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Detection of Glaucoma and Diabetic Retinopathy from Fundus Images by Bloodvessel Segmentation

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Abstract: ***Blood vessel segmentation of fundus images has obtained considerable importance during the past few years since it facilitates the early detection of eye diseases. A method based on high pass filtering and morphological operation is introduced in the proposed method for vessel segmentation. This method can be utilized to detect diseases effecting eyes like glaucoma and diabetic retinopathy. Glaucoma is detected by feature extraction and classification. The local binary pattern of the optic disc is extracted to classify the images on the basis of texture. Sparse representation classifier is utilized to classify the glaucomatous eye. Diabetic retinopathy is a disease caused by the complexity of diabetes. It damages the small blood vessels in the retina resulting in loss of vision. The blood vessel segmentation is an important task in Diabetic Retinopathy detection. Optic disc in the fundus image is detected by Hough transform. After the segmentation the vessels and optic disc are removed from the original image. Diabetic Retinopathy is characterized by the presence of exudates. The exudates are detected by means of imtool operator in the matlab. The simulations are performed on matlab 2011 and the data are collected from DIARETDB1 and HRF databases.***

Index Terms: Blood vessel segmentation, Diabetic retinopathy, Fundus images, Glaucoma, Hough transform, Sparse representation classifier

I. INTRODUCTION

To diagnose the diseases, the patients undergo imaging techniques. Image processing plays an important role in medical diagnosis. Examination of blood vessels has gained considerable importance during the past decades since this facilitates the early detection of diseases. The disease affecting the eyes like glaucoma and diabetic retinopathy can be analyzed by the examination of blood vessels. The fundus of the eye is the interior surface of the eye opposite the lens and includes the retina, optic disc ,macula, fovea and posterior pole. The fundus images are captured by fundus photography. Glaucoma and diabetic retinopathy are the major applications of fundus image processing. Glaucoma is a disease that leads to irreversible blindness. In glaucoma patients, the inter-ocular pressure will be very high. This leads to the damage to the optic nerves. Even though this damage is irreversible, the extent of the loss of vision can be controlled by the earlier detection. Glaucoma leads to (i) structural changes of the optic nerve head (ONH) and the nerve fiber layer and (ii) a simultaneous functional failure of the visual field.

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Diabetic Retinopathy (DR) is an eye disease which occurs due to diabetes. It damages the small blood vessels in the retina resulting in loss of vision. : (i) early stage or non-proliferate diabetic retinopathy, (ii) maculopathy and (iii) progressive or proliferate retinopathy. In diabetic retinopathy, fluid from the blood leaks and gets deposited in the retinal regions. These occur in the form of yellow spots called exudates. Thus Diabetic Retinopathy can be detected by the presence of exudates. For effective treatment, the disease has to be detected earlier. Diabetic Retinopathy leads to damage to the blood vessels and also formation of lesions. Another complexity of the disease is that new abnormal blood vessels grow in the retina, known as revascularization. These abnormalities lead to severe visual problems. If the exudates extend to the macular region it will lead to severe vision loss. For the detection of exudates, first the blood vessels in the retinal regions are to be segmented. After the segmentation of blood vessels, optic disc is to be segmented .The blood vessels are to be removed to detect the presence of exudates.

Several approaches have been presented earlier for the detection of Glaucoma and diabetic retinopathy. Most of the proposed methods for glaucoma detection is based on ISNT ratio and CDR value[1]. Glaucoma can be detected by first performing the blood vessel segmentation and then calculating the area of the blood vessels in the ISNT quadrants. A model based on fuzzy rules which are based on optic nerve defect detection and visual field examination is another method for the detection of glaucoma. Phase information can also be utilized for the detection process. The CDR is calculated by multi thresholding method and then classification is done [2]. For large scale glaucoma screening, a data based approach is taken. The main characteristics of diabetic retinopathy are the presence of exudates. . The exudates are detected by blob detection and feature extraction as in [1]. The optic disc center is found by back through radii method. After detecting the optic disc, it is blackened and removed. Binary thresholding method is used to identify the presence of exudates. Probabilistic Neural network (PNN), Bayesian Classification and Support vector machine (SVM) are described and their performances are compared to diagnose Diabetic Retinopathy [3]. The classifier makes use of features like blood vessels, haemmoraghes of NPDR image and exudates of PDR image. Detection of exudates and non-exudate detection is performed by means of BPN model at pixel level [4].Decision tree and GA-CFS method are used as input to the BPN model .Blood vessels are detected by thresholding methods and optic disc is detected by Hough transform [5].

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The paper proposes on the detection of hard exudates. The advantage of the method is that it works well in low quality images also. Gaussian smoothening and contrast enhancement can be used as preprocessing steps [6]. Feature extraction based on location of optic disc, shape index and area is carried out for exudates detection. Wavelet sub bands can also be utilized for detecting the presence of exudates [7]. The energy distributions over the wavelet sub bands can be analyzed for exudates detection. The exudates are also detected effectively from the retina fundus image using segmentation algorithm.

II. METHOD AND MATERIALS

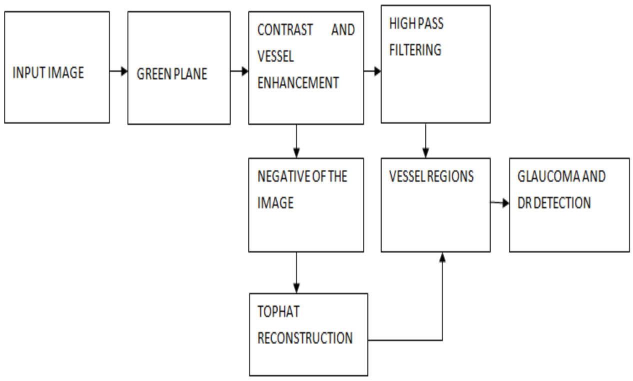

Fig.1 Block diagram of the proposed method

The algorithm of the proposed method is given below

1. Input image is selected from the database.
2. Contrast enhancement and vessel enhancement are performed on the green plane of the input image.
3. First a low pass filtering is done on the enhanced image using a median filter and then high pass filtered image is generated.
4. Negative of the enhanced image is taken.
5. Tophat reconstruction is performed on the negative of the image.
6. The region common to the high pass filtered image and tophat reconstructed image is taken as the vessel region.
7. For glaucoma detection the optic disc is detected using hough transform and the detected blood vessels are removed from it.
8. The LBP feature of the optic disc is extracted and classified by sparse representation classifier.
9. The diabetic retinopathy is detected by removing the detected blood vessels and optic disc.
10. The presences of exudates are identified after the removal of optic disc and blood vessels by means of imtool operator in matlab.

A. Data

1) STARE dataset contains twenty fundus images including their ground truth images. The images are captured by a fundus camera with 35 degree FOV (field of view).
2) DRIVE dataset contains 40 images with 45◦ FOV including their ground truth image. This dataset is separated by its authors into a training set (DRIVE Train) and a test set (DRIVE Test) with 20 images in each set. The DRIVE Train set of images are annotated by one human observer, while the DRIVE Test dataset is by two independent human observers.
3) HRF database which contains high resolution fundus images. The data base is publically available.

B. Glaucoma Detection By Sparse Representation Classifier.

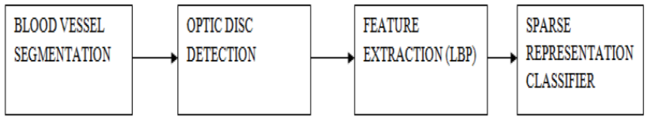

Fig 2.Block diagram for glaucoma detection

1. Blood Vessel Segmentation

The segmentation algorithm requires two pre-processed images. For the first pre-processed image, we require the green channel of the fundus image. The green channel extraction is the initial step. After the green channel is extracted, image enhancement is performed. Image enhancement involves contrast enhancement and vessel enhancement. Contrast enhancement increases the visibility of the image. It is performed by histogram equalization. Histogram equalization can be performed in the following steps:

1. Calculate the histogram of the input image;
2. Calculate the cumulative distribution of the histogram;
3. Use the cumulative distribution to construct a look-up table that maps each gray value to the equalized one (this step can be combine with the last one).
4. Update the image using the look-up table constructed in the last step.

Inorder to make the blood vessel more clear, each pixel value is squared and normalized in the range [0, 1]. This is an important process since squaring makes the vessels darker. The dark blood vessels are extracted from the enhanced image. First, a low pass filter is implemented by means of a median filter of size [25*25]. Median filtering is a nonlinear method used to remove noise from images. It is widely used as it is very effective at removing noise while preserving edges. It is particularly effective at removing 'salt and pepper' type noise. The median filter works by moving through the image pixel by pixel, replacing each value with the median value of neighbouring pixels. The pattern of neighbours is called the "window", which slides, pixel by pixel over the entire image 2 pixel, over the entire image. The blood vessels correspond to the high frequency components in the image. Inorder to obtain the high pass filtered image the low pass filtered image is subtracted from the enhanced image. This high-pass filtered image is thresholded to extract pixels less than 0. This is the first pre-processed image. For obtaining the second pre-processed image, red regions are extracted from the negative of the enhanced image. Next, 12 linear structuring elements are rotated through 15 degree to obtain the tophat reconstruction of the image.

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The tophat reconstruction is a morphological operation that is used to extract the minute details from the image. The mean value of each pixel from the 12 images is the final reconstructed image. This is the second pre-processed image. Both the pre-processed images are thresholded to obtain the binary images. The regions common to the two images are the vessel regions. The blood vessel regions in the optic disc are removed for further analysis of optic disc.

2. Optic Disc Detection

Optic disc detection is performed by Hough transform. Hough transform is used to detect objects in an image. Circular Hough transform is an extension of Hough line transform. It is a feature extraction technique for detecting circles. A circle is represented by,

$$(x-a)^2+(y-b)^2=r^2 \qquad (1)$$

(x, y) is the center coordinate and r is the radius. The curve obtained in the Hough Transform space for each edge point will be a right circular cone. Point of intersection of the cones gives the parameters a, b, r. If the point (x, y) is fixed, then the parameters can be found according to (1). If the radius is fixed, the parameter space will correspond to be 2D. The main advantage of using Hough transform is that it is less affected by noise.

3. Feature Extraction

The optic disc texture can be analyzed for the detection of glaucoma. For glaucoma affected patients, the LBP is non-uniform. The feature used in this method for classification is LBP (Local Binary Pattern). LBP is a powerful tool for texture classification. In LBP, the pattern is obtained by comparing its value with those in its circular neighborhood. After identifying the LBP pattern of each pixel (i, j), the whole texture image is represented by a histogram of LBPs. The detailed LBP calculation is as follows.

- Divide the image into various sections (windows).
- Compare each pixel to each of its eight neighbors. If the center pixel value is greater than the neighbors value 0 is written. Else a 1 is written.
- This corresponds to 8 bit binary pattern.
- Compute the histogram over the cells.
- Concatenate histogram of all cells. This gives the feature vector for the entire window.

4. Classification

Based on the LBP features, classification is performed by a sparse representation classifier (SRC). The sparse representation based classifier is a generalization of the nearest neighbor. The main advantage of using the classifier is that minimal number of training samples is required. Initially the SRC classifier is to be trained using the LBP features of the training samples. SRC makes the classification based on the SRC decision rule.SRC classifies the data on to the class that minimizes the difference between the estimated output value and the input value. If the LBP of the image to be classified has atmost 0-1 or 1-0 transitions then the image will be classified into the class corresponding to normal eye. Otherwise it will be classified as glaucomatous eye.

C. Diabetic Retinopathy By The Detection Of Exudates.

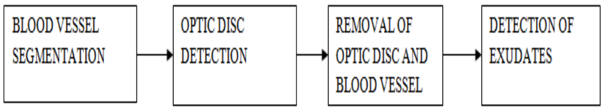

Fig 3.Block diagram of diabetic retinopathy detection

1. Blood Vessel Segmentation

The most important and initial step in the proposed method is the blood vessel segmentation. The images are collected from the DIARETDB1 and HRF databases. The green channel of the color fundus image is extracted. Contrast enhancement is performed to increase the visibility of the vessel regions. Contrast is the difference between the maximum and minimum pixel intensities. Contrast enhancement is done by histogram equalization. To make the vessel regions darker, vessel enhancement is performed. Vessel enhancement involves squaring the pixel values and normalizing in the range [0,1]. A low pass filter is implemented by means of median filtering. Median filtering is preferred since it reduces impulsive noises and preserves sharp edges. The vessel regions correspond to high frequencies in the images. Thus high pass filtered version of the image is obtained by subtracting the low pass image from the enhanced image. This yields the first preprocessed image. The red regions in the green plane image are extracted by taking the negative of the green plane image. Next, tophat reconstruction is performed on the negative image. Tophat reconstruction is a morphological reconstruction method that is defined as the difference between the input image and its opening by some structuring element. This is the second preprocessed image. The vessel regions are the intersected regions between the two preprocessed images.

2. Optic disc detection

Optic disc detection is performed by Hough transform. Hough transform is used to detect objects in an image. Circular Hough transform is an extension of Hough line transform. It is a feature extraction technique for detecting circles. A circle is represented by,

$$(x-a)^2+(y-b)^2=r^2 \qquad (1)$$

(x,y) is the center coordinate and r is the radius. The curve obtained in the Hough Transform space for each edge point will be a right circular cone. Point of intersection of the cones gives the parameters a, b, r. If the point (x, y) is fixed, then the parameters can be found according to (1). If the radius is fixed, the parameter space will correspond to be 2D. The main advantage of using Hough transform is that it is less affected by noise.

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3. Blood Vessel and Optic Disc Removal

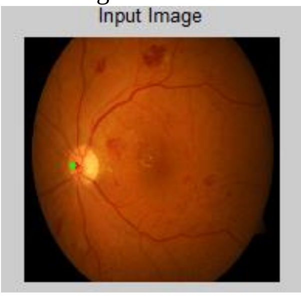
The blood vessels are detected by the intersecting regions between the high pass filtered image and tophat reconstructed image. The optic disc is detected by circular Hough transform. After the detection of these, the blood vessels and optic disc are subtracted from the original image .If there is the presence of exudates, then these are identified easily.

4. Exudate Detection.

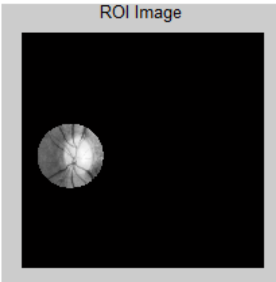
After the removal of blood vessels and optic disc, the exudates can be detected from the image by imtool in the matlab. The imtool facilitates the calculation of the pixel information. Based on the pixel information, the exudates are identified.

III. RESULTS AND DETECTION

The major steps in the glaucoma detection are the optic disc detection and blood vessel segmentation. The optic disc detection is performed by circular Hough transform. The results are given below:



(a)



(b)

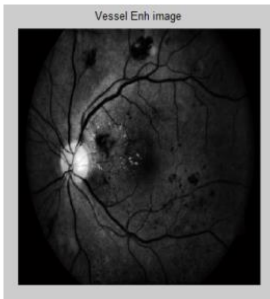
Fig 4.a) Input image b) Optic disc segmented image

The next step is the blood vessel segmentation. The vessel regions correspond to the intersecting region between the high pass filtered image and tophat reconstructed image. First a low pass filter is implemented using a median filter and it is subtracted from the original image to obtain the high pass filtered image. Tophat reconstruction is done to extract the red regions in the image. The results of blood vessel segmentation are given below:

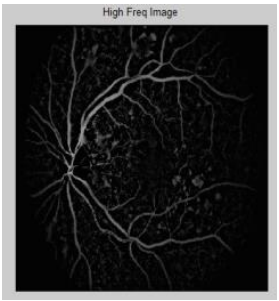
(a)

(b)

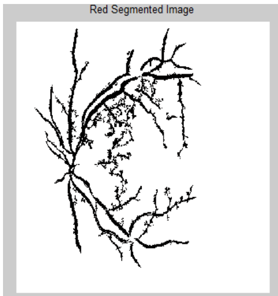
(c)



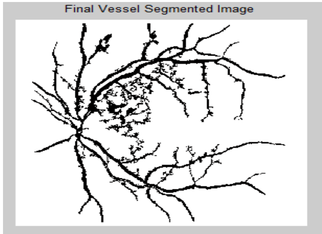
(d)



(e)



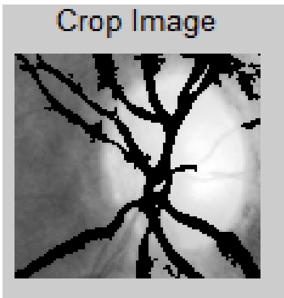
(f)



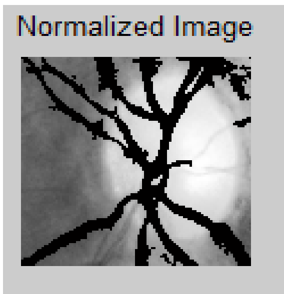
(g)

Fig 5. (a) Input image (b) Green plane image (c) Contrast enhanced image (d) Vessel enhanced image (e) High frequency image (f) Red segmented image (g) Final segmented image

The optic disc region is separated from the original image. This is normalized and feature extraction is performed. Local binary pattern of the optic disc disc is extracted .Based on the feature extracted, classification is performed by means of sparse representation classifier. The main advantage of using the classifier is that minimal number of training samples is required.. The results are given below:



(a)



(b)

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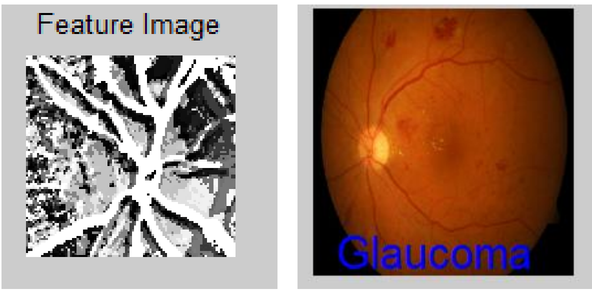


(c) (d)

Fig 6. (a) Blood vessel removed from optic disc (b) Normalized image (c) Feature image (d) Result after classification

The performance of a classifier can be expressed in terms of a confusion matrix. The accuracy of classification is derived on the basis of four parameters namely true positive (TP), true negative (TN), false positive (FP) and false negative (FN). The accuracy is given by,

Accuracy= (TP+TN)/(TP+TN+FP+FN) (2)

TP= Glaucoma detected as such
TN=Normal eye detected as such
FP=Glaucomatous eye detected as normal eye
FN= Normal eye detected as glaucomatous eye
The confusion matrix for the SRC classifier is given below

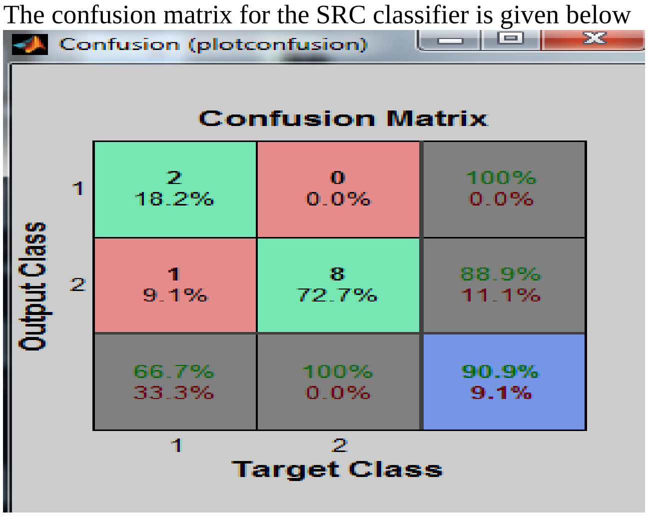


Fig 7. Confusion matrix of the classification for glaucoma detection.

The sensitivity, specificity and accuracy can be found out from this matrix.

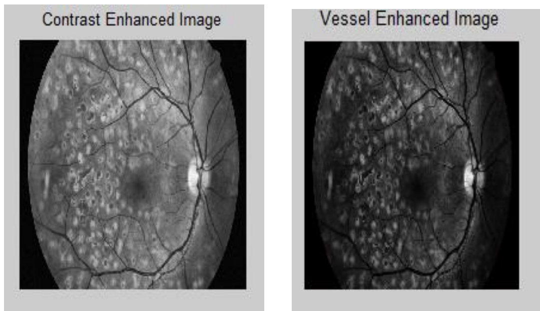
Table I. Comparison of the proposed method with the existing method.

Method	Sensitivity	Specificity	Accuracy
Method in [8]	76.67%	86.67%	85.67%
Proposed method	66.7%	100%	90.9%

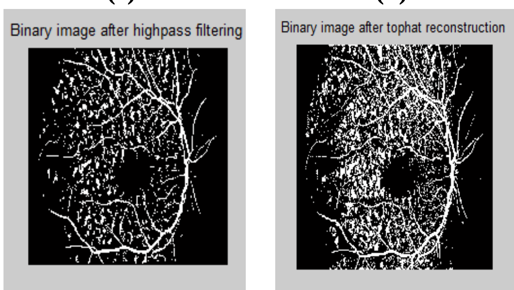
From the table we can conclude that the accuracy of classification of the proposed method is 90.9% whereas the method in [8] that utilizes the SVM classifier has an accuracy of 85.67%.The sensitivity of the proposed method is 66.7% and specificity is 100%.

The initial step in the Diabetic Retinopathy detection is the blood vessel segmentation. The vessel regions are the intersection regions between two preprocessed images. The first preprocessed image is the high pass filtered image and the second image is the to phat reconstructed image. High pass filtering is performed on the green channel and to phat reconstruction is performed on the red regions in the green channel. The results of blood vessel segmentation are given below:

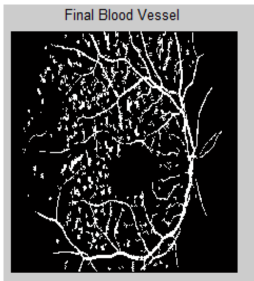
(a) (b)



(c) (d)



(e) (f)



(g)

Fig 8.Results of blood vessel segmentation.(a) Input image (b) Green plane image (c) Contrast enhanced image (d) Vessel enhanced image (e) High pass filtered image (f) Tophat reconstructed image (g) Final vessel segmented image.

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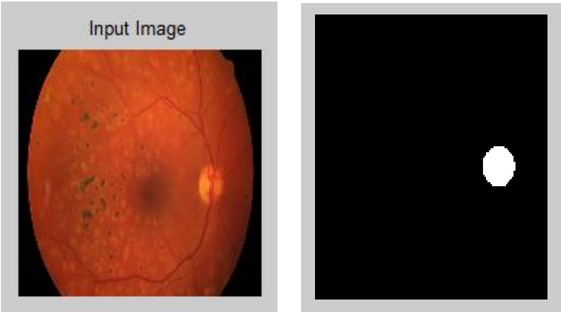
After the blood vessels are segmented from the fundus images, the optic disc is to be detected. Circular hough transform helps to detect circular objects in the image .The results of optic disc detection are given below.



(a) (b)

Fig 9. Optic disc segmentation result (a) Input image (b) Optic disc segmented image

Once the blood vessels and optic disc are detected these are subtracted from the input image. The results of blood vessel and optic disc removal are given below.

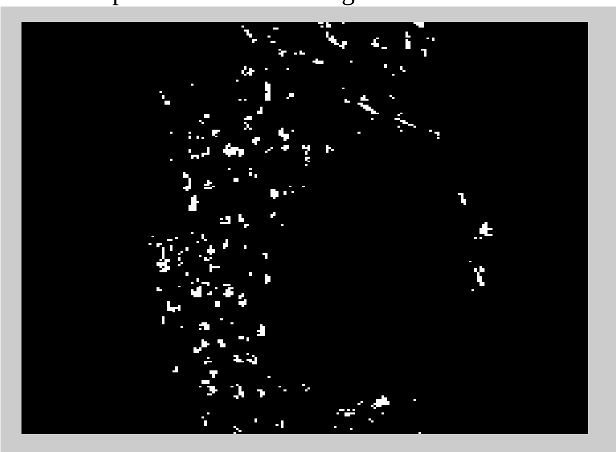


Fig 10. Results of blood vessel and optic disc removal

The exudates are detected by the imtool in the matlab. The imtool function makes use of the pixel information to determine whether it corresponds to exudates or not. The results of exudates detection is given below.

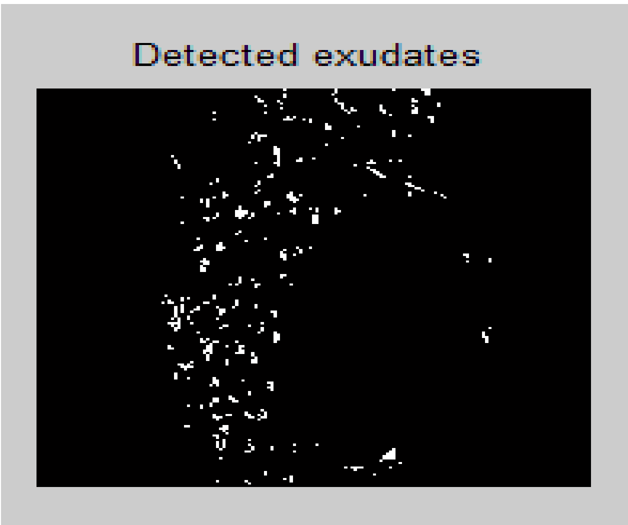


Fig 11. Results of exudates detection

IV. CONCLUSION

The examination of blood vessels plays a major role in the medical field. Several approaches are available for the segmentation of blood vessels from the fundus images. The paper proposes a method that identifies vessel region as the intersected region between the highpass filtered image and tophat reconstructed image. For glaucoma detection, the segmented blood vessels are removed from the optic disc segmented image. The disease is detected by feature extraction. The LBP feature is extracted and classified by means of sparse representation classifier. The classifier performance is evaluated in terms of sensitivity, specificity and accuracy. The sensitivity of the proposed method is 66.7% and specificity is 100%.The accuracy of the proposed method is 90.9%. Diabetic Retinopathy is a complicated disease that is caused by diabetes. The main symptom of Diabetic Retinopathy is the presence of exudates. The method in this paper makes use of the identification of exudates after the segmentation of blood vessels and optic disc. The exudates are detected by imtool operator. These methods provide a means to identify Diabetic Retinopathy to a certain extent.

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