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A Survey on Diabetic Retinopathy Detection Techniques

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Abstract: In most of the countries diabetic retinopathy has become common eye disease; it affects nearly 80% of diabetic patients and is the major cause of blindness. Diabetic Retinopathy is characterized by a group of lesions (Hemorrhages, Hard Exudates, Microaneurysms, and Cotton Wool Spots) in persons suffering from Diabetes for several years. Many approaches have been developed for detecting the lesions; This paper presents a survey on different techniques used for detecting Diabetic Retinopathy.

Keywords: Diabetic Retinopathy, lesions

I. INTRODUCTION

One of the most important causes of visual loss worldwide is Diabetic Retinopathy and is the main cause of impaired vision in patients of age between 25 and 74. [1].Diabetic Retinopathy causes 2 major problems , one thing is poor blood supply that can cause lack of oxygen in retina, which in turn leads to the formation of new blood vessels named as Neovasculrization,other being leakage from tissues and blood vessels which causes swelling in the central part of retina termed as Macular Edema [2]

The characteristic group of lesions is described as follows, Cotton wool spots are fluffy white patches found in the retina which are formed by damage to nerve fibers and also of the accumulation of the axoplasmic material within the nerve fiber layer. Hard Exudates are seen as yellow spots in retina formed by lipid break down products left behind after localized edema resolves. Aneurysm is the excessive localized swelling of the wall of an artery, Microaneurysms are found in the retina of the eye of DR affected patients, these miniature aneurysms can leak blood by rupturing. Hemorrhage is the escape of blood from ruptured vessel in the retina Earliest symptom of DR is Microaneurysms appearing as dark red spots in retina, Hemorrhages occur when microaneurysms rupture. Yellow colored lesions, hard exudates occur due to fluid leakage into retinal surface from capillaries or from microaneurysms.Cotton wool spots are the occlusions of the nerve fiber layer.DR is a progressive disease, first stage is the Non Proliferative Diabetic Retinopathy (NPDR) during which the lesions appear and increases as the disease progresses. Various lesions associated with Diabetic Retinopathy are shown in figure.

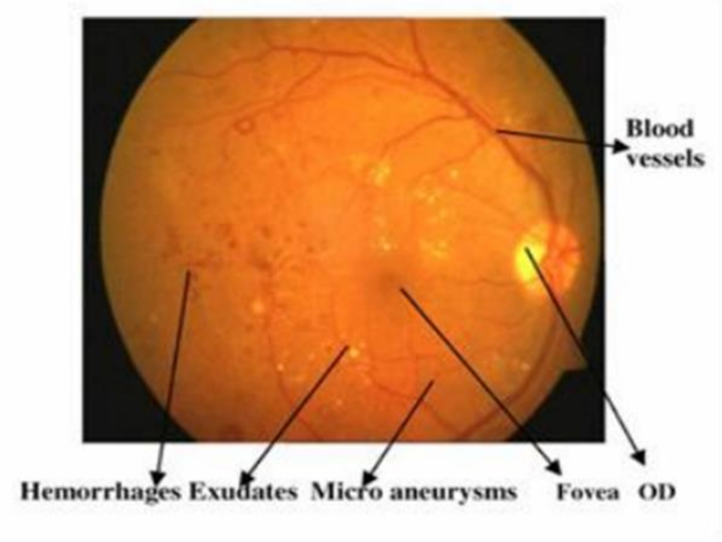

Fig. 1 Retinal Image

Fig.1 shows retina of a diabetic eye with anatomical features Optic Disc (OD), Vasculature, fovea and abnormal features as Hemorrhages, Exudates, and Microaneurysms.

II. Diabetic Retinopathy Detection Techniques

A. Contribution of Image Processing to the Diagnosis of Diabetic Retinopathy

Image processing of fundus images play a major role in the detection of diabetic retinopathy. Different ways in which it contribute includes image enhancement, mass screening (detection of pathologies and retinal features) and monitoring (feature detection). Optic disc is localized by means of homomorphic filtering , contour of OD is found using hexagonal structuring element and applying Watershed transformation[3].Robustness and accuracy in comparison to human graders are encouraging and a clinical evaluation will be undertaken to able to integrate the presented algorithm in a tool for detection of diabetic retinopathy.

Initially the candidate regions containing exudates are selected, and then Hard Exudates are identified through thresholding and morphological operations such as opening, closing, erosion and dilation.

Algorithm is quite robust with respect to parameter changes. The presence of hard exudates within 3000 μm of the centre of the macula enables macular edema to be detected with 94% sensitivity and 54% specificity. When the contrast is too low / red channel is saturated the algorithm does not work in desired way and the false positives (non exudates being detected as exudates) poses a question on the accuracy of the system.

B. Diagnosis System for Diabetic Retinopathy to prevent Vision loss

Soft computing neural networks are used in the detection and diagnosis of Diabetic Retinopathy which aids ophthalmologists in the early detection and treatment of the disease, so that vision loss could be avoided. Detection and Segmentation of blood vessels from retinal images is achieved by using morphological operations. For the correct classification of blood vessel pixel, features were extracted, trained and classified by using neural network classifier. For better blood vessel classification Efficient Local Binary Pattern (ELBP), Law's features [4] are extracted from the blood vessel segmented mapped image.ELBP can be computed as

$$ELBP = \sum_{P=1}^{8} 2^{P}.M(I_N - I_C) \qquad \text{eqn. (1)}$$

Optic disc segmentation includes elimination of blood vessels through anisotropic diffusion filter and contour points are identified by means of spline interpolation. Fovea detection plays a vital role in analysis of diabetic retinopathy by determining relation between fovea and exudates. Fovea constitutes the darkest black region in retina, so the pixel values below threshold are marked as fovea region pixel by morphological operation and a disc shaped structuring element. Exudates are marked using Krisch's Edge Detector which works over 8 directions of a pixel.

Severity of DR is calculated by the number of exudates to the area of fovea. Segmented OD proves to be accurate when compared with its ground truth image. Shortcomings of the proposed method includes, neural network model for classifying blood vessel has higher negative predictive value. Law's texture features were first applied for Fundus images (Blood Vessel Segmentation).

C. A Novel Curvature Based Algorithm for Automatic Grading of Retinal Blood Vessel Tortuosity

Tortuosity means having many turns, the algorithm aims in measuring single vessel and vessel network tortuosity. Tortuosity measure [5] is a curvature indictor of inflexion, point at which the curve changes from concave to convex or vice versa. Algorithm is based on methods of curvature which includes integral of curvature and integral of curvature squared. Template disk method with two modifications was used.

First step is the vessel detection done in the green plane of the RGB image, randon transform and local sinogram are used in vessel detection, vascular skeleton is extracted by morphological thinning algorithm [6]. Bifurcations and crossover of the vessel may cause difficulty in tortuosity measurement and they are eliminated. Local tortuosity at each point is calculated and then the global tortuosity is calculated as follows

$$\tau = \frac{1}{m}\sum_{i=1}^{m} k_i \qquad \text{eqn. (2)}$$

Where k_i specifies i-th point on the map, m indicates total number of points for which curvature is measured. Proposed algorithm poses low computational burden and an excellent matching to the clinically perceived tortuosity but the method does not possess linearity against curvature and also the state of arteries have a major impact on vessel network tortuosity

D. A Successive Clutter-Rejection-Based Approach for Early Detection of Diabetic Retinopathy

Two rejection stages [7] were used. Preprocessing involves median filtering of green plane of color image, green plane provides highest MA contrast when compared to other planes [8] [9] [10]. Candidate selection is done using morphological methods. Rejection Stage 1 identifies class of clutter which includes hemorrhages, candidates on vessels, junctions etc. Anisotropic filters, scaled difference of gaussians,inverted Gaussians are used in rejection stage 1.In Rejection Stage 2, clutters arised due to image noise, poor image resolution are rejected based on distance, correlation and level cut features.

Significance of the proposed method is that the candidate selection is kept simple and cascading rejectors retain only the true positive Microaneurysms , but the algorithm limits itself only to the images acquired through standard protocol and not suitable for heterogeneous dataset.

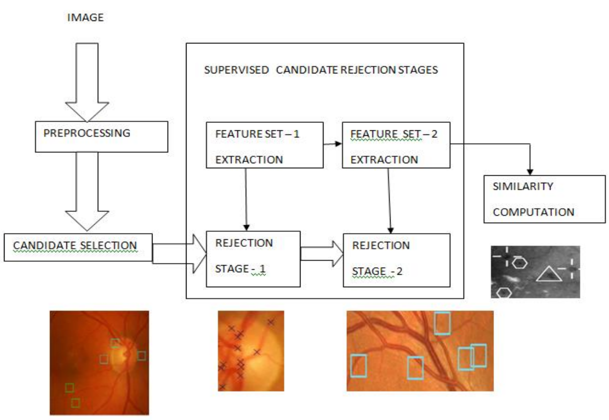

Fig.2 Proposed Approach – Flow Diagram

E. Automated Detection and Quantification of Hemorrhages in Diabetic Retinopathy Images Using Image Arithmetic and Mathematical Morphology Methods

Color image enhancement is made to highlight hemorrhages, median filter usage to remove salt and pepper noise. Image subtraction to extract blood vessels and hemorrhages. Image thresholding and strengthening shows only the blood vessels and hemorrhages. Image thinning, erosion and skeletonization are performed to thin blood vessels. Blood vessels are completely suppressed and actual hemorrhages are detected through morphological closing, Image complement and component labeling.

Algorithm [11] has very high specificity which shows algorithm does not recognize non hemorrhage pixel as hemorrhage. It provides a fast and reliable method for detecting hemorrhages.

F. Diabetic Retinopathy Analysis Using Machine Learning

The method provides a computer aided screening system which can analyze fundus images in various Field Of View (FOV) and illumination. A hierarchical classification is used wherein the first step lesions and nonlesions are separated and in the second step red lesions are classified as hemorrhages and microaneurysms and the bright lesions are classified as cotton wool spots and hard exudates. False positives and true lesions are classified using Gaussian Mixture Model (GMM) [12], other classifiers such as Support Vector Machine (SVM) or K Nearest Neighbor (KNN) can also be used for the purpose of classification.

Initially the foreground (lesion region) and background (Optic disc and blood vasculature) are separated through image segmentation. Optic disc detection is carried out by Minimum Intensity Maximum Solidity algorithm (MinIMaS) [13]. This algorithm utilizes the fact that Optic disc is the bright region and has the minimum pixel intensity and maximum compactness. Vasculature is detected and masked out so that wrong interpretation of blood vessels as red lesions can be avoided. False positives are eliminated by using classifiers , the number of features used to train the classifiers has been reduced to 30 which includes 16 structure based features and 14 features such as standard deviation,minima,maxima and so on. Based on the count of microaneurysms and hemorrhages the severity of DR is graded as mild, moderate, severe.

III. Results

Results are given in terms of sensitivity and specificity which are measured by the following formulas

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

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

Where TP denotes True Positives, TN represents True Negative; FN specifies False Negatives and FP refers to False Positive. Paper *A* achieves mean sensitivity of 92.8% and a predictive value of 92.4%.In Paper *B* it is found that, exudates detection achieves 98% sensitivity, 99% specificity, 88% positive predictive value, 97% negative predictive value and 98% accuracy for a set of retinal images available in DRIVE database with a success rate of 96.7%.The candidate selection stage in paper *D* has a sensitivity above 0.90 and detects, on average, 80 candidates per image. Both RS1 and RS2 altogether reject 60% of the candidates and retain an average sensitivity of 0.88.Paper *E* has sensitivity rate above 80% and specificity rate above 90%. The DREAM (Paper *F)* system achieves 100% sensitivity, 53.16% specificity, compared to the best reported 96% sensitivity, 51% specificity for classifying images as with or without DR.

IV. DISCUSSION

We have discussed the existing approaches for diabetic retinopathy detection in the above section. All of them are based on the fundus images and image processing plays an important role in this. Diabetes occurs when the level of glucose in the blood is higher than normal .Over several years diabetes can damage the blood vessels of the retina causing what is called diabetic retinopathy (DR) and is the major cause of poor vision which can also lead to blindness. If the disease is detected in the early stage, treatment can slow down the progression. The automatic assessment of diabetic retinopathy helps the ophthalmologists in offering better treatment to their patients. Each of the techniques discussed above have both advantages and disadvantages. Among the above mentioned techniques, detection based on Machine learning is more recommended, using which abnormality detection and severity classification will be more accurate.

V. Conclusion

In this paper a survey on different techniques for the detection of diabetic retinopathy has been done.Diabetic Retinopathy has been a growing threat whose early detection can prevent blindness.DR is the main cause for vision loss in developed countries. In the year 2011, more than 360 million people suffered from diabetes and according to estimation this will grow to 550 million by 2030.Thus the above sections present the various methods for automatic assessment of Diabetic Retinopathy.

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