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Identification of Exudates Using an Image Processing Algorithm Designed for Early Diagnosis of Diabetic Retinopathy

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Abstract: One of the most primitive and common symptoms of diseases leading to loss of sight among individuals are exudates. Diabetic retinopathy is considered as a key root of blindness, particularly among working-age adults. The extent of retinopathy is extremely correlated with the exudates. Definite areas of the retina in eye with prevalent conditions are to be photocoagulated by laser techniques to impede the disease progress and avert blindness. To summarize the areas relies on outlining the lesions and the anatomical composition of the retina. In this dissertation work, we endow with a new biomedical feature extraction technique for blood vessels that encourages the exudates detection in funds images useful for diagnosis of retinopathy. The technique proceeds with an edge detection algorithm which yields segmented image as an input. Then the novel feature-based algorithm has been employed to detect the features of blood vessels properly. This algorithm is regarded as the feature extraction key for a retinal blood vessel and considers its width range, intensities as well orientations for the function of selective segmentation. Because of its bulb-shape and its colour resemblance with exudates, the optic disc can be extracted by means of the common Hough transform technique. The extracted blood vessel tree and optic disc could be excluded from the over segmented image to acquire an initial estimate of exudates for primary diagnosis. The eventual estimation of exudates can then be achieved by morphological reconstruction based on the appearance of exudates in retinal images.

Keywords: Diabetic retinopathy, blood vessels extraction, Hough transforms, exudates detection

I. INTRODUCTION

Recent advancements in medical imaging are through in domains viz. instrumentation, diagnostics studies, and therapeutic applications; mostly based on imaging technology as well image processing. Actually, medical image processing has been recognised as a principal aspect of innovation in modern health care involving medical informatics, neuro-informatics and bioinformatics.

Latest developments in digital imaging and computing have assisted a lot to utilize facts & figures provided from medical images in novel and innovative ways. The development of automatic medical diagnosis systems to improve the services provided using technology has been also appreciated by the medical community.

These systems support general physicians to analyse, diagnose, measure important anatomical structures, monitor changes by matching sequential images and plan for the best treatment they could offer.
Colour retinal images as inputs are extensively used nowadays in medical ophthalmology for the detection and diagnosis of diseases related to eye, hypertension and various vascular disorders. Visual impairment is possibly the most feared complication in diabetes. Largely the worrying complications are in the retina that leads to a clinical condition called retinopathy.

Today Diabetic retinopathy (DR) is one of the major reasons of blindness in the age group (32-60 yrs.) of people around the world.
Awkwardly because visual impairment is often a late symptom of advanced DR, many affected patients remain undiagnosed even if retina is getting damaged towards severity. It has been observed that well-timed diagnosis and referral for management of DR can avoid 98% of severe visual loss. DR screening tests at regular intervals may be the first diagnostic step towards prevention.

The method involves obtaining the retinal image by standard digital colour fundus camera and thereby ophthalmologist practices with images as input for diagnosis facilitation such as to make measurements of the normal anatomical structures, to locate abnormalities and to look for a change in lesions.

II. STAGES OF DR

The earlier signs of developing diabetic eye diseases embrace alterations in diameter of arteries and vein, causing tortuosities, blood vessel swelling, unexpected rupture of vessels, etc. The upsurge in blood sugar level causes diabetes and excess sugar affects retina which leads to blindness. Based on the severity, DR can be classified

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into two stages: Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Retinopathy (PDR).

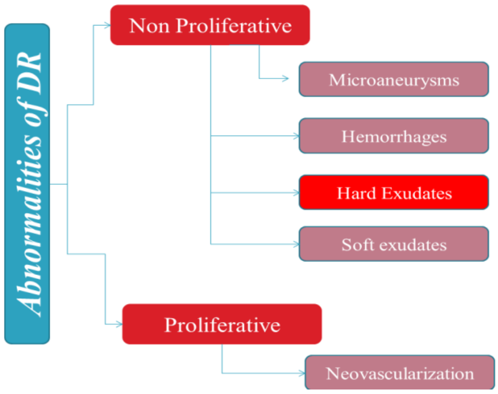

Figure 1: General classification of DR

The stages of diabetic retinopathy are as follows:
a. Mild NPDR: This is the initial stage in which micro-aneurysms occur. It is minor area which looks like swollen balloon in small blood vessels of retina.
b. Moderate NPDR: With progress of disease, blood vessels which provide nourishment to the retina are blocked.
c. Severe NPDR: In this stage more blood vessels are blocked which leads to depriving of blood supply to various areas of retina. These areas of retina are essential for sending signals to the body which in turn grow new blood vessels for nourishment.
d. PDR: This is the advanced stage in diabetic retinopathy. In this stage growth of new blood vessel is triggered due to signals send by the retina for nourishment. This stage is referred as Proliferative diabetic retinopathy. These new blood vessels formed are abnormal and fragile. By themselves these blood vessels do not cause symptoms or vision loss. However they have thin, fragile walls. If they leak blood, severe vision loss and even blindness can results. The PDR may cause sudden loss in visual acuity or even a permanent blindness due to vitreous haemorrhage or tractional detachment of the central retina. At this advanced stage, circulation problems cause the retina to become oxygen deprived and new fragile blood vessels begin to grow in the retina thereby clouding vision. The prime objective of assessing diabetic retinopathy is to avoid, retard, or reverse visual impairment. In computer based retinal image investigation system, image processing techniques becomes critical so as to facilitate and improve diagnosis of patients. Manual analysis of the images can be better and problem of detection of diabetic retinopathy in the late stage for optimal treatment may be fixed.The automatic detection of anatomical structures and lesions are anticipated during the mass screening of input images for the detection and diagnosis of diabetic retinopathy. The detection of anatomical structures facilitates in characterizing the noticed lesions and in classifying and recognising the false positives. Lesion detection is crucial for monitoring purpose and to classify the severity stages of the disease. Based on these the main objectives of the work are summarized as follows:

- ♦ To automatically detect the following normal features in image to progress the pathology detection.
(i) Automatic detection of optic disc boundary
(ii) Automatic detection of retinal blood vessels
- ♦ To automatically detect lesion, i.e., exudates in retinal images for the early detection of diabetic retinopathy.
- ♦ To develop an automatic retinal analysis system to classify severity of the disease.

III. METHODOLOGY

The prime indication for DR detection is exudates. Exudates are abnormalities observed in the first phase of DR. Exudates typically are found in cluster forms. These clusters could be neighbouring to group of micro-aneurysms or around fovea. Exudates are found to be yellowish in shade, intra-retinal deposits which are normally observed in the posterior pole of the fundus. Fig. 2 below shows the Retinal fundus image with hard exudates as well depicting typical parts of retina such as optic disc and main blood vessel.

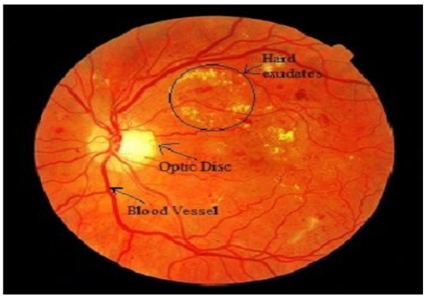

Figure 2: Retinal fundus image with hard exudates

The methodology adopted here consists of nine main steps as shown in the fig. 3. The colour retinal fundus images are given as the input to the system which is analysed automatically to give the analysis of the presence of Hard Exudates.

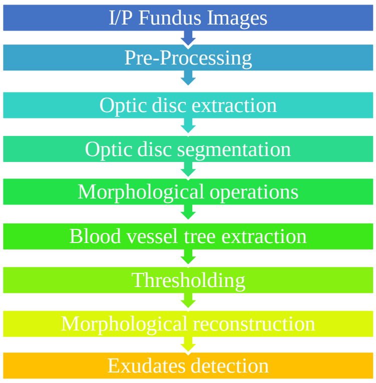

Figure 3: Methodology

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The colour fundus images are given as the input to the system which is analysed automatically to give the analysis of the presence of Hard Exudates. These colour images may differ in size, luminosity and may vary in many physical parameters with each patient. These problems of uneven illumination, non-sufficient contrast between exudates and image background pixels and presence of noise in the input fundus image can be corrected through the pre-processing stage.

This pre-processed stage provides with the contrast enhanced image. Thus the bright lesions in the image becomes more prominent, hence these bright lesions can be segmented easily using various method like thresholding, Fuzzy c-mean clustering, k-means clustering techniques, etc. These bright lesions include both hard exudates and optic disc of the retina.

The optic disc is similar to hard exudates in luminance and its colour property, hence while clustering both, exudates and optic disk gets clustered together. The optic disk may be misclassified as one of the exudates which may lead to wrong diagnosis. This elimination can be done using various methods like morphological operations, Hough transform, etc. Hence elimination of optic disc is necessary. This image containing only exudates is further processed for validation purpose.

Mostly retinal fundus images are to be pre-processed to resolve the complications arise from non-uniform brightness and illumination. The low contrast retinal fundus images and the noise presence often lead to these complications. The colour fundus images used in this study were RGB images. The green component always has the highest contrast and comprehends rational evidence about the diverse anatomical structures and lesions of the retina. Because of that, we took a RGB image and divided in red, green and blue component. Initially, the images were pre-processed for noise removal using median filtering. The technique is based on top-hat morphological operations.

These morphological reconstructions are based on morphological dilation, and the following unique properties are observed:

♦ Instead of one image and a structuring element, processing is based on two images viz. a marker and a mask.

♦ Instead of one structuring element, processing is based on the concept of connectivity.

♦ Processing repeats until stability; i.e. the image no longer changes.

The aim of this work is to accurately detect the presence of exudates in fundus images; since an early symptom of diseases that may lead to blindness. During our work, we noticed that most of the techniques of exudates detection are centered on edge detection.

IV. RESULTS AND DISCUSSION

More than forty images have been tested on MATLAB. Each image took approximately 42 secs to process including the optic disc removal step. The previously unclear exudates regions have been visibly highlighted and the exudates can be visibly observed after the process. The optic disc was also detected well and removed. Usually there are no exudates pixels nearby the optic disc so the removal of the optic disc did not affect the exudates detection.

Fundus images from DIARETDB1 - Standard Diabetic Retinopathy Database has been used. DIARETDB1 is a public database for benchmarking diabetic retinopathy detection from digital images. An algorithm for accurate detection of blood vessels that increases the accuracy of exudates detection has been applied. The algorithms have been applied to the images for contrast enhancement, removal of optic disc, detection and removal of blood vessels and finally detection of exudates.

Sensitivity, specificity and accuracy have been considered as performance parameters for measurement of accuracy of the algorithms at the various pixels level. Not only does this evaluation mechanism show how accurate our detection can be, but also shows how inaccurate our detection can be. Our algorithm gives the parameters of sensitivity, specificity and accuracy as 82.23%, 99.65% and 99.6%.

A test can be very specific without being sensitive, or it can be very sensitive without being specific. Both factors are equally important. A good test is a one has both high sensitivity and specificity. The results that are calculated using the above calculations are given in the table 1.

Table 1: Performance parameters

Retinal Image cases	Sensitivity	Specificity	Accuracy
01	96.13	99.67	99.67
02	98.44	99.86	99.86
03	82.47	98.92	98.79
04	66.13	99.48	99.29
05	59.65	99.92	99.91
06	69.05	99.58	99.45
07	91.13	99.62	99.58
08	91.58	99.57	99.55
09	99.12	99.92	99.92
10	69.52	99.96	99.98
AVERAGE	82.23	99.65	99.60

Hard exudates are successfully classified from colour retinal images using matched filter enhanced retinal features and maximum likelihood estimator. The frequency response of matched filters is tuned to enhance the pixels associated with hard exudates. The performance of the method is evaluated on DIARETDB1 database. The average pixel level accuracy of 99.60 is obtained. The average accuracy 99.60 percent to show presence of retinopathy is reported. Since it outlines even the minor vessels while removing the noise that may arise from some haemorrhagic spots in the image. This is because of the fact that the blood vessels seems to be dark structures in a brighter background. We applied this method for diverse element locations to get the full extent of the blood vessels. In future, we intend to extend our proposed method to help improve the detection of haemorrhagic and build an integrated screening and diagnostic system.

V. CONCLUSION

Retinal image analysis has become a potential research area in recent years as diabetic population is exponentially increasing. For effective and maximum reach out of clinical diagnostic benefits especially in developing countries it has become essential to develop the computer based diagnostic systems with reliable performance and acceptability.

We proposed a new algorithm for the detection of exudates in retinal images based on detecting optic and blood vessel tree by using morphological operations and filtering method to accurately detect the features of retinal image and hence after their subtraction from image getting exudates if present. This algorithm can work properly with lower quality retinal images and images containing haemorrhagic and exudates together even. The proposed techniques work effectively even on a meagre computing system. The results of this work can be developed and used to produce an automated system to detect exudates. Micro aneurysm and haemorrhage detection could be added to the system in order to increase its ability to verify the degree of diabetic retinopathy. It will be useful to outspread this work by developing a system to detect them.

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