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"Categorization of Diabetic Retinopathy by Dissociating features in a Retinal image"

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Abstract: Diabetic retinopathy is a common eye disease associated with diabetes. Diabetes, by stressing the circulatory system, can cause severe damages to the small blood vessels of the retina, by developing certain undesired abnormal features. There are two major forms of diabetic retinopathy, Nonproliferative and Proliferative. Nonproliferative Diabetic Retinopathy (NPDR), also known as background retinopathy, is an early stage of diabetic retinopathy. In this stage, tiny blood vessels within the retina leak blood or fluid. The leaking fluid causes the retina to swell or to form deposits. It can cause severe changes in the eye, including exudates, microaneurysms and haemorrhages. Proliferative Diabetic Retinopathy (PDR) occurs when new fragile abnormal blood vessels begin to form in damaged areas of the retina, and may lead to decreased vision, or sudden loss of vision. Diabetic retinopathy may progress through four stages: Mild NPDR, Moderate NPDR, Severe NPDR and PDR This paper focuses on the detection and classification of all the four stages of Diabetic Retinopathy by detecting and eradicating normal features like optic disc, macula and blood vessels and by analyzing abnormal features like exudates, microaneurysms, haemorrhages and new fragile blood vessels using Morphological processing and Grading techniques.

Index Terms: Exudates, Microaneurysms, Hemorrhages, Neovascularization.

I. INTRODUCTION

Diabetes can harm the eyes. It can damage the small blood vessels in the retina [1], the layer of tissue at the back of the inner eye. This condition is called diabetic retinopathy. Diabetic retinopathy is a painless disease. It changes light and images that enter the eye into nerve signals, which are sent to the brain. A healthy retina is necessary for good vision. In some people with Diabetic Retinopathy, blood vessels may swell and leak fluid [2]. In others, abnormal new blood vessels may grow on the surface of the retina. Typically, Diabetic Retinopathy does not cause noticeable symptoms until significant damage has occurred and complications have developed. It usually affects both eyes. Based on the presence of features like microaneurysms, haemorrhages, hard exudates, abnormal weak blood vessels, it can be classified as shown into Non Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR) [3] as shown in Fig.1. Non-Proliferate Diabetic Retinopathy is also known as Background Retinopathy. In this stage, the vision of the patient is rarely affected and most of the people remain unaware of this condition. Symptoms of this disorder include vision spots, floaters (floating areas of blurred vision), decreased or loss of vision, or loss of fine vision for detailed activities such as reading. Proliferate Diabetic Retinopathy may cause vision loss as it leads to the growth of new abnormal fragile blood vessels in the retina, known as, Neovascularization. Sudden vision loss may occur if one of the newly formed blood vessels ruptures. All people with Diabetes, including type 1 and type 2 are at risk. Diabetic Retinopathy is an eye complication of diabetes that affects 99 percent of people with type 2 diabetes and 60 percent of those with type 1. Diabetic retinopathy is one of the leading causes of blindness in industrialized countries. During the initial stages of diabetic retinopathy, no treatment is needed. Vision loss can usually be prevented in people with diabetes by regular eye examinations throughout their lifetime. In addition, the better the control in levels of blood sugar, blood pressure, and blood cholesterol, the better the chances of preventing complications that could lead to vision impairment. The signs and symptoms of diabetic retinopathy can appear in one eye only, but usually both eyes are affected, though not necessarily equally. As Diabetic Retinopathy is a disease that remains asymptomatic until a very advanced stage [4], the importance of regular eye examinations cannot be overemphasized, especially for people who are diabetic. An optometrist or ophthalmologist can detect DR by examining the back of the eye (ocular fundus examination), which will also indicate the type and severity of the disease.

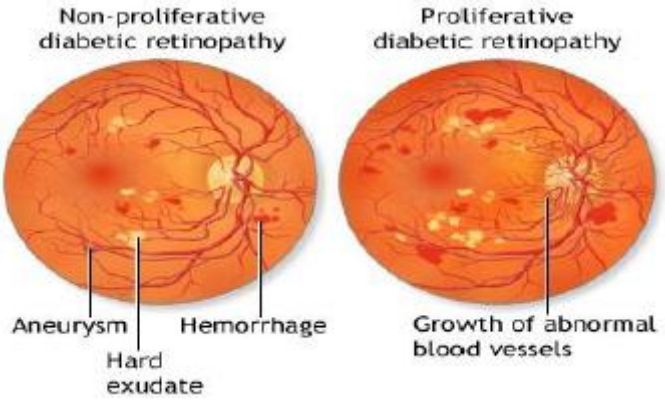


Fig.1. Types of Diabetic Retinopathy

II. LITERATURE REVIEW

Mahendra Gandhi et al. [1] focused on the automatic detection of Diabetic Retinopathy using Morphological Process and SVM classifier. In the first stage, the RGB input color image was converted into appropriate lab color space. In the second stage, Adaptive Median Filter was used to remove the salt and pepper noise and to reduce the distortions. In the third stage, Histogram equalization was used to enhance the contrast of the image. Then, normal features like the Optic Disc and Blood vessels were eliminated for the proper detection of exudates. For the elimination of Optic Disc, edge detection algorithm was applied on the preprocessed image.

Canny edge detector was used to find the edges and enhance them by preserving all local maxima in the gradient image. Then, a mask was created considering the Region of Interest (ROI). The obtained masked image was then subtracted from the edge detected image. For the elimination of Blood Vessels, Dilation process was followed by Erosion operation. After the elimination of both Optic Disc and Blood Vessels, closing operation was performed on eroded image to identify the exudates clearly. At last, the severity level of the disease was classified using Support Vector Machine.

Sujith Kumar et al. [13] discussed a method for the automatic detection of Diabetic Retinopathy in color fundus images. The proposed method was made up of three fundamental parts which includes Preprocessing, Feature extraction and Classification based on count to grade the severity of the disease. Preprocessing was done to attenuate the noise and to correct non-uniform illumination. Initially, the green channel of the image was extracted and then was converted to gray scale image. Normalization and contrast enhancement was performed to improve the image quality. The vessels and MAs were binarized by using multi level thresholding method. After the image was preprocessed, the microaneurysms were detected and segmented based on perimeter and circularity. Then, based on the count of microaneurysms, the eye images were classified as diseased or normal. To measure the accuracy of the algorithm, two important parameters such as specificity and sensitivity were assessed and found out to be 94.44% and 87.5% respectively.

Sathvika Mudigonda et al. [15] diagnosed Proliferate Diabetic Retinopathy through the detection of neovascularization. In the initial process, ROI around the optic disc was manually segmented. Then, the green channel of the original RGB image was extracted as it displayed maximum contrast compared to other RGB channels. Since the blood vessels appear lighter than the background in the inverted green channel, they are effectively used for further analysis. Then for the blood vessel enhancement, Gabor filters were used instead of Matched filters. As the blood vessels have directional pattern, 2-D Gabor wavelets were found to be a best option. The obtained image was thresholded to obtain a binary image and box counting method was used to estimate Fractal Dimension. The fractal dimension values obtained with abnormal images were higher than those of the normal images. The mean fractal dimension obtained for abnormal cases was 1.66 compared to the mean value of 1.52 for the normal cases. Thus, the results indicated the usefulness of the proposed method in indicating the second type of Diabetic Retinopathy known as Proliferate Diabetic Retinopathy.

Mr. Jayakumar Lachure et al. [16] proposed a system to detect Diabetic Retinopathy using Morphological Operations and Machine Learning. Initially for preprocessing stage, the input color image of size 2240*1488 pixels in .tiff format was converted into HSI model. The converted images were then filtered to remove noise using hybrid median filter. Then contrast of the image was enhanced using Contrast Limited Adaptive Histogram Equalization (CLAHE). After the preprocessing stage, edge detection algorithm was applied for the detection of optical disc and blood vessels. The mask image was created and then the mask image was subtracted from the edge detected image. Then, Morphological operations were used for the removal

of blood vessels and optic disc. Inorder to identify exudates, closing operation was done which included dilation followed by erosion operator. And for the detection of microaneurysms, opening operation was performed which included erosion followed by dilation. Depending upon the counts of microaneurysms present, Diabetic retinopathy severity or grade as normal, mild and severe was determined. Then features such as entropy, contrast ,energy and homogeneity were calculated and fed to both SVM and KNN classifier which concluded SVM as best classifier which directly concluded the disease grade as normal, moderate and severe. The achieved a specificity and sensitivity were 100% and 90% respectively.

III. METHODOLOGY

A. Preprocessing

The main aim of pre-processing is to enhance the visual appearance of images thereby improving the manipulation of datasets. The images were taken from DRIVE (Digital Retinal Images for Vessel Extraction) database and STARE (Structured Analysis of the Retina) database. The acquired images with the resolution of 567*437 pixels were resized to 256*256 pixels for this work. The input retinal image as shown in Fig. 2 is a RGB image.

Fig. 2: Sample input retinal image

The green channel of the image as shown in Fig. 3 extracted from the input RGB image as it has good contrast between the vessels and the background. It was then converted into grayscale image as displayed in Fig. 4 because this monochromatic shading helps to remove the uneven illumination present within the retinal image contains only shades of gray and no color [7]. Grayscale conversion was followed by 2-Dimensional median filtering of the image.

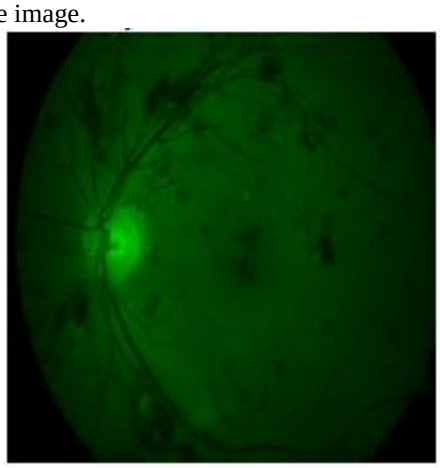


Fig. 3: Green component

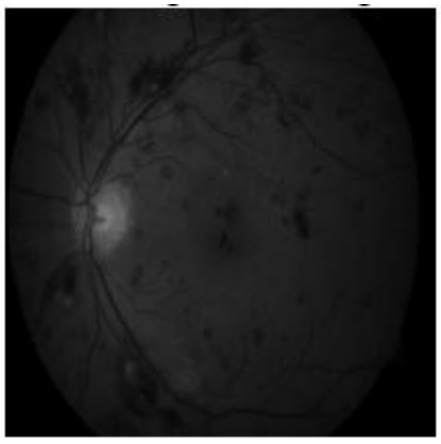


Fig. 4: Grayscale image

Median filtering preserves the image without getting blurred and it is done on an image matrix by finding the median of the neighborhood pixels by using a window that slides pixel by pixel [8]. Inorder to enhance the contrast of the median filtered image, contrast limited adaptive histogram equalization (CLAHE) was used [9]. The median filtered image and contrast enhanced image are shown in Fig. 5 and Fig.6.

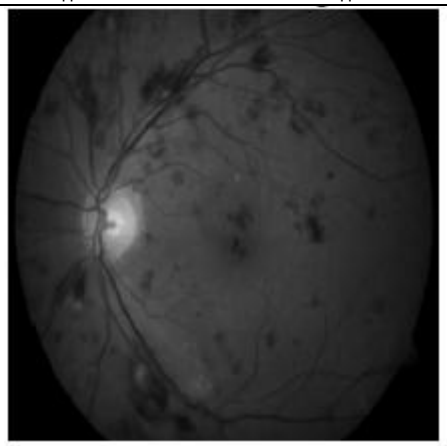


Fig. 5: Median filtered Image

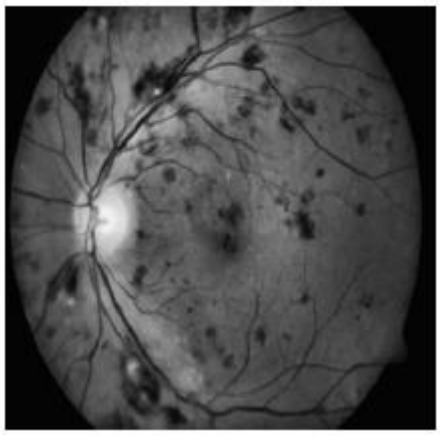


Fig. 6: Contrast Enhanced Image

B. Optic Disc Detection

The optic disc is a round area in the back of the eye where retinal nerve fibers collect to form the optic nerve. The optic disc is sometimes called the optic nerve head because it is the head of the optic nerve as it enters the eye from the brain. It is located slightly to the nasal side of the globe. The optic disc is known as the blind spot because it contains no photoreceptors. Thus, any light focused on the optic disc cannot be converted into sensory impulses nor sent to the brain for interpretation. Inorder to obtain the optic disc or optic nerve head from the contrast enhanced image, it was first dilated and then binarized. The dilation process was performed by laying the structuring element and sliding it across the image in a manner similar to convolution [6]. Dilation adds pixels to the boundaries of object in an image.

Notation: $A \oplus B$

Where,

$\oplus$= morphological dilation

A = image

B = structuring element

The dilated image is as shown in Fig. 7. Binarization on dilated image replaced all the pixels with luminance greater than level with the value 1 (specifies white) and replaced all other pixels with value 0 (specifies black). After performing dilation followed by binarization, the desired optic disc was detected as shown in Fig. 8.

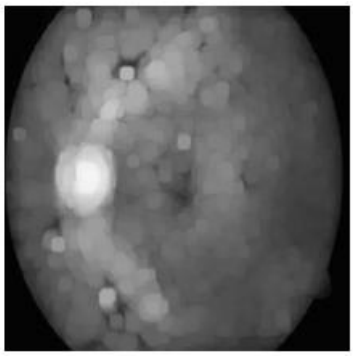


Fig. 7: Dilated Image

Fig. 8: Optic Disc

IV. EXUDATES DETECTION

Exudates are yellow spots seen in the retina, usually in the posterior pole near the macula. They are lipid break-down products that are left behind after localized edema resolves. The input RGB image was initially converted to gray scale of the image. Matlab built in function „fspecial" creates a two-dimensional filter „h" of the specified type „average" which returns an averaging filter h of size hsize. Finally, the image was thresholded to obtain an image as shown in Fig. 9. But the thresholded image consisted of optic disc which was not required or unnecessary as it can lead to false detection by the opthalmologists as exudates as both have same intensity value [16]. Therefore, the detected optic disc was subtracted from the thresholded image to obtain the required feature exudates. The detected exudates are as shown in Fig. 10.

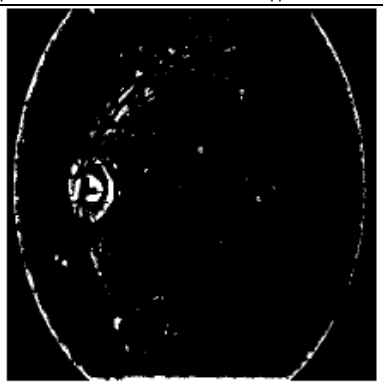


Fig. 9: Thresholded Image

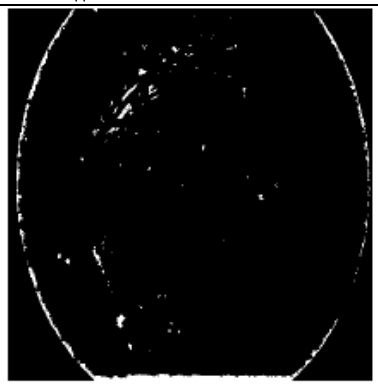


Fig. 10: Detected Exudate

V. BLOOD VESSELS DETECTION

Blood vessels are the tubular vessels used for conveying the blood. Presence of blood vessels can be mistaken as hemorrhages or microaneurysms by ophthalmologists so it was necessary to remove blood vessels from the retinal fundus image. For the detection of Blood vessels, two methods were used. The methods used are named as follows:

1. Kirisch Operator
2. Morphological Operations

Method 1. The Kirsch operator or Kirsch compass kernel is a non-linear edge detector that finds the maximum edge strength in a few predetermined directions. This operator is also known as direction mask. In this operator we take one mask and rotate it in all the eight compass directions to get edges of the eight directions. : North, North West, West, South West, South, South East, East, and North East. The edge magnitude of the Kirsch operator is calculated as the maximum magnitude across all directions. The kirisch edge detected image is as shown in Fig. 11. Inorder to remove red lesion present in the edge detected image, certain threshold value was used which left behind only extracted blood vessels as shown in Fig. 12. Using image subtraction, the extracted blood vessels was subtracted from the kirisch edge detected image to obtain Red lesion regions as shown in Fig. 13. Red lesion region detection was found to be useful to spot the presence of microaneurysms and hemorrhages but will be analyzed later during the detection of microaneurysms and hemorrhages. However, Kirisch operator was found to be effective and efficient method for the extraction of blood vessels from retinal image.

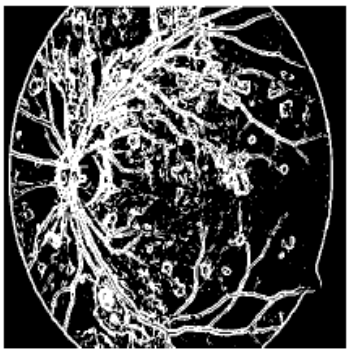


Fig 11: Kirisch edge detection

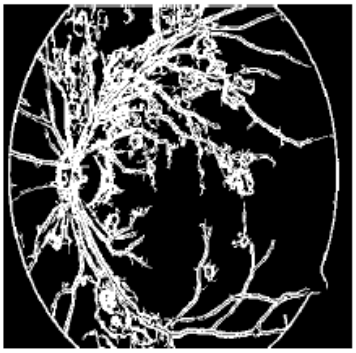


Fig. 12: Extracted Blood vessels

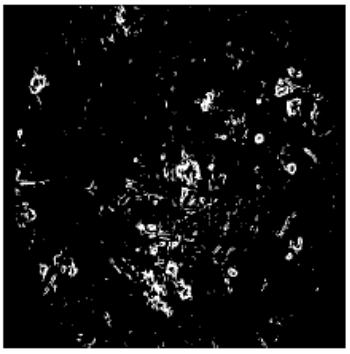


Fig. 13: Red lesion region 1

Method 2. Blood vessels act as a landmark for the detection of optic disc, fovea and exudates [10]. So, morphological operations were used to detect blood vessels. At first, morphological closing operation was performed on contrast enhanced image which includes dilation followed by an erosion operation with the same structuring element. Closing tends to eliminate small holes and fills gaps in the contour [11]. Therefore, the closing of A by B is the dilation of A by B, followed by the erosion of the result by B. Closing was then followed by filling operation as it would fill holes in the regions keeping the initial region sizes [11]. The closing and filling operation performed on contrast enhanced image is shown in Fig. 14 and Fig. 15 respectively.

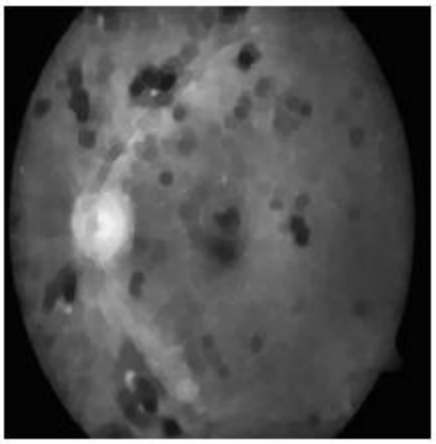


Fig. 14: Closing

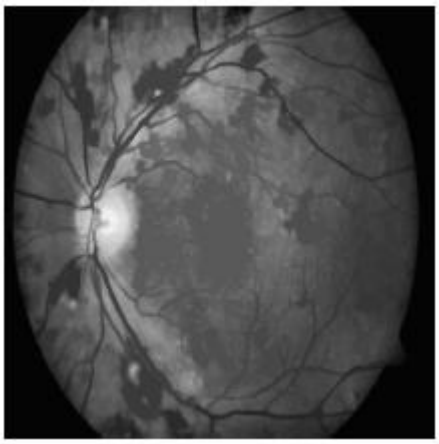


Fig. 15: Filling

Image differencing is an image processing technique used to determine changes between images. The difference between two images was calculated by finding the difference between each pixel in each image, and generating an image based on the result [11]. Here, image differencing was performed between the closing and the filling images. Thus, a difference image was obtained as shown in Fig. 16. Otsu‟s thresholding was done on the obtained difference image (between the closing and the filling images) [3]. It led to the reduction of a gray level image to a binary image as shown in Fig. 17.

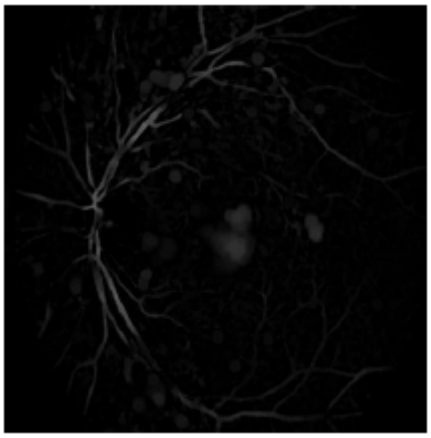
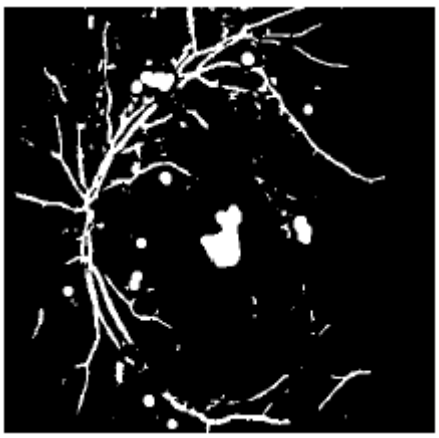


Fig. 16: Difference Image Fig.



17: Otsu Thresholded Image

VI. MACULA DETECTION

Macula is located temporal to the optic disc and has no blood vessels present in its center. In a retinal image, the contrast of macula is often quite low and sometimes it may be obscured by presence of exudates in its region. Once the optic disc was detected, the macula was localized by finding the darkest region in the image. For macula detection, opening operation was done on Otsu Thresholded image which generally smoothes the contour of an object and eliminates thin protrusions. Matlab built in function „Bwareaopen‟ was used to eliminate small regions from the Otsu thresholded image to obtain the resultant image shown in Fig. 18. The resultant image consisted of blood vessels and macula. From that resultant image, macula can be separated by considering the object having largest area. As macula has the largest area, it can be easily detected as shown in Fig. 19. Using image subtraction, extracted blood vessels in Fig. 18 was subtracted from the Otsu Thresholded image in Fig. 17 to obtain Red lesion region 2 as shown in Fig. 20 which was required for further detection of abnormal features.

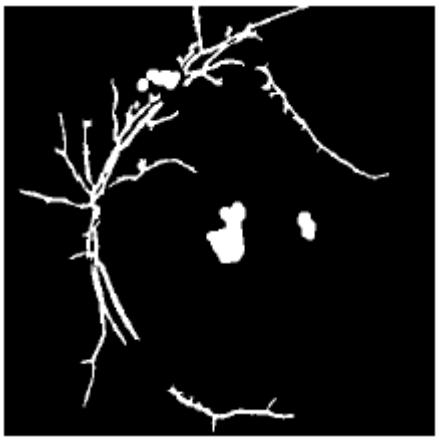


Fig. 18: Extracted blood vessels

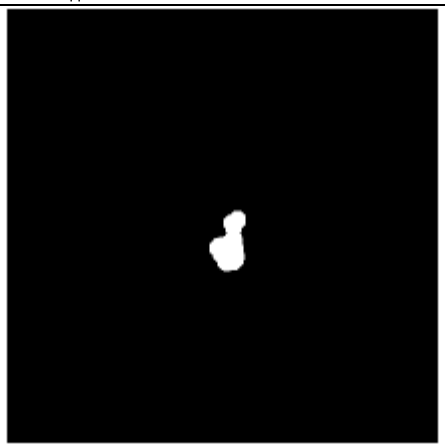


Fig. 19: Macula

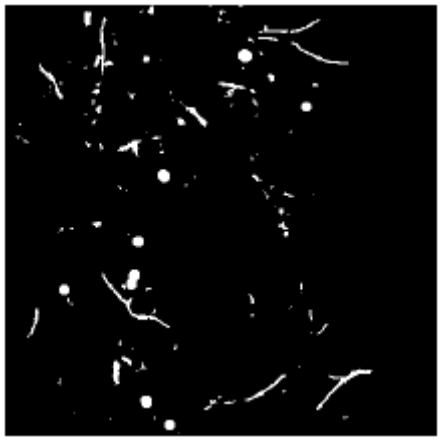


Fig. 20: Red lesion region 2

VII. MICROANEURYSMS AND HAEMORRHAGES DETECTION

A Microaneurysm (MA) is a tiny aneurysm, or swelling, in the side of a blood vessel and their sizes ranges from 10-100 microns [13]. These miniature aneurysms can rupture and leak blood. Some research indicates that these microaneurysms can predict the progress of diabetic retinopathy, a condition in which blood vessels of the retina are damaged by diabetes and can even lead to blindness [14]. Retinal haemorrhage is the abnormal bleeding of the blood vessels in the retina, the membrane in the back of the eye [12]. Red lesion region 1 shown in Fig. 13 and Red lesion region 2 shown in Fig. 20 are added together to obtain the resultant image shown in Fig. 21. The Red lesion added Image contains unwanted blood vessels, microaneurysms and haemorrhages. Inorder to remove the unwanted blood vessels, Opening operation was performed. The remaining microaneurysms and haemorrhages were distinguished based on the aspect ratio which was calculated using bounding box technique. The detected Haemorrhages and Microaneurysms are shown in following Fig. 22 and Fig. 23 respectively.

Fig. 21: Haemorrhages

Fig.22: Microaneurysms

VIII. NEOVASCULARIZATION DETECTION

The abnormal features associated with the weak and fragile blood vessel formation is known as "Neovascularization" and the Neovascularized image is as shown in Fig. 23. In cases of retinal diabetic retinopathy, the presence of neovascularization defines a particular stage of eye disease known as Proliferate diabetic retinopathy. The neovascularization may proliferate along surface of the retina and other structures inside the eye. Fractal dimension analysis using box counting method was done for the estimation of abnormal blood vessels [15]. For Box-counting method, the binary image of the bloodvessels which was extracted from the kirisch method was skeletonized and the blood vessels were indicated with white pixels and the rest pixels are assigned as black. The order of resolution, res = 1, 2, 4...2_n cover the image, n is defined as the smallest integer such that max(size(I)) $\leq 2_n$, where max(size(I)) is the maximum dimension of the image. The numbers of boxes containing at least one pixel of the blood vessels boundary are counted. The procedure is repeated for increasing box sizes until the largest box fits the whole image and returns 1 for the box number and in our case the largest box size is 256 pixels. The fractal dimension corresponding to the slope of the log(boxnum) versus log(res) plot is calculated by least-squares linear fitting as shown in Fig. 24.

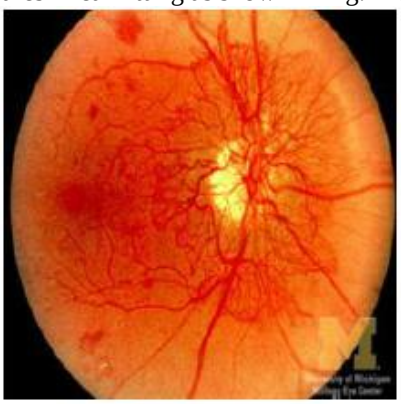


Fig. 23: Neovascularized image

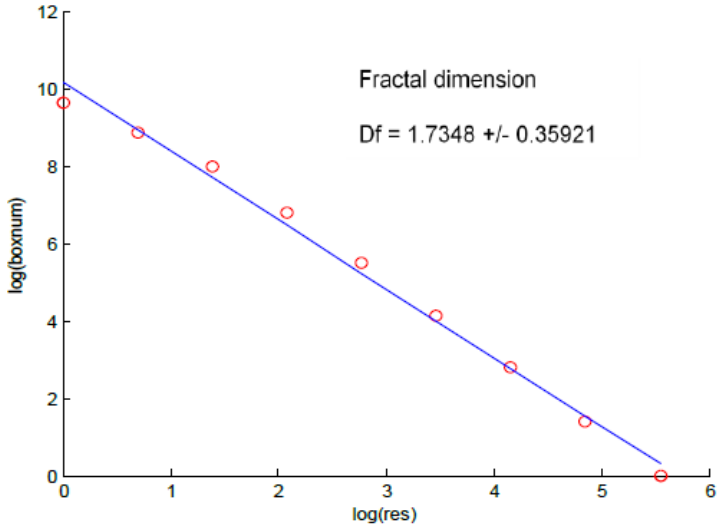


Fig. 24: Log (boxnum) versus log (res) plot

Similarly, the Fractal dimension for 10 images were estimated and tabulated as shown in Table 2. and their values were found to be higher(>1.61) than the other images as it has increased complexity in vascular patterns [15].

Non-Neovascularized image		**Neovascularized image**	
Image ID	**Fractal Dimension**	**Image ID**	**Fractal Dimension**
Image001	1.51	Neo1	1.73
Image002	1.50	Neo2	1.74
Image003	1.47	Neo3	1.73
Image004	1.44	Neo4	1.71
Image005	1.56	Neo5	1.69

Table1: Statistical Analysis of retinal images using Box Counting Method

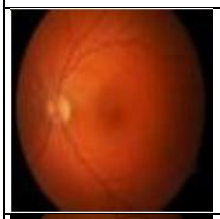
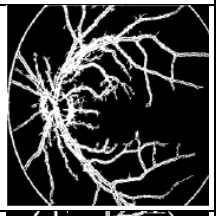
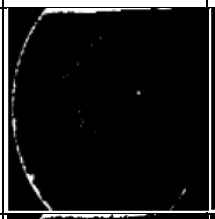
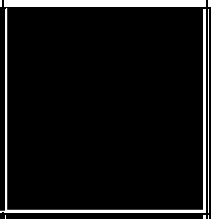
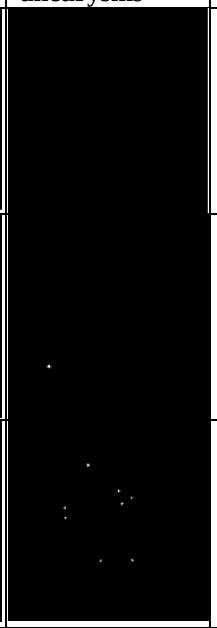
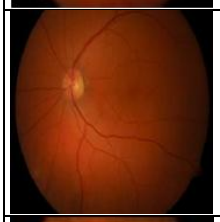
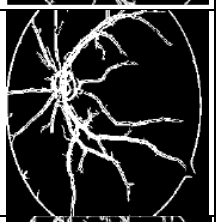
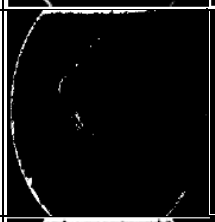
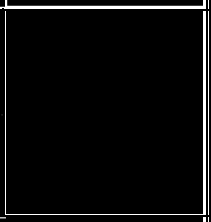
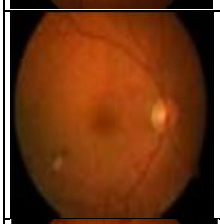
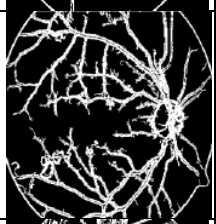
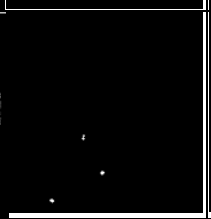
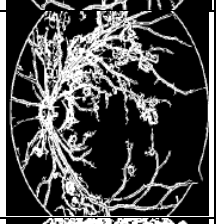
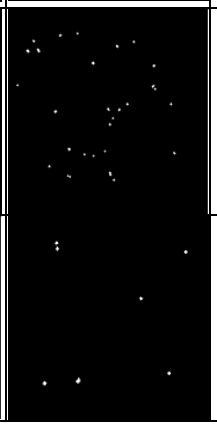
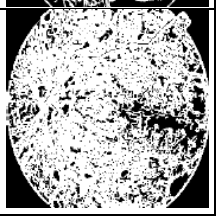
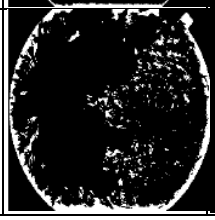
IX. FEATURE CLASSIFICATION

The number of Microaneurysms and Haemorrhages were counted to generate the severity grade for Diabetic Retinopathy [5].

Diabetic Retinopathy grades	Microaneurysms counts	Haemorrhages counts	Fractal Dimension
Normal (GRADE 0)	0	0	<1.61
Mild NPDR (GRADE 1)	<5	0	<1.61
Moderate NPDR (GRADE 2)	5<MA<15	>5	<1.61
SEVERE NPDR (GRADE 3)	MA>15	<5	<1.61
PDR (GRADE 4)	Any counts	Any counts	**>1.61**

Table 2: Diabetic Retinopathy Grading and Classification

X. RESULTS

Images	Bloodvessels	Exudates	Haemorrhages	Micro aneurysms	Classification
					**Normal [FD =1.52]**
					**Mild NPDR [FD =1.48]**
					**Moderate NPDR [FD =1.55]**
					**Severe NPDR [FD =1.59]**
					**PDR [FD =1.74]**

XI. CONCLUSION

Diabetic Retinopathy, a devastating threat of vision loss and irreversible blindness became a major medical problem in India- the diabetic capital of the world. This project work aims to stabilize changes in the eyes caused by diabetes and prevent further sight loss by accurately examining and grading Diabetic Retinopathy. Overall 200 images were acquired and analyzed from publically available databases like DRIVE (Digital Retinal Images for Vessel Extraction) and STARE (Structured Analysis of the Retina). The parameters like Sensitivity, Specificity and Accuracy were calculated and found out to be 97.1%, 96.15% and 97% respectively. The results obtained will surely help the opthalmologists to interpret the current progression of the disease accurately and do the treatment accordingly.

REFERENCES

[1]. Mahendran Gandhi and Dr. R. Dhanasekaran, "Diagnosis of Diabetic Retinopathy Using Morphological Process and SVM Classifier", International Conference on Communication and Signal Processing, 3-5 April 2013.

[2]. D U Ning and LI Yafen, "Automated Identification of Diabetic Retinopathy using Support Vector Machine", Proceedings of the 32nd Chinese Control Conference, 26-28 July 2013.

[3]. Nagaveena, Deepashree Devaraj and Dr. S. C. Prasanna Kumar, "Vessels Segmentation In Diabetic Retinopathy By Adaptive Median Thresholding", The International Journal of Science and Technoledge, (ISSN 2321-919X), July 2013.

[4]. A.S Jadhav and Pushpa B. Patil, "Classification of Diabetes Retina Images using Blood Vessel Area", International Journal on Cybernetics and Informatics(IJCI), Vol. 4, no.2 , April 2015.

[5]. Mr. M. Naveenraj, Mr.M.Naveenraj, K.Haripriya, N.Keerthana, K.Mohana Priya, R.Mounika, "Severity Grading For Diabetic Retinopathy", International Journal of Recent Trends in Engineering and Research, Volume 02, Issue 03; March - 2016 [ISSN: 2455-1457].

[6]. Morium Akter and Mohammad Shorif Uddin, "Morphology-Based Exudates Detection in Diabetic Retinopathy", Advances in Biomedical Science and Engineering, Vol 1, no 1, September 2014.

[7]. Nikhil Amrutkar, Yogesh Bhandkar , Sharad Chitalkar and S. L Tade, "Retinal Blood Vessel Segmentation Algorithm for Diabetic Retinopathy and Abnormality Detection using Image Subtraction", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 4, April 2013.

[8]. J. Ramya, S. Soundarya, A. Nagoormeral and E. Revathi, "Detection of Exudates in Color Fundus Image", International Journal of Innovative Research in Science, Engineering and Technology, Vol.3, Issue 3, March 2014.

[9]. Mahendran.G, Dhanasekaran.R and Narmadha Devi.K.N, " Morphological Process based Segmentation for the Detection of Exudates from the Retinal Images of Diabetic Patients", 2014 IEEE International Conference on Advanced Communication Control and Computing Technologies(ICACCCT), 8-10 May 2014.

[10]. Kanika Verma, Prakash Deep and A. G Ramakrishnan, "Detection and Classification of Diabetic Retinopathy using Retinal Images", India Conference (INDICON), ISBN: 978-1-4577-1110-7, 16-18 Dec 2011.

[11]. Oakar Phyo and AungSoe Khain, "Automatic Detection of Optic Disc and Blood Vessels from retinal images using image processing techniques", International Journal of Research in Engineering and Technology, Vol 03 Issue 03, March 2014.

[12]. Joshi Manisha Shivaram, Dr. Rekha Patil and Dr. Aravind H.S, "Automated Detection and Quantification of Haemorrhages in Diabetic Retinopathy Images Using Image Arithmetic and Mathematical Morphology Methods", International Journal of Recent Trends in Engineering, Vol 2, No. 6, November 2009.

[13]. Sujith Kumar S B and Vipula Singh, "Automatic Detection of Diabetic Retinopathy in Non-dilated RGB Retinal Fundus Images", International Journal of Computer Applications, Volume 47 No.19, June 2012.

[14]. M. Sridevi Maheshwari and Adarsh Punnolil, "A Novel Approach for Retinal Lesion Detection Diabetic Retinopathy Images", Volume 3, Issue 3, March 2014.

[15]. Sathvika Mudigonda, Faraz Oloumi, Kalyana M. Katta and Rangaraj M. Rangayyan, " Fractal Analysis of Neovascularization due to Diabetic Retinopathy in Retinal Fundus Image", The 5th International Conference on E-health and Bioengineering, November 19-21,2015.

[16]. Jayakumar Lachure, A.V. Deorankar, Sagar Lachure, Swati Gupta, Romit Jadhav, " Diabetic Retinopathy using Morphological Operations and Machine Learning". IEEE International Advance Computing Conference (IACC),13 July 2015.

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