Automatic Detection of Microaneurysms and Haemorrhages in Fundus Images: A Survey

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***Abstract*— Diabetes has spread all around the world in number of humans. Diabetes also causes related diseases with it, among them 80% of people may suffer from Diabetic Retinopathy (DR). Diabetic Retinopathy is a rapid loss of vision and which may even cause blindness if not detected in early stages. The first stage of DR is non-proliferative diabetic retinopathy (NPDR) which has got no symptoms, and the only way to detect is by retinal Fundus photography which are often noisy, in which Microaneurysms (microscopic blood-filled bulges in the artery walls) can be seen. It is identified as a small reddish/black dot in human retinal image. The number of Microaneurysms determines the severity of DR. The Fundus images are preprocessed in order to remove noise and various image processing techniques are applied for the detection of retinal changes in DR images. Also review of various algorithms used for detection of various stages of DR is described. Image preprocessing provides guidelines for image enhancement and Microaneurysms detection phases. Results will be shown based on the comparison of different image processing techniques.**

Keywords—*Diabetic Retinopathy, Fundus Imagess, Microanuerysms, Haemorrhages, Sensitivity, specificity*

I. INTRODUCTION

Diabetic Retinopathy (DR) is a disease found is long term diabetic Patient. If DA is not detected and treated on time, it may cause permanent loss of vision. Moreover it is more common in working people of young age. The initial stage of Diabetic Retinopathy is leakage from blood from blood vessels onto the surface of retina. This leakage of blood forms a small red spots called Microaneurysms (MA) and large red spots as Haemorrhages (HM). These red spots are called as Red Lesions [1] as shown in Fig-1.Thus it is important to detect this MA and HM at early stage as soon as possible. These MA spots are too small to be visible with naked eye, thus there is a need of automatic detection system to detect this Red Lesions in Medical Retinal Images. Also the ratio of number of DA affected patients to the number of eye specialist is very high. Thus having an automatic detection system will also save time and can prove to be cost saving for public health system [2]. It is observed that the retinal fundus images are mostly noisy and low in contrast. Thus these images are first pre-processed to remove noise, Shade Correction, Contrast Enhancement [3]. After pre-processing Candidate Region Extraction step is done which finds the regions consisting of red lesions. Later in large Object Elimination Step, Large Objects are removed which are identified as false positives in Candidate Region. RThese Large Objects are Blood Vessels, Optic Disc, Exudates, Fovea. In fourth step Features are extracted viz. Microaneurysms and Haemorrhages. In the final step classification of images are done based on DR Affected Images and Non-Affected DR Images.

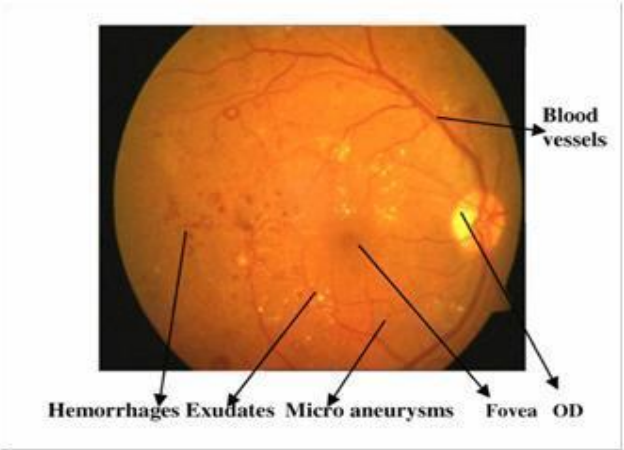

Fig. 1 Retinal lesions associated with diabetic retinopathy [3]

The paper is divided into sections. In section II relative work is shown in the form of literature review. In section III Step-wise general procedure for detection of red lesions viz. Microaneurysms and Haemorrhages in digital fundus images are shown. Section IV shows the use of various datasets for carrying out the work. Section V consists of Performance Analysis of various methods for detection of red lesions and section VI shows conclusion.

II. LITERATURE REVIEW

Vijay Mane et al. [1] has proposed a 5 step approach for detection of red lesions viz. Microaneurysms and haemorrhages from the fundus images. Blood vessels are responsible for leakage of blood on the surface of retina which appears as small red spots called microaneurysms and large red spots called haemorrhages. Thus it is required to remove blood vessels to simplify the eye operation. But before extraction of blood vessels it is required to pre-process the fundus image by applying Histogram Equalization Technique,

thus pre-processing of image for contrast enhancement and noise removal is first step of proposed approach and blood vessel removal is second step which uses Matched Filtering, Gaussian Kernel of matched filter depends on Sigma which lies between 1.5 and 3. Thus it uses two values for sigma for applying matched filtering. In the third step Candidate Lesion Detection is done by applying some mathematical and morphological operations performed on local entropy threshold and length filtered images. In the fourth step 11 features is formed which is combined of both geometrical and intensity features for each lesion detected. Fifth step uses SVM classifier for classification of images into red lesions and non red lesions. **The proposed approach gives sensitivity as 96.42% and specificity as 100% and accuracy as 96.62%.**

Niladri Shekhar Dutta et al. [2] has implemented the proposed approach in two phases. In the first phase an image enhancement technique has been applied by the author and after that detection of Microaneurysms is done so that the images are classified as DA affected or DA normal. For Image Enhancement CLAHE algorithm is applied at pre-processing step where the image is divided into tiles and first CLAHE algorithm is applied followed by median filtering. CLAHE algorithm is an extention of Histogram Equalization. Median Filtering helps to remove the noise from retinal images and improve its quality. In second phase of Microaneurysms Detection green channels are used to detect the MAs from the original RBG colour image. First it removes large objects like exudates, bright lesions etc. making use of morphological methods. It also detects Blood Vessel and removes it by applying morphological operation with image segmentation of threshold value. Then it detects optic disc and removes it by creating mask to enclose optic disc. Thus microaneurysms are obtained after removal of other existing elements. **The average sensitivity and specificity of this system is revealed as 82.64% and 99.98%.**

Lama Seoud et al. [3] has proposed 4 steps Novel Approach for detection of both microaneurysms and haemorrhages from fundus images for detection and diagnosis of Diabetic Retinopathy. First step is of pre-processing to deal with low contrast, noise and shade corrections. It uses a 401*401 mean filter for shade correction. Stretching and clipping is applied for contrast enhancement. Finally 7 by 7 median filter is used to remove noise. Second step is of Candidate Extraction where all regional minima with sufficient contrast are extracted and considered as candidates. Third step is of Feature Extraction where image flooding scheme is applied and new set of dynamic shape features is computed. Fourth and last step is of classification where the lesions and non-lesions images are classified by random forest classification technique.

Istvan Lazar et al. [4] have proposed a Novel Approach for automatic detection of microaneurysms in fundus images. Microaneurysms detection is the preliminary way to classify an image as DA affected image. Thus here author has explained two steps for detection of Microaneurysms. First the retinal fundus image is pre-processed without using complicated pre-processing steps. The image is resized and the original ratio quality of image is maintained by using bicubic interpolation. Secondly MA candidates are identified and eliminated.

Hatanaka et al. [5] has proposed an approach based on double-ring filter and feature analysis for automatic detection of microaneurysms in retinal fundus images. First image pre-processing is done in order to enhance contrast and remove noise from images. After that, Microaneurysm is detected, which is an overall 4 steps process. First microaneurysms are detected using a double-ring filters they appear darker than the surrounding region of the image. Secondly blood were that appear as false positives are identifies and removed using a combined method of double-ring filter and black-top-hat-transform. In the third step the shapes of the MA lesions were examined based on their features. In the last step the MA lesions are classified as microaneurysms or false positives by rule-based method and ANN. **This method gives accuracy of only 68%.**

Nadeem Ashraf et al. [6] has proposed the approach to detect both microaneurysms and haemorrhages together by implementing Texture Feature Analysis. It consists of three steps, in this first step pre-processing of fundus image is done without any complicated steps. It just carries out conversion of RGB to green channel of all collected ROI. ROI is Region of Interest where there is a possibility of occurrence of Microaneurysms and haemorrhages. In second step they apply LBP (Local Binary Pattern) on ROI for feature extraction. In the last step SVM is used in order to classify images as healthy or unhealthy. **This proposed methods brings 87.48% sensitivity, 85.99% specificity and 86.15% accuracy.**

Meera Malvekar et al. [7**]** here detects the diabetic retinopathy affected images and also detects the severity of the affected images. Feature Extraction Technique is used here to detect DA. The features extracted are Microaneurysms, Blood Vessels, Eexudates, Optic Disc. It takes retinal image as an input and pre-process the image to enhance contrast, remove noise and then apply different image processing techniques for feature extraction. In Image pre-processing Median Filtering is applied to remove noise and Adaptive Histogram Equalization is applied for contrast enhancement. In second step features are extracted using morphological operations like opening, closing, erode and dilate. In the last step the severity of the disease is calculated as mild, moderate and severe stage based on the ROI calculated and features extracted.

Rukhmini Roy et al. [8] have proposed an Novel Approach to improve the detection of MA candidates. It a two stage technique. In the first stage both image pre-processing and fractal analysis is done. Pre-processing is done making use od CLAHE algorithm, it divides the region into equal sizes and then histogram equalization is applied at every tile. It processes only green channel. Blood Vessels are segmented using thresholding technique considering local entropy. Fractal Analysis is performed on retinal vascular tree to differentiate healthy and unhealthy retinal image. Second stage aims at detection of a typical shape of MAs as the unhealthy retinal images goes through canny edge detection

and morphological reconstruction. **This approach gives sensitivity as 89.5% and specificity as 82.1%.**

Istvan Lazar et al. [9] have presented the method for microaneurysms detection by applying local rotating cross-section profile analysis on pre-processed image. The retinal fundus image is first pre-processed by applying convolution with a Gaussian mask with the value of sigma to be 1. Here the number of pixel are reduced by considering only the local maxima, thus less number of pixels are processed. Next features are extracted and finally Baye's Classification is used to classify MA affected images and MA non-affected images.

Eman Shahin et al. [10] has proposed an approach to detect microaneurysms, exudates, haemorrhages from blurred fundus images. It extracts blood vessels by first applying image pre-processing step by processing green channel of the RBG colour, then histogram equalization is used for contrast enhancement, and then morphological operation like opening is applied to smooth the background. In order to detect exudates, first green channel is extracted and then morphological closing operation is performed. Likewise microaneurysms are also extracted. At the end different deblurring techniques like Wiener-filter deblurring method and Regularized-filter deblurring methods are applied to remove the blur from fundus images. Finally the images are classified as affected or non-affected by using ANN. **This proposed approach gives 88.8% sensitivity and 100% specificity.**

The comparison of various work is shown is Table I.

TABLE I Literature survey [1-10]

Sr. No.	Paper Title	Year /Publication	Pros	Cons
1	Detection of Red Lesions in Diabetic Retinopathy Affected Fundus Images	2015 /IEEE	It performs well in detecting red lesions in comparison to other existing methods	Post Processing is required to be done.
2	Effective Approach: Image Quality Enhancement for Microaneurysms Detection of Non-Dilated Retinal Fundus Image	2013 /Elsevier	**1.**Reduces the burden of eye specialist as only diabetic eye will be send for further diagnosis. Thus reduces cost of public health systems. **2.** The proposed algorithm enhances the image quality while preserving sharpness and minute details of the image. **3.** It may be implemented on any Image processing Techniques for any high or low resolution images	CLAHE algorithm increases background in-homogeneities and thus some post processing is required to be done.
3	Automatic Detection of Microaneurysms and Haemorrhages in Fundus Images using Dynamic Shape Features	2014 /IEEE	It detects not only Microaneurysms but also Haemorrhages.	The extracted features are dependent on the edges found by region growing.
4	A Novel Approach for the Automatic Detection of Microaneurysms in Retinal Fundus Images	2010/ IEEE	It does not require complicated pre-processing step and the algorithm is fast even on common desktop computers.	It is more time demanding.
5	Automated Microaneurysms Detection Method based on Double-Ring Filter and Feature Analysis in Retinal Fundus Images	2012 /IEEE	It is simple to implement.	Gives very less accuracy that means it identifies only 68% of true positives at 15 false positives per image.
6	Texture Feature Analysis of Digital Fundus Images for Early Detection of Diabetic Retinopathy	2014 /IEEE	Texture Analysis helps to reduce the number of false positives. No complicated pre-processing, thus avoids loss of any valuable information from the images. LBP is simple, easy to use and takes O(n) execution time	LBP is highly sensitive to noise.
7	Detection of	2015	This approach	The overall

	Diabetic Retinopathy with Feature Extraction using Image Processing	/ (IJETAE)	not only detects the disease but also detects the severity of the disease.	output depends on accurate extraction of every features
8	Detection of Retinal Microaneurysms using Fractal Analysis and Feature Extraction Technique	2013 /IEEE	This algorithm gives high sensitivity means it identifies even low intensity microaneurysms.	CLAHE algorithm increases background in-homogeneities and thus some post processing is required to be done.
9	Retinal Microaneurysms Detection Through Local Rotating Cross-Section Profile Analysis	2012 /IEEE	The processing time per image is 2 s, without parallelization while with other methods it is approximately 15 s.	The performance can further be improved by adding detection of other features.
10	Automatic Detection of Diabetic Retinopathy in Blurred Digital Fundus Images	2012 /IEEE	Regularized filter gives the best results.	The overall output depends on accurate extraction of blood vessels, exudates and microaneurysms

III. Steps for MA and Haemorrhages Detection

Microaneurysms are small red spots in digital fundus images and Haemorrhages are large red spots in digital fundus images. The detection of these red lesions is the only way to detect DR affected images in its initial stage. So the general steps for detection of red lesions viz. Microaneurysms and Haemorrhages is explained below. The flow in shown in diagrammatic form in fig-2.

A. Pre-processing

Fundus images are often noisy and low in contrast so there is need to remove noise and enhance the image quality so that the red lesions can be detected accurately. In pre-processing step various techniques can be used for image enhancement like Histogram Equalization (HE) Technique, Adaptive Histogram Equalization (AHE), Contrast Limited Adaptive Histogram Equalization (CLAHE), Mean Filter, Median Filter, Intensity Conversion.

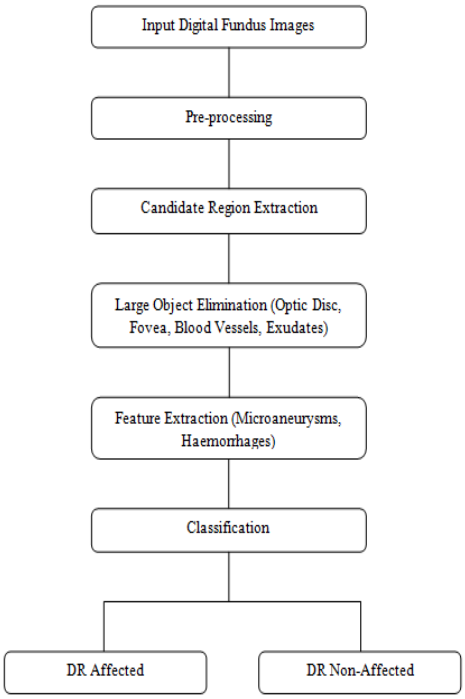

Fig.2 Steps for Red Lesions Detection

B. Candidate Region Extraction

In this step, candidate region mean the suspicious regions for discovery of Microaneurysms and Haemorrhages. Here the Region of Interest is extracted. ROI should consist of Microaneurysms and Haemorrhages. If we are able to detect the region where there are red lesions then red lesions can also be easily detected. Mostly Morphological approach is used to extract Candidate Region.

C. Large Object Elimination

After extracted Region of Interest if that region consist of large objects that is the objects other than red lesions then those objects should be eliminated. After elimination of Large Objects, the Candidate region will consist of only red lesions and thus would be easy to detect Microaneurysms and Haemorrhages. Matched filtering for blood vessel removal, canny edge detection method, mathematical morphological methods, Kirsch's non-linear edge detector, Thresholding Techniques are mostly used for large object elimination.

D. Feature Extraction

Feature Extraction is Extraction of Microaneurysms and Haemorrhages from candidate region after removal of large objects. Different methods use different number and different types of features. These features may include area, aspect ratio, perimeter, eccentricity, mean intensity, standard deviation, major axis, minor axis, compactness, diameter, roundness etc [3]. Mostly methods like Morphological Flooding, Watershed Algorithm, Local Binary Pattern,

Morphological Operations like opening, closing, erode and dilate are used for Feature Extraction.

E. Classification

This is the last step. In this step after the red lesions are detected , the images are classified to be affected or non-affected. All fundus images after gone through the previous four steps will be classified as the images which consist of DR and images that are not infected. Presence of Microaneurysms and Haemorrhages means DR affected eye and absence of Microaneurysms and Haemorrhages means non-affected DR eye. Mostly SVM classifier is used to carry out the classification. Sometimes Random Forest Classifier is also used. Even the number and Size of Microaneurysmsm are used to identify the stage of Diabetic Retinopathy [7].

IV. Dataset

A. DRIVE Dataset

The DRIVE database has been established to enable comparative studies on segmentation of blood vessels in retinal images. The research community is invited to test their algorithms on this database and share the results with other researchers through the website [11]. So far, a total of eight vessel segmentation methods have been tested on the DRIVE database. Table-1 shows the results of various segmentation methods on the DRIVE Dataset.

TABLE II Segmentation Methods on DRIVE Dataset [11]

Method	Accuracy	Kappa	Az	Implementation
Human observer	0.9473 (0.0048)	0.7589	n/a	-
Staal [12]	0.9442 (0.0065)	0.7345	0.9520	J. Staal
Niemeijer [13]	0.9416 (0.0065)	0.7145	0.9294	M. Niemeijer
Zana [14]	0.9377 (0.0077)	0.6971	0.8984	M. Niemeijer
Jiang [15]	0.9212 (0.0076)	0.6399	0.9114	J. Staal
Martínez-Pérez [16]	0.9181 (0.0240)	0.6389	n/a	M. Niemeijer
Chaudhuri [17]	0.8773 (0.0232)	0.3357	0.7878	M. Niemeijer
Al-Diri [18]	0.9258 (0.0126)	0.6716	n/a	B. Al-Diri
All background	0.8727 (0.0123)	0	n/a	-

B. STARE Dataset

STARE [19] was initiated by Michael Goldbaum at the university of California. It is publicly available and consists of 81 images, out of which 50 are DR infected and 31 are normal images. STARE Dataset is used for evaluating the automatic optic disc localization method.

C. DIARETDBI Dataset

DIARETDBI [20] was initiated by Tomi Kauppi for DR detection from digital fundus images. It is publicly available. It consists of 89 images, out of which 84 are infected and 5 are normal.

D. ROC Dataset

ROC was initiated by Michael D. Abramoff, Bram Van Ginneken and Meindert Neimeijer at university of Lowa. It consists of 50 training images in which Microaneurysms are identified [8].

V. Performance Analysis

TABLE III Comparison of Different Approach

Sr. No	Approach	Sensitivity	specificity	Accuracy
1.	CLAHE [1]	96.42%	100%	96.62 %
2.	CLAHE + Median Filtering [2]	82.64%	99.98 %	-
3	Texture Feature Analysis [6]	87.48%	85.99%	86.15%
4	CLAHE + Thresholding Technique [7]	89.5%	82.1%	-
5	Morphological Operation + Deblurring Technique [10]	88.8%	100%	-

Sensitivity is the percentage of actual MA and HM pixels that are detected and specificity is the percentage of the non MA and non HM pixels that are correctly classified as non MA and non HM pixels [2].

VI. Conclusion

In this paper, we have tried to present a broad survey on Automated Detection of Diabetic Retinopathy. We have explained different types of Red lesions and focused more on Microaneurysms and Haemorrhages as they are only red lesions present in the initial stage of DR. Along with that general steps for detection of Microaneurysms and Haemorrhages is explained. Almost all approaches mahe use of green channel for image enhancement. Along WITH Image enhancement it takes care of maintaining the sharpness and minute details of the image. Also Particular comparison of various techniques for detection of red lesions is shown in tabular format which as per my knowledge helps the

researcher to decide which method to select according to the particular application. Still the performance of different techniques differs from each dataset as each dataset has their own characteristics. We have also described four different dataset which are commonly used to carry out experiments. This paper also reveals the sensitivity and specificity for each approach. Thus comparison of different approaches can be done considering their sensitivity and specificity.

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