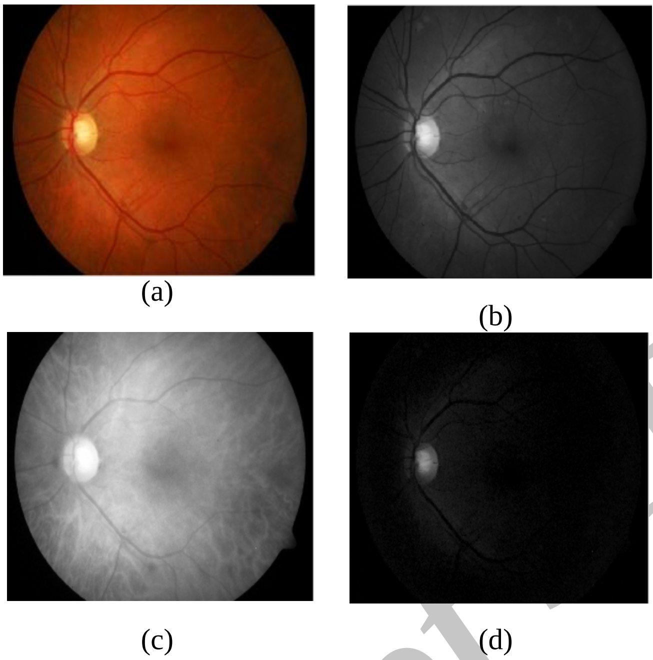


Figure 3. Channel extraction of RGB image (a) main image (b) green channel (c) red channel (d) blue channel.

2.2 Optic disc detection

Optic disc (OD) which has a circular shape and high intensity appears as bright, yellowish color. Optic disc might be diagnosed as a part of exudates region, because the colors of optic disc and exudates are similar. In this work, detection of OD is done by using the idea of Saleh by increasing the steps and changing the size of structure elements [14]. At this step, morphological Top-Hat operation is applied on the image. Top-Hat operation computes the morphological opening of the image and then subtracts the result from the original image based on a structuring element (SE). A disc structuring element with radius of 3 pixels is demonstrated in Figure 4.

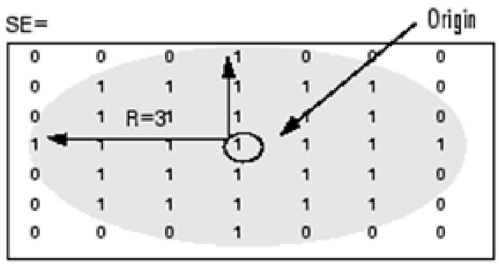


Figure 4. A disc structuring element

In this work, we use a ball structuring element with radius of 48 pixels and height of 55 pixels. The resulting image after top-hat operation is demonstrated in Figure 5(e). Then contrast stretching is applied on the image. This task expands the range of intensity values of the image. Contrast stretching can be performed by specifying lower and upper limits which can be used for contrast stretching image. By default, values in Low and High are specified the bottom 1% and the top 1% of all pixel values. The resulting image is illustrated in Figure 5(f). In the next step the resulting image converts to a binary image by using a threshold value or level of 0.9. Threshold value is in the range of [0, 1]. This range is relative to the signal levels possible for the image's class. Therefore, a level value of 0.5 is midway between black and white, regardless of class. The output image replaces all pixels in the input image with luminance greater than level with the value 1 (white) and replaces all other pixels with the value 0 (black).The outcome image after this task is shown in Figure 5(g). At the end, both morphological opening and closing operations are used. Opening operation is used to eliminate small objects. Closing operation is applied using a disc structuring element with radius of 10. The resulting image after applying these two operations is shown in Figure 5(h). In the last part, only one object which represents the optic disc will remain. After the optic disc detecting, this area is eliminated from the retinal image. Figure 5(i) is showing the end image.

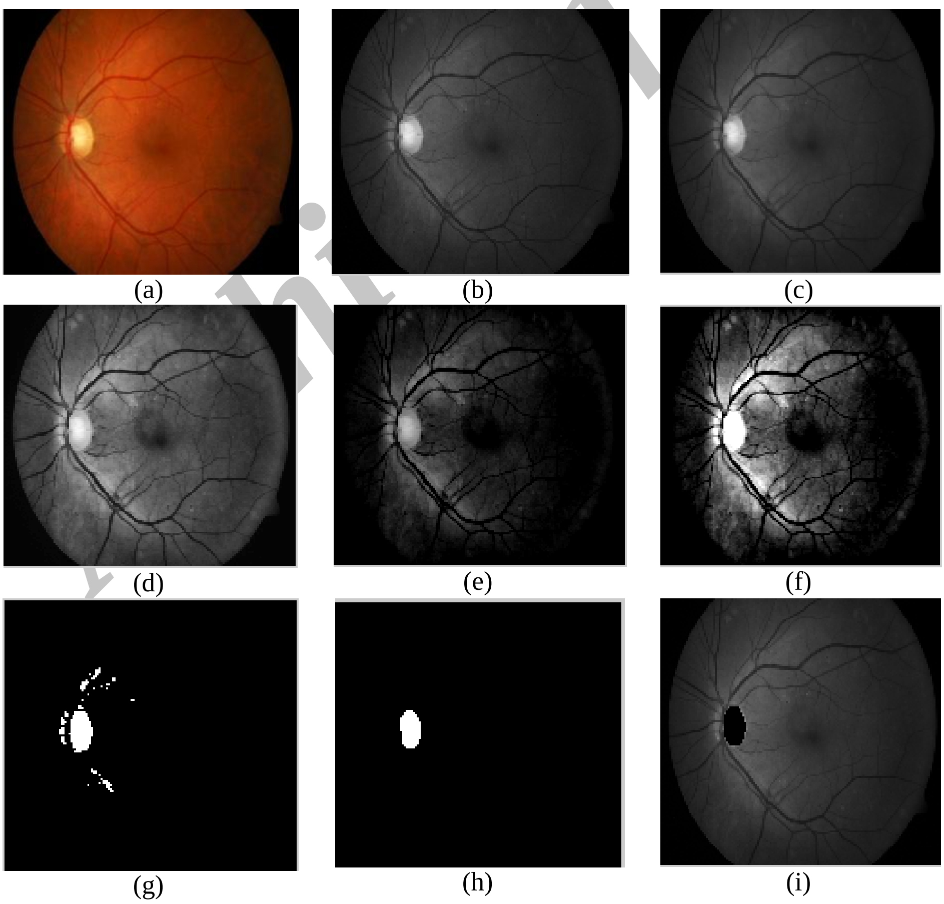


Figure 5. Optic disc detection (a) main image (b) green channel (c) median filter (d) contrast equalization (e) Top-Hat operation (f) contrast stretching (g) binary image (h) opening and closing (i) removed optic disc.

2.3 Background removal

The foreground objects more easily will be analyzed, if background removal is done. In the next step, the image which is resulted after background removal is used as another feature. Both morphological Top-Hat and Bottom-Hat operation are used for eliminating the background. At first Top-Hat operation is applied on the image and then Bottom-Hat operation is performed on the image. The image which is resulted by applying Top-Hat operation is shown in Figure 6(b). Bottom-hat operation is a combination of minus and closing operations. Bottom-hat operation computes the morphological closing of the image and then the original image base on a structuring element subtracts from the closing result image. In this work we use a disc structuring element with radius of 5 pixels. The outcome images after Top-Hat and Bottom-Hat operations are demonstrated in Figure 6(c). At the next step, the resulting image after applying both Top-Hat and Bottom-Hat operations is subtracted from the result of adding the green channel of the main image and the resulting image after applying the Top-Hat operation. The result is illustrated in Figure 6(d). After that, the total resulted image is subtracted from a median filtered image with 25*25 pixels. The result of applying median filter is shown in Figure 6(e) and the subtracting images is shown in Figure 6(f).

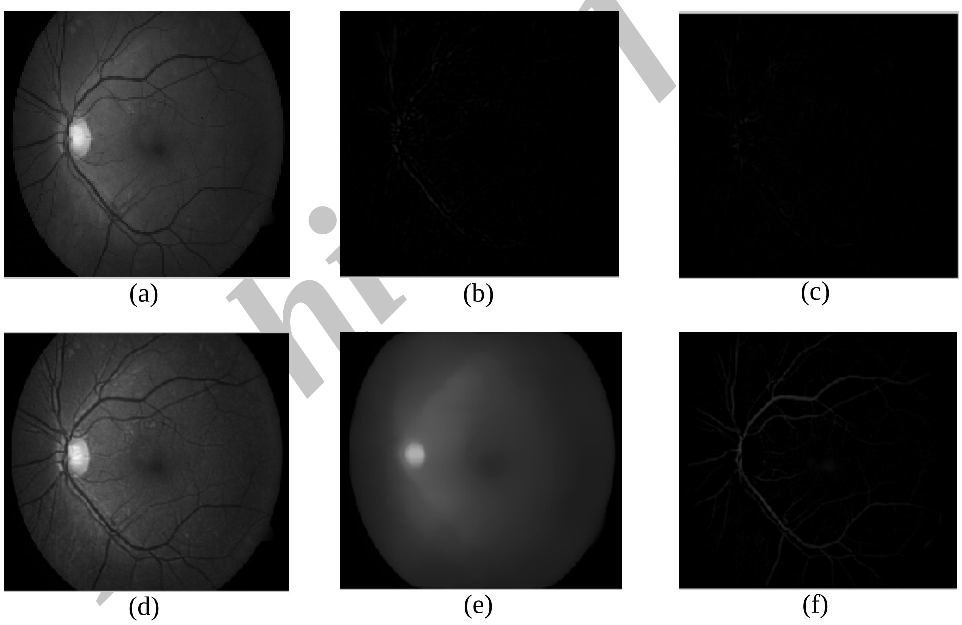


Figure 6. Background removal (a) Green channel of the main image (b) Top-Hat operation (c) Bottom-Hat operation (d) ((a)+(b))-(c) (e) Median filtering (25*25) (f) Background removed image

2.4 Exudates detection

One kind of diabetic retinopathy lesions is exudates, with hard white or yellowish colors with varying sizes, shapes and locations. Exudates occur when lipid or fat leaks from abnormal blood vessels. In this research the FCM algorithm is used for diagnosing the exudates of the retinal images. FCM applies the Fuzzy C-means clustering method (FCM) on a given data set [15].

2.4.1 FCM clustering

FCM is a soft, overlapping clustering algorithm, where each point may belongs to two or more clusters with different degrees of membership. FCM employs fuzzy partitioning such that a given data point can belong to several groups with the degree of belongingness specified by membership grades between 0 and 1. The input arguments of FCM function are the data set to be clustered and the number of clusters. Output is a list of cluster centers and n membership grade for each pixel, where n is a number of desired clusters. A pixel will be assigned to the cluster with a highest membership grade. The number of clusters is selected 5 in this work.

2.4.2 Features Extraction

Four features are selected and used as input to the FCM algorithm. At first the Red, Green and Blue (RGB) space of the original image is transformed to Hue, Saturation and Value (HSV) format of image. The features are explained in this section.

- Background removal image
- H channel of HSV format of retinal image
- V channel of HSV format of retinal image
- Standard deviation of green channel of retinal image

Hue and Value are extracted from the HSV format of retinal image because exudates have yellowish colors. The extraction of Hue channel of retinal image is shown in Figure 7(a) and the Value channel of retinal image is shown in Figure 7(b). The forth feature is Standard deviation of green channel of retinal image. A window size of 3*3 pixels was used in this step. The result of Standard deviation is shown in Figure 7(c) and the background removal image is shown in Figure 7(d).

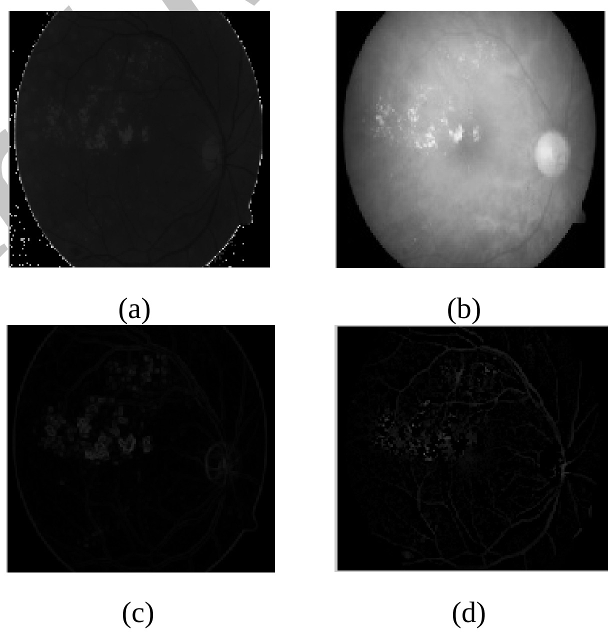


Figure 7. Features selection (a) H channel of HSV (b) V channel of HSV (c) Standard deviation of green channel (d) Background removal image.

At the next step, the mentioned features are used as input to the FCM algorithm for classification. Next, the desired cluster is selected among 5 output clusters. The output clusters of FCM are shown in Figure 8. In this step, the appropriate cluster is selected and after contrast enhancement and optic disc removal, is resulted as a final output and the exudates area is detected in the retinal images.

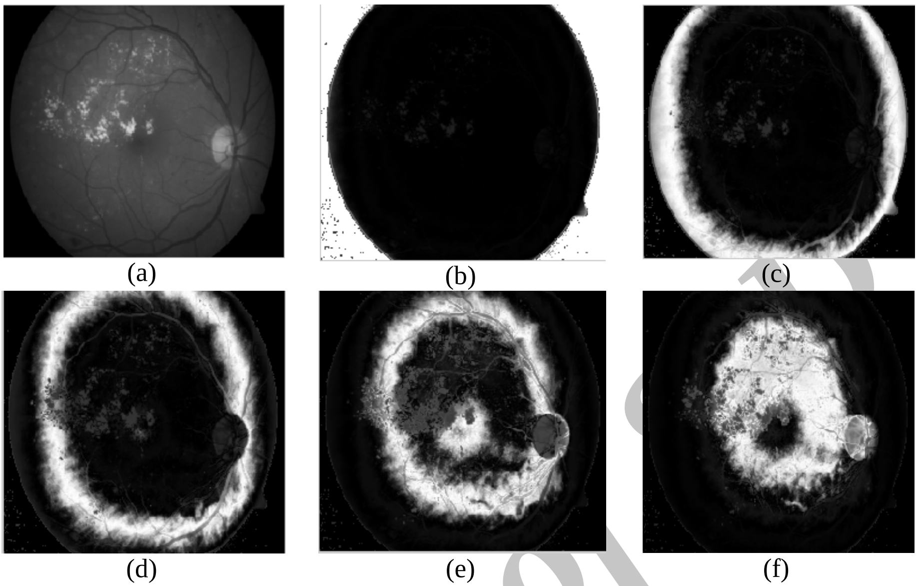


Figure 8. FCM output clusters (a) main image (b) cluster1 (c) cluster2 (d) cluster3 (e) cluster4 (f) cluster5.

2.5 Performance measurement

In this section we introduce the formulas for measuring the performance. After the implementation of this algorithm, the performance is evaluated based on various metrics like positive predictive value (PPV), sensitivity, specificity and accuracy. The parameters which are used for measuring the performance are TP (a number of exudates pixels correctly detected), TN (a number of non-exudates pixels which are detected correctly as non-exudates pixels), FP (a number of non-exudates pixels which are wrongly detected as exudates pixels) and FN (a number of exudates pixels that are not detected). Below equations show the computation of positive predictive value (PPV), sensitivity, specificity and accuracy, respectively:

$$\text{PPV} = \frac{TP}{TP+FP} \tag{1}$$

$$\text{Sensitivity} = \frac{TP}{TP+FN} \tag{2}$$

$$\text{Specificity} = \frac{TN}{TN+FP} \tag{3}$$

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+FN+TN} \tag{4}$$

3. Results

This system was tested on a portable 2.0 GHz PC using MATLAB platform. The retinal images of Diaretdb0, Diaretdb1databases are used for testing the algorithm. The resulted images are validated by comparing with the ophthalmologists' hand-drawn ground-truths. Figure 9, is showing the result of applying proposed optic disc detection algorithm with true, false and no detection on the images of Diaretdb0, Diaretdb1databases.

(a) (b) (c)

Figure 9. Optic disc detection(a) True detection (b) False detection (c) No detection

As we saw in Figure 8, in some cases the algorithm didn't diagnose the optic disc due to low contrasted retinal images or in some cases it had a wrong detection. The performance of optic disc detection algorithm is estimated by testing the algorithm on the image of Diaretdb0, Diaretdb1databases. The number of True, False and No detection of OD is determined on mentioned databases and then the average value is calculated. Table 1 shows the results.

Table 1. Performance of optic disc detection

Retinal images databases	Number of images	True detection	False detection	No detection	Average (%)
Diaretdb0	129	113	6	10	87.59
Diaretdb1	89	77	3	9	86.51

The comparison of proposed optic disc detection algorithm with other methods is shown in Table 2. It is necessary to notice that the optic disc detection is one part of this system. If this task is done with high accuracy, the performance of total work will increase. Using more features of the optic disc such as circularity and the start point of the retinal vessels will improve the total performance.

Table 2. comparison of optic disc detection methods

Optic disc detection methods	Diaretdb0 databases	Diaretdb1 databases
Sinthanayothin et al.(1999)	-	84
Lalond et al.(2001)	77.56	75.46
Sopharak et al.(2008)	95.29	93.70
Ravishankar et al.(2009)	80.12	76.41
Niemeijer et al.(2009)	78.20	77.04
Proposed method	87.59	86.51

Also the algorithm of exudates detection is tested on ten retinal images with exudates of Diaretdb0, Diaretdb1 databases. Table 3 is illustrated the calculated average of the Sensitivity, Specificity, Accuracy and the PPV parameters on ten images of Diaretdb0 and Diaretdb1.

Table 3. Average of proposed exudates detection algorithm

Method	Sensitivity (%)	Specificity (%)	PPV (%)	Accuracy (%)
FCM	88.66	99.98	95.66	99.90

As illustrated in section 1, there are numerous methods which used Neural Network, Morphology operations, Region growing and other methods to diagnosis of exudates on retinal images. The comparison of the proposed exudates detection with other methods is shown in Table 4. Also, Comparison of the values of Specificity is shown in Figure 10 and the comparison of the Accuracy is shown in Figure 11.

Table 4. Comparison of exudates detection methods

Methods	Sensitivity (%)	Specificity (%)	PPV (%)	Accuracy (%)
Sopharak et al. (2008), Morphology	80.00	99.46	-	-
Sopharak et al. (2009), FCM	97.2	85.4	5.9	85.6
Sopharak et al. (2009), FCM & Morphology	87.28	99.24	42.77	99.11
MLP García et al.(2009),	88.14	-	80.72	-
RBF García et al.(2009),	88.49	-	77.41	-
SVM García et al.(2009),	87.61	-	83.51	-
Ramaswamy et al.(2011), morphology	82.23	99.95	40.93	99.18
Ramaswamy et al.(2011), FCM	92.08	99.95	86.96	99.79
Ramaswamy et al.(2011), Region Growing	82.23	99.93	42.70	99.31
Kavitha et al.(2011), Neuro-Fuzzy	98.68	99.88	-	99.90
Kose et al.(2011), Inverse segmentation	98.10	99.80	-	-
Proposed Method, 10 images	88.86	99.98	95.66	99.90

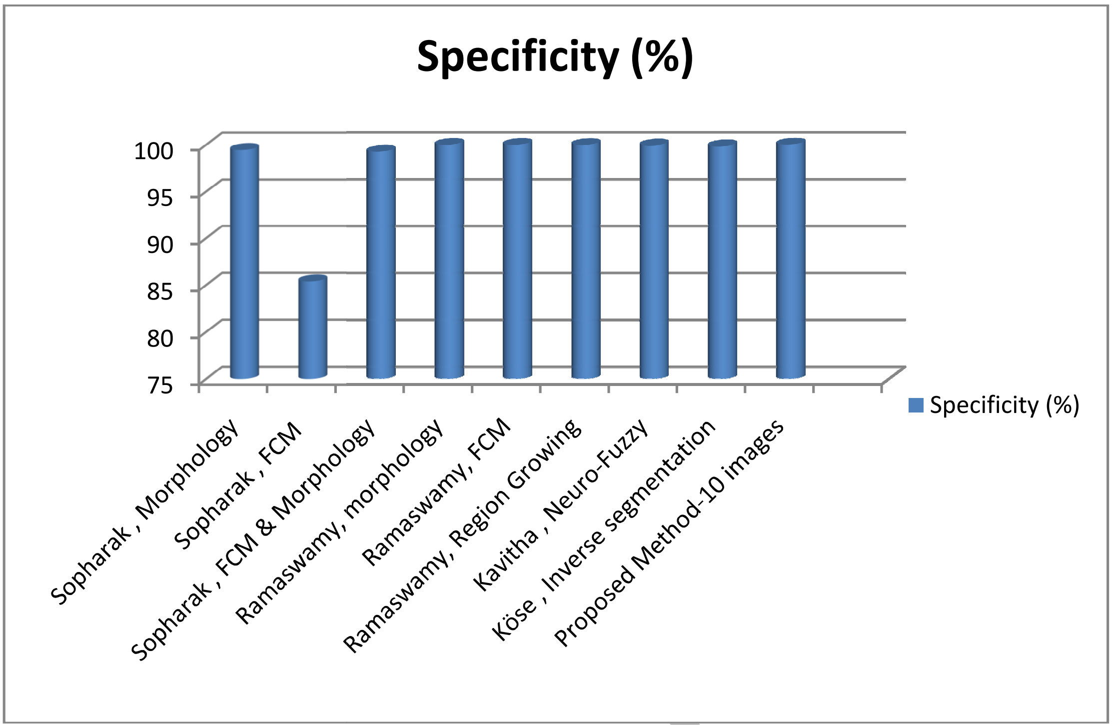


Figure 10. Comparing the Specificity of the exudates detection algorithms

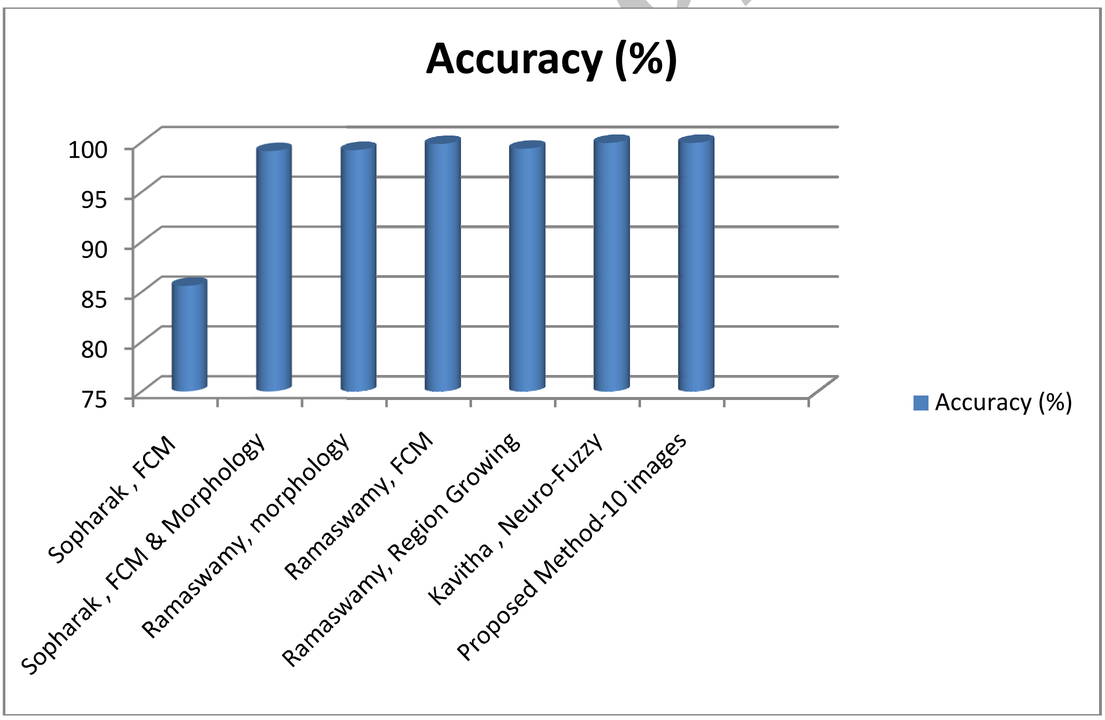
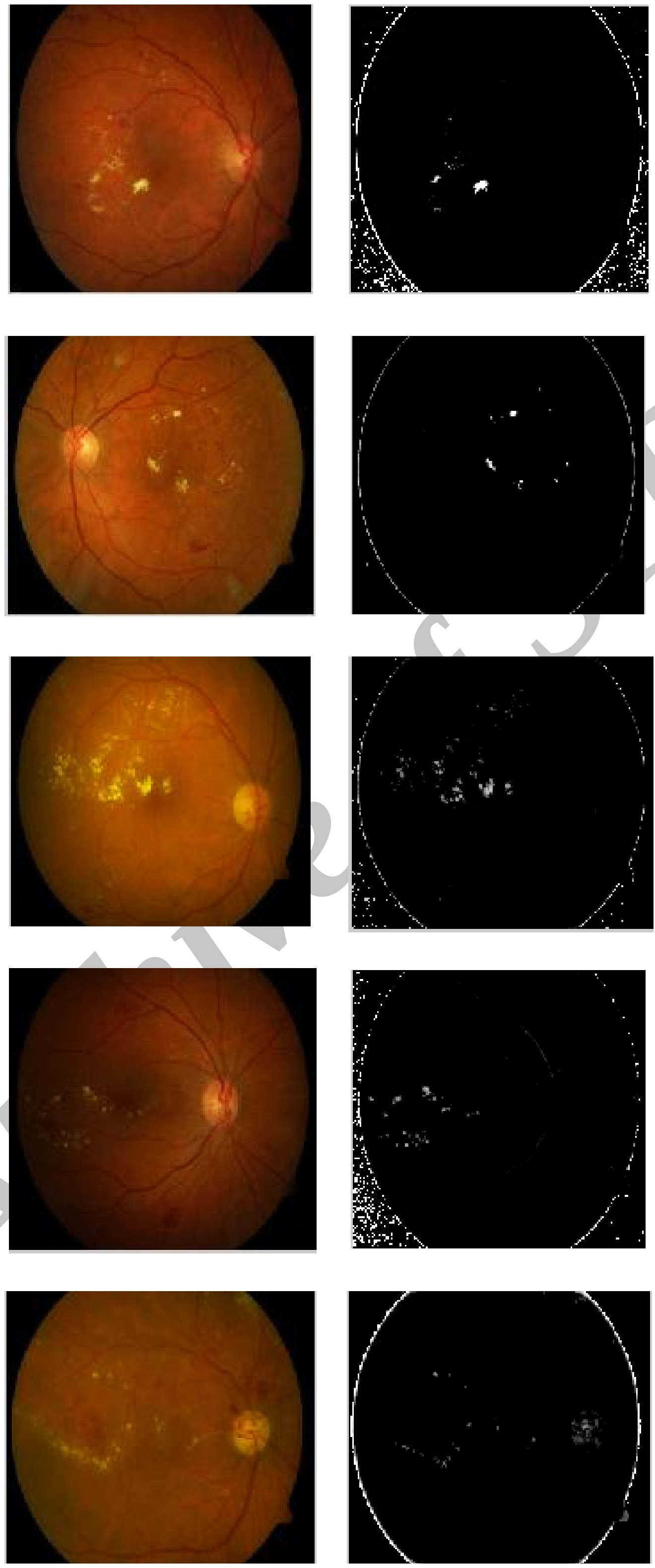


Figure 11. Comparing the Accuracy of the exudates detection algorithms

The output images after executing proposed exudates detection algorithm are shown in Figure 12.



(a) (b)

Figure 12. Exudates detection(a) main images (b) output images

The output images after executing proposed optic disc detection algorithm are shown in Figure 13.

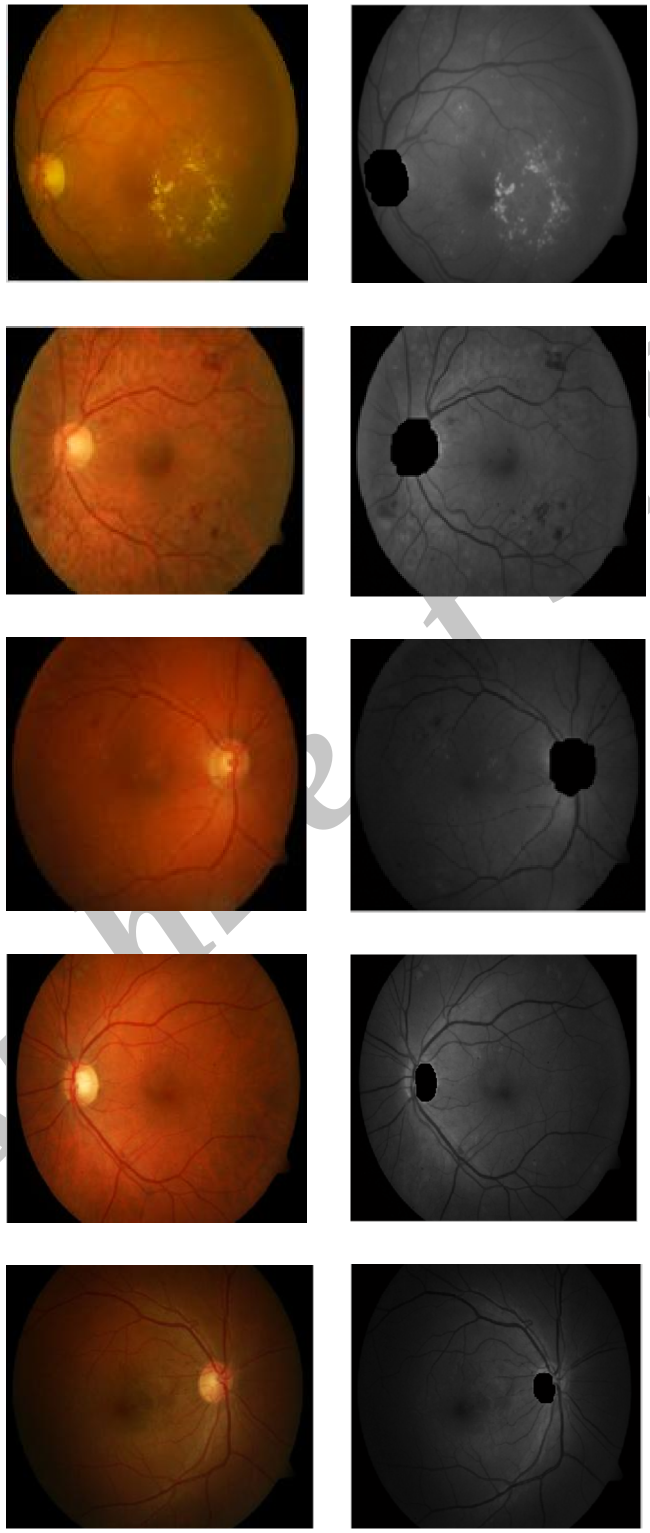

(a) (b)

Figure 13. OD detection(a) main images (b) output images

4. Discussion and Conclusion

In this paper, we have investigated to intelligent diagnosis for one kind of retinopathy lesions named exudates by image processing techniques. This system used the images taken from the patients retina. We used FCM algorithm for data clustering. The H and V channel of HSV format of image, standard deviation on green channel of retinal image and background removal image data are selected as features which are used as input to the FCM. The area of optic disc is detected and removed from the image by using morphological operations due to the same color with the exudates area. At the end, the performance of the algorithm is evaluated. Some performance index such as Positive predictive Value (PPV), Sensitivity, Specificity and Accuracy are used for evaluating the proposed algorithm. The results show that, this system depends on the other task like optic disc detection. If this task is done with high performance, the total system works with high accuracy. Using the maximum features of optic disc can be useful for this task. This algorithm has a good performance on retinal images that have bright and connected exudates areas. We didn't use vessel removal in this work. For the future work the detection of optic disc with more features increase the accuracy. Also, adding the vessel removal task can improve the performance of the system. Combining FCM clustering with other method or using a supervised clustering method may obtain superior results.

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