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A Survey on Various Techniques for Detection of Diabetic Retinopathy in Retinal Fundus Images

Archana K[1], Praveen Kumar K[2]

PG Scholar, Computer Science and Information Security, LBS College of Engineering, Kasargod, India [1]

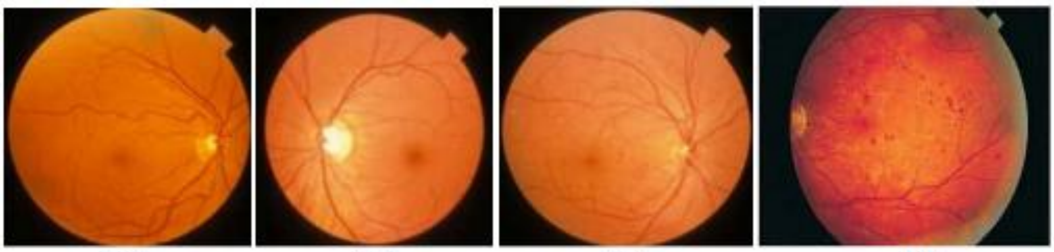
Professor, Computer Science and Engineering, LBS Institute of Technology for Women, Trivandrum, India [2]

Abstract: Diabetic Retinopathy refers to the retinal disease that occurs in Diabetic Mellitus Patients. It happens when the pancreas produces very little or no insulin. The blood vessels in retina will get blocked or grow without order in different directions. It can lead to vision loss over a period of time, if left untreated. Early detection of Diabetic Retinopathy (DR) is essential to treat DR effectively. The number of people suffering from Diabetics increased significantly over the last years. The traditional screening programs at an opticians Clinic is highly time consuming and the screening facilities available are less compared to the large population of Diabetic Patients in India(around 35 million).So the need for an effective computer based screening program arises, which can detect DR even in earlier stages. Various image processing techniques have been developed so far for the detection of DR. In this paper, a study of various DR detection methods and their comparisons are performed. The techniques can be broadly classified into optic disk segmentation, blood vessel detection, exudates detection and Microaneurysm (MA) detection methods. Different methods used are based on the feature to be extracted for DR detection. The image processing techniques are useful in identifying the location, size and severity grade of micro aneurysms and exudates in the retinal images. This survey gives an insight into the various prevailing methods for DR detection in retinal fundus images

Keywords: Diabetic Retinopathy, Microaneurysm, Image processing, retinal fundus images.

I. INTRODUCTION

Diabetic Retinopathy is a retinal disease associated with persons who had diabetes for a longer time. The disease hampers the normal vision ability if it is not treated in time. The earliest symptom of DR is the presence of Microaneurysm (MA) which is swelling of the capillaries caused by a weakening of the vessel wall. The blood can leak into the retina through the MAs and can hamper normal vision. The DR is a very silent disease in the initial stages. The people mostly notice it only when some vision problem occurs. The DR is curable in initial stages whereas in later stages some vision loss will occur and the cost of treatment is also higher. There are 2 types of DR namely proliferative DR and non-proliferative DR.



(a) (b) (c) (d)

Fig1: a) healthy DR b) Mild DR c) Moderate DR d) Severe DR

The DR is common in the working age population (25-60 years) now a days and the early detection and treatment of DR is the only way to prevent the vision loss associated with it. There are different methods through which DR can be detected on a Diabetic patient. The methods can be broadly classified as Optic Disk (OD) segmentation, Blood vessel detection and segmentation, Micro aneurysm detection and exudates detection. Identifying the presence of MAs and Exudates are the most effective ways to detect DR. Exudates are the deposition of lipids in the retinal images.

The Blood vessel segmentation methods are used to identify the vessel vasculature and removing it to avoid MAs and lesions appearing on it.

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II. RELATED WORK

Automated screening techniques for diabetic retinopathy detection have great significance in saving cost, time and labour. Image processing techniques for diabetic retinopathy detection can help in extracting the location, size and severity grade of microaneurysm and exudates in the retinal images. The screening of diabetic patients for DR can reduce the risk of blindness by 50%. Image processing techniques can be used to pre-process the images to have desired quality and reduce noises. Also the Optic Disks and blood vessels can be extracted from the retinal images.

Various techniques have been developed so far for the detection of diabetic retinopathy. In this section we discuss about the approaches used for the assessment of diabetic retinopathy. Most of the techniques are based on the image processing techniques and uses retinal images from online databases like STARE, DRIVE and ROC. The detection methods are mainly classified as optic disk segmentation, blood vessel detection, exudates detection, micro aneurysm detection and classification.

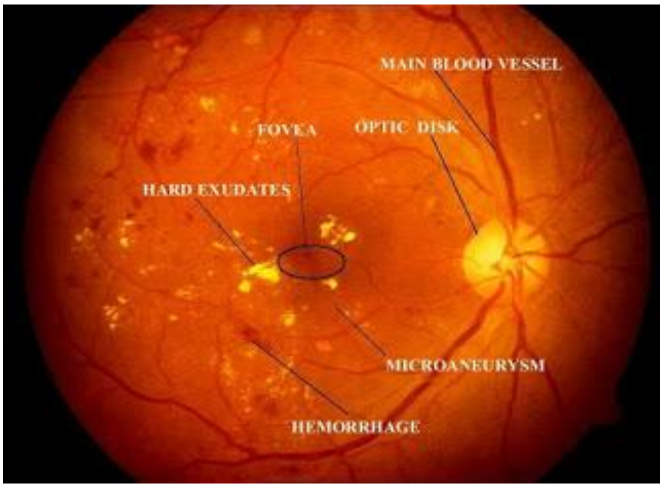

Fig 2: Image showing MAs, Exudates, Haemorrhage and OD

In Optic Disk segmentation, the OD is identified and removed from the retinal images as Microaneurysm will never be on an OD .By removing OD, false positives from the OD part can be avoided. During vessel segmentation, the blood vessel structure is identified and the newly grown vessels as part of DR and blood leaking points can be identified. This will help in diagnosis of DR. Exudates are yellowish lipid deposits found in the posterior pole of the retina. The exudates is made up of serum lipoproteins, thought to leak from the permeable blood vessels, especially across the walls of leaking microaneurysm .Exudates are found as clusters or individuals. The presence of exudates indicates presence of DR and Diabetic macular edema. The Microaneurysm is the earliest known clinical symptom of DR. These are tiny spots/lesions in retinal images. These lesions can leak fluids and blood into the retina, leading to vision threatening exudates, macular edema and haemorrhages. The detection of microaneurysm in earlier stages can help in detection and treatment of DR without vision loss.

2.1 OPTIC DISK DETECTION

The Optic Disk (OD) appears toward the left-hand or right-hand side of a fundus image as an approximately circular area. Its size is nearly 1 by sixth of the diameter of the image. The average dimensions are 1.76mm horizontally by 1.922mm vertically [23].Optic disk is the brightest part in most of the images.

Xiaolu Zhu et.al [1] in (2008) proposed a method for optic disk segmentation using Hough Transform. In this paper, the image was pre-processed using Median Filters and the edge detection is performed using Sobel and Canny operators. The Hough transform to detect lines were extended here to identify circles such that the optic disks can be identified. The points lying on the circles are represented as Hough space and the Hough accumulator is updated with the centre and radius of the image. Hough accumulator is a 3D matrix that stores the edge values of the circles. The potential circles are identified and ranked .
The first 30 of them is compared with the reference intensity, considering the radius of the identified circles. Since OD has the highest intensity, the potential circle with highest intensity and approximate radius is selected. The method shows to yield good results for DRIVE database.

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N B Prakash et.al [16] proposed an entropy filtering method for optic detection. The image is pre-processed and the enhanced image is further processed for OD Detection. The entropy filtering gives an output value which is the entropy value of 9 by 9 neighbourhood of candidate pixel. The centre of OD is calculated by Euclidian distance method. The blood vessel segmentation is performed by range filtering here.

2.2 BLOOD VESSEL SEGMENTATION

Subashish Chowdhary et.al [17] in 1989 proposed a method to detect blood vessels using matched filters .The concept of matched filter detection is used here to detect piece wise linear components of the blood vessels.It is better than the edge detection methods available at that time. But takes longer time to run the algorithm since the convolution kernel of matched filters have a larger size.

Yilian Zhao et.al in 2015[3] uses infinite perimeter regularizer provided by using $\propto^2$ lebesgue measure of the gamma neighbourhood boundaries. Infinite perimeter Active contour Models have been used here to analyse retinal blood vessels. This method is best suited to detect vasculature structures like blood vessels more than the conventional shortest length constraints. This model uses Eigen value-based (FR), wavelet-based (IUWT), and local phase-based (LP) filter to detect vessel maps. Along with infinite perimeter active contour method a novel extension is introduced to integrate hybrid region information into the segmentation model of vessels. This method is applied on both colour fundus and fluorescein angiography images. And according to authors this method can be used to address segmentation problems on other organ images obtained by CT, MRI and X-ray. This is an unsupervised method, so it requires very less training period .Extra classifier is not used here.

X.Merlin et.al [4] in 2011 proposed a new approach to classify segmented blood vessels as vessels or no vessels based on ELM Classification. This supervised method makes use of pre-processing of images and then extract features, i.e. pixel characterization by means of a feature vector. Two methods are used here to segment blood vessels, first based on the grey level feature where pixels are identified by grey level variation of vessels and their backgrounds, 7D vector values are calculated to analyse images. In the second method, moment in variation based feature is used .It is based on the fact that blood vessels are linear and originate only from fovea .In this method ,discrete logarithms are calculated instead of the moment invariations. This reduced the dynamic range and complexity of calculations. After identifying blood vessels ELM classifier used to classify and provided accuracy than existing systems. STARE and DRIVE databases are used for the testing purpose.

Alan D Fleming et.al [9] in 2006 used the Local contrast Normalization methods to identify Local contrast for the image and divide each pixel with this value to normalize the contrast of entire image. Region growing method is used to derive regions that don't contain any vessels. The images are segmented and vessels are removed from these regions by watershed transformation. The MAs are detected from these regions. Local vessel detection is used to identify and exclude dots on vessels. No optic disk detection or exudates detection done here.

2.3 MICROANEURYSMS DETECTION

In 2011, Yuji Hatanaka et.al [6] proposed a new method for automatic detection of microaneurysm using double pass filter. Here the retinal fundus images are converted to RGB colour profile and over the green channel the target pixel values are compared with the neighbouring pixel values. The ring consists of an inner circle and outer rings of specified diameters .Edges are removed and then MAs over the blood vessels (false positives) are removed by extracting blood vessels from images. Based on the features extracted, these MAs are classified using 3layered feed forward ANN classifier. Drawbacks include detection of too many false positives on the smaller capillaries. Accuracy depends on the entire removal of capillaries from retinal image.

A Radom transform based approach is used by L. Giancardo et.al in [7] 2011 to identify MAs in retinal images by the use of Radon transform. An image is pre-processed by pixel inversion and in green channel the Gaussian filters are used to normalize the image. The Radon based feature vectors are calculated for different windows of the image with MA, without MAs, with vessel crossing and vessel bifurcation etc. And feature vectors for different images are calculated and finally classified using SVM classifier. The advantage of this method is that the training is simple and does not require vessel or optic disk segmentation.

Keerthi Ram et.al [11] used clutter rejection method to reject false positives of MAs. Here 2 stages of rejection are used. MAs are detected using local morphological operations. In first stage the lesions from haemorrhage and blood vessels are rejected. In the second stage, lesions or dots from background noise, contrast variations in the image ,optic disc etc are eliminated .A similarity score has been computed for all remaining MAs to that of a true MA profile and based on the similarity score MAs are selected. In the rejection stages, anisotropic filters and Gaussian filters are used.

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A novel method has been proposed by Istavan et.al [12] where the image is pre-processed and their local intensity maximum is calculated to identify MAs. The intensity value will be high for peaks and vessel crossings. And 2 different thresholds are used to extract the true MAs from foregrounds and size is specified to avoid detecting large lesions from images. Usually MA s are in size <125 μ meters. A final scanning is performed where scan lines of equal distances will perfectly intersect MAs (since they don't have any directions vessel crossings will have directions) and non-circular objects can be excluded. The vessel crossings are detected as false positives.

They have also proposed another method [15] in which local rotating cross section profile is analysed to detect MAs. Large cross sections are created and a angular distance of 6 degree is suggested between them to cover the entire image. The local maximum regions are extracted from the image based on their intensity values and suppression of non maximum regions is performed. The slope, ramp height, peak width, peak height etc features of the local maxima are calculated and based on this feature set ,classification of MAs are performed. The images from DIARETDB and Moore's hospitals collection are used to test and train the system.

Balint Antal and Andras Hajdu [19] proposed an ensemble based method in 2012 .They proposed an effective MA detector based on the combination of existing pre-processing methods and candidate extractors. It provides an ensemble creation framework to select the best combination. An ensemble is a pair of pre-processing and candidate extractor. The ensemble is selected from a pool of pre processing steps and Candidate extractors. The best ensemble is created by selecting the best from both the groups. However to select the optimal solution for detecting MAs, all the combinations should be tried and select the solution with optimal value. Selecting the optimal ensemble is a very resource demanding step since all the combinations need to be tried. This method achieved the highest score in ROC online challenge as it was able to identify majority of MAs. It can be used for both DR grading and MA detection.

2.4 HARD EXUDATES DETECTION

DU Ning et.al [8] in 2013 classified hard exudates present in the retinas using an SVM classifier as PDR and NPDR and obtained a specificity of 95%. Here hard exudates are detected with the help of structuring elements, where the size and shape of structuring elements are selected based on the features that we need to extract i.e. hard exudates. Blood vessels removed by selecting structuring element less than blood vessels.dis advantage is that performance depends on the Structuring element and requires expertise to select SE which can be used on all retinal images.
Thomas Walter et.al in 2002 [10] proposed a new method to identify exudates in retinal images using water shed transformations .Morphological operators are used to pre-process the image and then optic disk is identified using water shed method. The image is converted to its greyscale image and then optic disk identified in Red scale. Two circles are marked as internal and external marks around optic disk to avoid over segmentation of image. Then hard exudates are detected from the image using an algorithm consisting in shade correction, contrast enhancement, sharpening, and a manually chosen threshold is applied to image. Colour normalization and local contrast enhancement are followed by fuzzy C-means clustering and neural networks in the second method. A third method based on morphological operators is applied to find the candidate regions and active contours are identified. Morphological reconstruction is used to reconstruct the image and a simple threshold is selected to differentiate between the original and reconstructed image. Performance is impacted if the colour enhancement and local contrast are not proper.

In [14] Vesna Zeljković et.al used a classification of hard exudates to detect DR. Pre-processing and image enhancement is done over the retinal images. Optic Disk removed using morphological operators and logarithm functions of different intensity are applied to different regions. Such that brighter exudates can be detected easily .It can be classified based on the number of pixels in the detected exudates. This limited performance when the exudates are tiny or the image intensity levels are different for different retinal images. Uneven illumination in the retinal images limits the performance of proposed method. This is a cost effective method to detect bright exudates.

Different methods for detecting diabetic retinopathy are discussed in this paper .The methods used vary based on the feature that we have to extract and classify. The pre-processing methods tend to improve the feature extraction process. Noise filtering, smoothening and image contrast enhancement are the most widely used pre-processing methods over retinal images.

III. CONCLUSION

Diabetic Retinopathy is a complication associated with Diabetes Mellitus and it can lead to blindness if not detected and treated in time. DR occurs in almost 80% of the Diabetic patients. But if detected early, the vision loss can be prevented .A Computer Aided System can help in massive screening and detection of DR in less time. Most of the

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methods available have used some image processing techniques and classification of the images. Classifiers like Naïve Bayes, Support vector machine (SVM), K-Nearest Neighbour (KNN), Artificial Neural Network (ANN) and Extreme Learning Machine (ELM) are used for the classification

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