

Automatic Screening of Fundus Images for Detection of Diabetic Retinopathy

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Received: 13-01-2014, **Revised:** 21-02-2014, **Accepted:** 15-04-2014, **Published online:** 29-05-2014

Abstract—The World Health Organization estimates that 135 million people have diabetes mellitus worldwide and that the number of people with diabetes will increase to 300 million by the year 2025. A great effort of the research community is geared towards the creation of an automatic screening system able to promptly detect diabetic retinopathy with the use of fundus cameras. The key for low cost widespread screening is a system usable by operators with little training. In this proposed project we aimed for automatic screening of fundus (retinal) images for detection of diabetic retinopathy using its spatial features and classifying the images using an artificial neural network. Automatic screening will help for the doctors to quickly identify the condition of the patient with more accurate way. Automatic screening system will detect and identify precisely the size of Exudates, microaneurysms, Neovascularisation from the fundus images. This information is fed into an artificial neural network based classifier to identify Diabetic Retinopathy level of the patients. Early detection can potentially reduce the risk of blindness.

Key Words—Diabetic Retinopathy, exudates, Microaneurysm.

1. INTRODUCTION

Diabetic Retinopathy (DR) is an eye disease that can lead to partial or even complete loss of visual capacity, if left undiagnosed at the initial stage. Retinal lesions associated with diabetes are used to evaluate different stages. Microaneurysms are among the earliest signs of diabetic retinopathy they arise due to high sugar levels in the blood. According to WHO (World Health Organisation) there will be 79 million people with diabetes by 2030, making the India Diabetic capital of the world [26]. Among the patients below the age of 30 years, when first diagnosed with diabetes, the prevalence of retinopathy is 17% during the first 5 years.

This increases to 97% after 15 years of diabetes. Amongst the patients above the age of 30 years, 20% have showed signs of retinopathy immediately after diagnosed and this increased to 78% after 15 years of diabetes. The ratio of ophthalmologists to the number of Diabetic patients is very low. Ophthalmologists in India are insufficient to support the growing Diabetic population. India has 1 Ophthalmologists per 1,00,000 patients and this ratio is

even smaller for rural settings. Today Diabetic Retinopathy is the 3rd cause of blindness in India.

Medical imaging allows scientists and physicians to understand potential life-saving information using less invasive techniques. This automated algorithm indicates places in the image that require extra attention from the physician because they could be abnormal. These technologies are called Computer Aided Diagnosis (CAD). This paper describes components of an automatic system that can aid in the detection of diabetic retinopathy. As the number of diabetes affected people is increasing worldwide, the need for automated detection methods of diabetic retinopathy will increase as well. To automatically detect diabetic retinopathy, a computer has to interpret and analyze digital images of the retina. The Fundus Image Analysis system described in this paper is developed to assist ophthalmologist's diagnosis by providing second opinion and also functions as an automatic tool for the mass screening of diabetic retinopathy. Color fundus images are used by ophthalmologists to study eye diseases like diabetic retinopathy, age related macular degeneration (AMD) and Retinopathy of pre-maturity (ROP). Extraction of the normal features like optic disk, fovea and blood vessels and abnormal features like exudates, cotton wool spots, microaneurysms (MA) and hemorrhages from colour fundus images are used in fundus image analysis system for comprehensive analysis and grading of diabetic retinopathy.

Microaneurysms and exudates are the primary symptoms indicating diabetic retinopathy, their detection is critical for a diabetic retinopathy screening system.

There have been an increase in the use of digital image processing techniques for the screening of DR after it was recommended as one of the method for **screening DR at the conference on DR held in Liverpool UK in 2005**. This increases more work have been done to improve some of the existing screening methods, while new methods have also been introduced in order to really increase the accuracy of this method. GiriBabuKande [1] proposed a method of polynomial contrast

enhancement and dark lesion detection based on Mathematical Morphology.

In this method Morphological top-hat transformation is used to segment candidate MAs from blood vessels. A.M. Mendonça et al. [2] used mean filter to the original image, obtaining an normalized image and scaling as preprocessing techniques. To discriminate microaneurysms from blood vessels “top-hat” transform and a gaussian shaped matched filter is used. AbhirBhalerao et al. [3] used median filter for contrast normalization and contrast enhancement as preprocessing techniques. Orientation matched filter was used to differentiate microaneurysms from blood vessels. Thresholding on the output of orientation matched filter is done to obtain a set of potential candidates (MAs). Eigen image analysis applied to the potential candidate regions and a second threshold applied on the eigen-space projection of the candidate regions eliminated certain noise artifacts. Iqbal, M.I et al. [6] used Color Space Conversion, Edge Zero Padding, Median Filtering and Adaptive Histogram Equalization as pre-processing techniques and they used segmentation to group the image into regions with same property or characteristics. Methods of image segmentation include simple thresholding, K-means Algorithm and Fuzzy C-means. AkaraSopharak et al. [8] used median filtering, contrast enhancement by Contrast Limited Adaptive Histogram Equalization and shade correction as pre-processing steps and he used Extended-minima transform for feature extraction. Priya R et al. [9] used pre-processing techniques like Gray scale Conversion, Adaptive Histogram Equalisation, Matched Filter Response and proposed a method for feature extraction based on Area of on pixels, Mean and Standard Deviation.

In this paper automatic screening of the fundus image for the detection of DR. Initially the paper has been broadly divided into various modules like Microaneurosism detection, Exudates Segmentation, Optic Disc localization, retinal vessel segmentation etc. The architecture gets the retinal angiogram image acquired from fundus camera and pre process the image for shade correction, histogram equalization, vessel suppression, background normalization and performs the segmentation Algorithm for extracting and validating Microaneurysms and exudates. Then the segmented results will be fed into ANN system which will analyze the features and classify the patients with level of diabetic retinopathy.

2. DIABETIC RETINOPATHY

Diabetic retinopathy is the prime cause of vision loss

amongst the working age population of the developing and the developed countries. Diabetic patients are 25 times more probable to become blind than non-diabetic patients. Diabetic retinopathy is a complication of diabetes to the retina and to the blood vessels.

Blood vessels are continuous patterns with little curvature, originated from optic disc and have a tree shape branching. The mean diameter of the vessels is about 100 μm , i.e 1/40 of retina diameter. Optic disk or optic nerve head is the bright yellowish disk, from which, blood vessels and optic nerve fibers emerge. Optic disk transmits electrical impulses from the retina to the brain. It measures 1.5 to 2 mm in diameter. Macula is the central area of the retina, temporal to the optic disk. It is responsible to have fine central vision and colour vision. The center of macula is called fovea as shown in fig 1. This region of the retina is the most sensitive region. The diameter of the macula is about 4 to 5 mm.

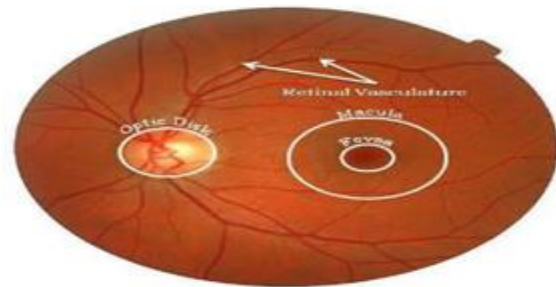


Fig 1: Anatomy of Eye

Diabetic retinopathy is caused by both the forms of diabetes i.e. diabetes mellitus and diabetes insipidus. It is a very asymptomatic disease in the early stages and it could lead to permanent vision loss if untreated for long time. The problem here is the patients may not know about it until it reaches advanced stages. Once it reaches advanced stages vision loss becomes inevitable. As diabetic retinopathy is the third major cause of blindness particularly in India, there is an immediate requirement to develop efficient diagnosis method. The main stages of diabetic retinopathy are non proliferative diabetic retinopathy (NPDR) and proliferative retinopathy (PDR).

NPDR is the early stage of Diabetic retinopathy. Nonproliferative diabetic retinopathy (NPDR) is a microvascular complication of diabetes mellitus that can lead to irreversible visual loss. In this case, at least one microaneurysm with or without the presence of retinal haemorrhages, hard exudates, cotton wool spots, or venous loops is present.

Microaneurysms are the first clinical abnormality to be noticed in the eye. They may appear in isolation or in clusters as tiny, dark red spots or looking like tiny hemorrhages within the light sensitive retina as shown in fig 3.

Their sizes ranges from 10-100 microns i.e. less than 1/12th the diameter of an average optics disc and are circular in shape, at this stage, the disease is not eye threatening.

In NPDR, depending on the presence and extent of the features such as hemorrhages, hard exudates, microaneurysms or cotton wools spots due to leakage of fluid and blood from the blood vessels, NPDR can be classified into i) mild, ii) moderate and iii) severe. In mild NPDR, microaneurysms are small areas of balloon-like swellings in the retina's tiny blood vessels as shown in fig 2(b). As the disease progresses, some blood vessels that nourish the retina are blocked and this stage is called Moderate NPDR as shown in fig 2(c). The next stage is Severe NPDR during which many more blood vessels are blocked as shown in the figure2.

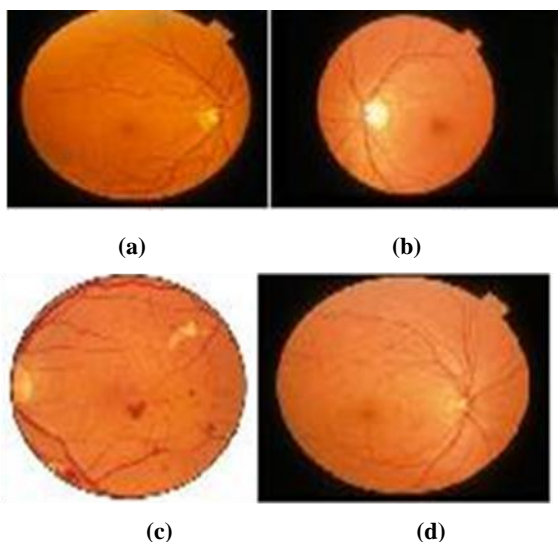


Fig 2: (a) Healthy image (b)Mild DR (c)Moderate DR (d)Severe DR

PDR is the advanced stage whereby signals are not sent by the retina to the brain for the lack of blood supply and this triggers the growth of new blood vessels. Hemorrhages occurs in the deeper layers of the retina and are often called, blot hemorrhages because of their irregular shape. As the disease progresses, microaneurysms will be ruptured. This results in retinal

hemorrhages either superficially or in deeper layers of the retina.

3. AUTOMATIC DETECTION OF DIABETIC RETINOPATHY

Automatic detection of Diabetic Retinopathy (ADDR) is a fully automated system for detection of Diabetic Retinopathy (DR). Fig 3 shows the block diagram of ADDR. Input to this system is a fundus image which is part of human eye that can be seen through the pupil. Fundus image is the interior surface of the eye, opposite the lens, and includes the retina, optic disc, macula, Blood vessels and fovea. As the quality of the image is not satisfactory because of noise, bad contrast, uneven illumination etc. pre-processing is used to get better results. The proposed method is made up of three fundamental parts, (1) pre-processing, which involves obtaining an gray image from green channel, background normalization, contrast enhancement and image binarization (2) feature extraction of the microaneurysms based on circularity, area and other features and (3) Classification based on count, thereby we can grade the severity.

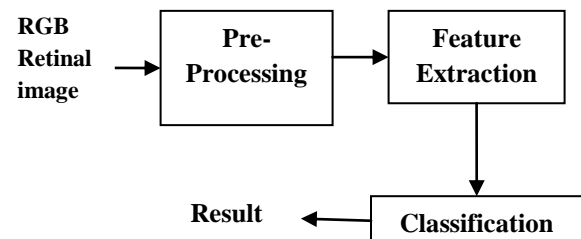


Fig 3: Basic system level block diagram

3.1 PRE-PROCESSING

The aim of pre-processing is to attenuate the noise, to improve the contrast and to correct the non-uniform illumination. In the RGB image the green channel exhibits the best contrast between the vessels and background while the red and blue ones tend to be more noise. Hence green channel is used for further processing.

The next step is conversion of green channel image into an gray scale image, as the retinal blood vessels appear darker in the gray image. All the features like

blood vessels, MAs etc are hidden in the background and are not clearly visible. Thus Normalization and contrast enhancement is performed to improve the image quality. Normalization is performed by subtracting an approximate background from the gray image. A 30x30 median filter is applied to the gray image and the resulted image is subtracted plane to get normalized image. Adaptive Histogram Equalization is applied for contrast enhancement. A dark region including vessels, MAs, exudates and noise are dominant after contrast enhancement. The gray threshold is selected to determine the vessels, Microaneurysms and exudate.

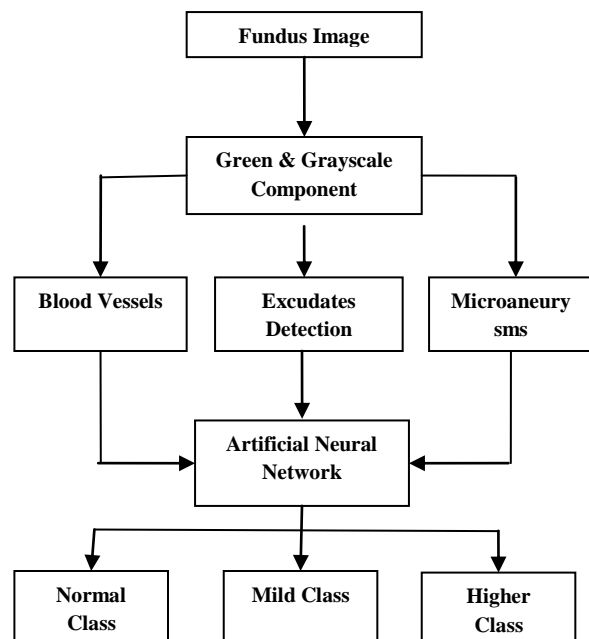


Fig 4: Overall Block Diagram for Detection of DR

The last step in the pre-processing stage is binarization. The candidate vessels, MAs and exudate are then binarized by multi level thresholding. A correct threshold value is crucial, because smaller threshold value induces more noise and higher threshold value causes loss of some fine vessels. Now the output image is ready for feature extraction.

3.2 FEATURE EXTRACTION

Objective of Feature Extraction is to extract the vessels, Microaneurysms and exudate present in the pre-processed image. Microaneurysms and exudate appear as isolated patterns and are disconnected from the vessels. The features of microaneurysms and exudate can be extracted based on shape, size and intensity level. Microaneurysms are dark reddish in colour, they appear as small red dots of 10 to 100 microns diameter and are circular in shape. Exudate are yellow-white patches of varying sizes and shapes.

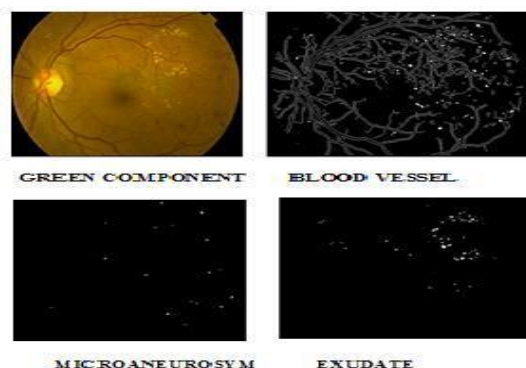
After the image is pre-processed, the candidate microaneurysms and exudate are segmented by separating them from the blood vessels. MA and vessels both appear in a reddish color and exudates are the yellow patches. MAs and exudate cannot occur on vessels. Blood vessels are large in area and

are connected component, thus can be identified from MA and exudate based on area. Threshold value is decided by experimentation.

To remove blood vessels, objects having area greater than threshold value are eliminated. The result image may include microaneurysms, exudate and some noise which are unconnected vessels and other particles in fundus image. MAs are circular 10-100 microns diameter in size and exudate are larger in size, thus MAs and exudate can be identified from noise based on area. Two threshold values are decided by experimentation to remove noise objects having area greater and lower than MAs and exudate. The resulting image having objects which have the same area and some of them are microaneurysms and others are exudates.

As MAs are circular in shape, they can be identified from noise which is irregular in shape and from the remaining exudates are identified. Based on the major and minor axis, we can eliminate the noise having same area as microaneurysms but is elongated in shape. Finally, microaneurysms are detected based on perimeter and circularity. Canny edge detection is performed on the resulting image from the previous section. Each object's area and perimeter is calculated and these results are used to form a simple metric indicating the roundness of an object. Then the exudates are identified they are of irregular shapes and are the yellow patches.

The exudates are the brighter region, while the microaneurysm are darker and smaller region. The unwanted features can be identified by applying Otsu threshold method.



3.3 CLASSIFICATION

After the detection of blood vessel, Microaneurysms and exudate classifying the groups as either diseased or normal depending on the count of detected blood vessel, Microaneurysms and exudate. Classification can be used to grade the DR into three stages as normal DR, mild DR and severe DR.

SUMMARY OF THE FEATURE EXTRACTION:

Feature	Higher Stage	Mild Stage	Normal
Image			
Blood Vessels			
Exudates			
Micro-aneurysms			

Feature	Higher	Mild	Normal	P-Value
Mean Blood Vessel Area ± Std dev	43412 ± 11044	39097 ± 9374	36161 ± 6987	0.0081
Mean Exudates Area ± Std dev	919.68 ± 714.98	58.25 ± 108.09	6.09 ± 11.88	<0.0001
Mean Microaneurysms Area ± Std dev	314.56 ± 174.40	72.31 ± 70.52	15.03 ± 20.69	<0.0001

4. RESULTS AND DISCUSSION

For easier analysis of intermediate results achieved by proposed algorithm and to make this analysis process automated, we designed a Graphical User Interface (GUI).The GUI is designed in such a way that it is easier to be understood and used even by non-ophthalmologists. The results of the analysis are presented in lucid and simpler way. The fundus images once fed to the GUI will be automatically analyzed and classified into three distinct classes i.e., Normal, Non-Proliferative, Proliferative class.The performance analysis had been made out of 40 images 37 images were correctly identified and 3 images were incorrectly identified.

4.1 OVERALL RESULTS FOR CLASSIFICATION

4.2 PERFORMANCE ANALYSIS

Sensitivity and specificity are the important parameters used to measure the accuracy of the algorithms. The accuracy can be calculated based on four values, namely the true positive (TP) rate, the false positive (FP) rate, the false negative (FN) rate, and the true negative (TN) rate. True Positive is when an „abnormal“ image is correctly identified as „abnormal“. False Negative is when an „abnormal“ image is incorrectly identified as „normal“. True Negative is when an „normal“ image is correctly identified as „normal“ and False Positive is defined as „normal“ image is incorrectly identified as „abnormal“. These values are also defined in Table 3. Sensitivity is the percentage of the actual MA pixels that are detected, and specificity is the percentage of non-MA pixels that are correctly classified as non-MA pixels. Ideally Sensitivity and Specificity is 100% but because of presense of noise and artifacts in the image it is difficult to achieve 100% results.

Test Result	Present	Absent
Positive	Time Positive (TP)	False Positive (FP)
Negative	False Negative (TN)	True Negative (TN)

$$Sensitivity = \frac{TP}{TP+FN}$$

$$Specificity = \frac{TN}{TN+FP}$$

V. CONCLUSION

In this paper, we have successfully designed an automatic screening system for detection of diabetic retinopathy from the fundus image. Initially we detected the symptoms of diabetic retinopathy such as neo-vasculatures, soft and hard exudates and microaneurysms. The results are quantified and fed to four layer backward propagation artificial neural network. Neural network classifies the images into three distinct classes' i.e. normal, non-proliferative, proliferative class. Based on the results of the classifier, this project has a sensitivity of 92.5%. Our Proposed method is able to achieve accurate classification for 37 images of the total 40 images given in drive database.

The false classification of 3 images is due to poor illumination condition of the captured fundus image. This can be improved in the future by working on the preprocessing steps for illumination normalization of fundus images. A graphical user interface (GUI) is created for easier analysis of images. The designed system is useful for automatic screening process and can be used in mass eye screening programs.

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