

A Survey on Exudates Detection From Fundus Images for Diagnosis of Diabetic Retinopathy



Engineering

KEYWORDS : Retinal exudates; Diabetic Retinopathy; White Lesions

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ABSTRACT

Diabetic Retinopathy (DR) is retinopathy (damage to the retina) caused by complications of diabetes, which can eventually lead to blindness. It is an ocular manifestation of diabetes, a systemic disease, which affects up to 80 percent of all patients who have diabetes for 10 years or more. The presence of exudates in the retina is one among the earliest symptom of diabetic retinopathy. The number and shape of exudates is used to indicate the severity of the disease. Early detection of retinal exudates can help to reduce blindness. In this paper we review the techniques, algorithms, and methodologies used for detection of retinal exudates from DR retinal images.

1.INTRODUCTION

In the developed world, most of them are facing high range of work stress in their industrialized environment. Now-a-days, the number of people affected by diabetes is increasing drastically. The most common effect of diabetes is vision defect. Among working people visual impairment is an intimidating problem. Patient’s get complicated by cataracts, glaucoma, and damage to blood vessels due to diabetes.

For example, millions of Americans are affected by Type I (juvenile onset) or Type II (adult onset) diabetes. The major complication of diabetes that has developed so far is eye diseases affecting vision. Most of the cases who registered for blindness in Singapore are affected only by retinal diseases. More than 70% patients with diabetes are affected by Diabetic Retinopathy (DR).

DR is a critical eye disease that is considered as manifestation of diabetes on the retina. The severity of the disease increases due to other abnormalities such as micro aneurysms, hemorrhages, and cotton wool spots. At the back of the eye, new blood vessels will be formed as a part of PDR which bleed and cause blurred vision. It may not be severe at the initial stage. A few specks of blood or spots will be left which tend to float in visual field. The spots may often go after few hours. However within a week, a greater leakage of blood follows the spots which further blur the vision. The blood may clear in months or years or it may not clear at all.



Fig 1 : Normal Vision



Fig 2 : Same view by Diabetic Retinopathy patients(Image courtesy Wikipedia)

Figure 1 is the view of a normal person whereas figure 2 is the view of a Diabetic Retinopathy affected person. The leakage of proteins and lipids from the blood stream into the retina via damaged blood vessels is the cause for the formation of exudates. It has high content of protein and is yellowish or white in color. Hard Exudates (HE) appears as lesions which are bright yellowish in nature. The small, white lesions which appear with blurry edges are known as Soft Exudates (SE). SE tends to be less visible than HE.

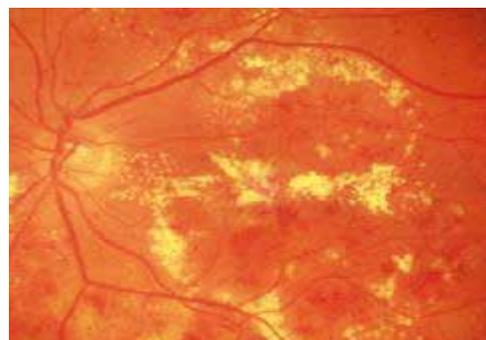


Fig 3:Hard Exudates

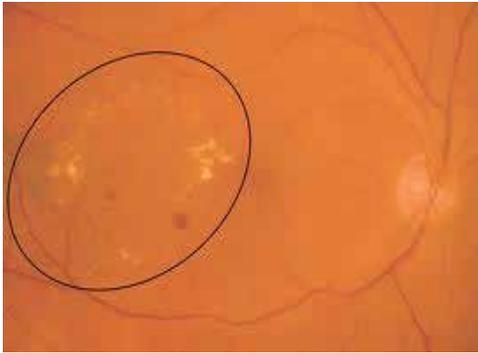


Fig 4:Soft Exudates

Figure 3 shows a color fundus image where multiple HE appear as bright lesions. Figure 4 shows a color fundus image where SE lesion is marked with a round. Retinal Hemorrhages and Microaneurysms are the initial signs of DR. Figure 5(b) show the microaneurysms (red dot). Retinal Hemorrhages is a disorder of the eye in which bleeding occurs in the blood vessels of the retina. Microaneurysms are small swelling that forms on the side of tiny blood vessels. Retinal Hemorrhages can be classified based on their sizes as Dot, Blot and Flame Shaped. Figure 6 (a) shows the hemorrhage that is formed on the optic disc area and figure 6(b) shows the hemorrhage that is formed on the macula region. A retinal hemorrhage also varies in size. Detection of retinal hemorrhages helps to develop an automatic screening system which may promptly detect sight-threatening DR and eye disease. Early detection and diagnosing aids in prompt treatment. Such an automated diagnostic tools are going to be notably useful in health camps particularly in rural areas in developing countries wherever an outsized population laid low with these diseases goes unknown. Automated detection of lesions in retinal images may be a crucial step towards economical early detection, or screening, of enormous at-risk populations, especially, the detection of micro-aneurysms, typically the primary sign of diabetic retinopathy (DR), and also the detection of drusen, the hallmark of age-related degeneration area unit of primary importance. Automated detection of diabetic retinopathy (DR) is very important for permitting timely treatment, and thereby increasing accessibility to and productivity of eye care suppliers. Some of the methodologies have been described for detection of microaneurysms and detection of retinal hemorrhages.

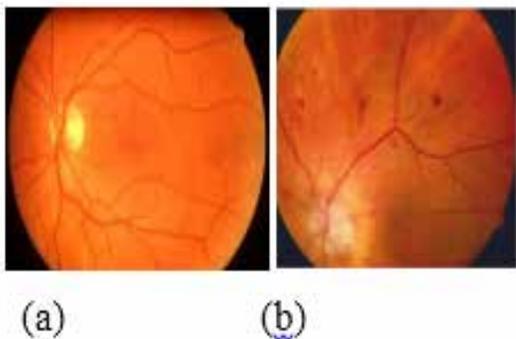


Fig 5. (A) Retina of a normal person and (B) Retina of a person affected by DR

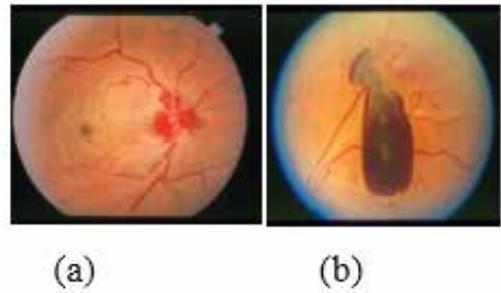


Fig 6. (a) Hemorrhages formed on optic disc and (b) Hemorrhages formed on the macula region

2. VARIOUS METHODS USED IN DETECTION OF RETINAL Exudates

Maria Garcia et al., "Neural Network Base Detection of Hard Exudates in Retinal Images" proposed an algorithm for detection of HE in neural networks. Automatic recognition of DR lesions in fundus images can contribute to the diagnosis of the disease. Three NN classifiers were investigated: multilayer perceptron (MLP), radial basis function (RBF) and support vector machine (SVM). DR signs include red lesions, such as microaneurysms (MAs), intraretinal microvascular abnormalities (IRMAs) and haemorrhages (HEs), and bright lesions like hard exudates (EXs) and soft exudates or cotton-wool spots (CWs). Other bright lesions that can appear in fundus images are drusen, EXs are lipid and lipoprotein deposits, white, yellowish or waxy, that appear as compact patches with well-defined borders in retinal images. In order to classify candidate regions as EX or non-EX, we extracted a set of features from each region and used them as inputs to the NNs. The classifiers used are Multilayer perceptron (MLP), Radial basis function (RBF), Support vector machine (SVM). Prior to classification, we pre-processed the image in order to normalize the variability in color, brightness and contrast that images can show in a clinical environment. Subsequently, the candidate EXs regions were detected by means of a segmentation algorithm. The parameters of this algorithm were chosen in order to achieve a high sensitivity (detect a high percentage of true EXs), even if that meant a lower specificity (detecting also some non-EXs regions) [1].

Doaa Youssef "Accurate Detection Of Blood Vessels Improves The Detection Of Exudates In Color Fundus Images" is used for the detection of blood vessels that improves the detection of exudates in fundus photographs. The method starts with an edge detection algorithm which results in a over segmented image. Then the new feature-based algorithm can be used to accurately detect the blood vessels. This algorithm considers the characteristics of a retinal blood vessel such as its width range, intensities and orientations for the purpose of selective segmentation. Because of its bulb shape and its color similarity with exudates, the optic disc can be detected using the common Hough transform technique. The extracted blood vessel tree and optic disc could be subtracted from the over segmented image to get an initial estimate of exudates. The final estimation of exudates can then be obtained by morphological reconstruction based on the appearance of exudates. This method is shown to be promising since it increases the sensitivity and specificity of exudates detection to 80% and 100% respectively [2].

Akara Sophara et al., "Automatic Detection Of Diabetic Retinopathy Exudates From Non-Dilated Retinal Images Using Mathematical Morphology Methods" proposed an

automatic detection of diabetic retinopathy exudates from non-dilated retinal images using mathematical morphology methods. Detection of exudates by ophthalmologists normally requires pupil dilation using a chemical solution which takes time and affects patients. Non-dilated pupil and low-contrast images. These automatically detected exudates are validated by comparing with expert ophthalmologists sensitivity and specificity for our exudates detection is 80% and 99.5% Patient's sight can be affected by diabetes which causes cataracts, glaucoma, and most importantly, damage to blood vessels inside the eye, a condition known as "diabetic retinopathy". Hemorrhages occur when blood leaks from the retinal vessels. It is intended to help the ophthalmologists in the diabetic retinopathy screening process to detect symptoms faster and more easily. The proposed techniques work effectively even on a poor computing system [3].

Daniel Welfera et al., "A Coarse-To-Fine Strategy for Automatically Detecting Exudates in Color Eye Fundus Images" "proposed a coarse-to-fine strategy for automatically detecting exudates in color eye fundus images. The detection of exudates is a prerequisite for detecting and grading severe retinal lesions, like the diabetic macular edema. A mathematical morphology method for detecting exudates is carried out in two stages. In Stage A, Coarse Detection of Exudates is performed whereas in Stage B, fine detection of Exudates is being performed [4].

Clara I. Sanchez et al., "A Novel Automatic Image Processing Algorithm for Detection Of Hard Exudates Based On Retinal Image Analysis" introduces an automatic image processing algorithm to detect hard exudates. Automatic detection of hard exudates from retinal images is an important problem since hard exudates are associated with diabetic retinopathy and have been found to be one of the most prevalent earliest signs of retinopathy. The algorithm is based on Fisher's linear discriminant analysis and makes use of color information to perform the classification of retinal exudates. We prospectively assessed the algorithm performance using a database containing 58 retinal images with variable color, brightness, and quality. Our proposed algorithm obtained a sensitivity of 88% with a mean number of 4.83±4.64 false positives per image using the lesion-based performance evaluation criterion, and achieved an image-based classification accuracy of 100% (sensitivity of 100% and specificity of 100%)[5].

Clara I. Schez et al., "Retinal Image Analysis based on mixture models to detect hard exudates" analyzed the retinal image based on mixture models to detect HEs. HEs have been found to be one of the most prevalent earliest clinical signs of retinopathy. Thus, automatic detection of hard exudates from retinal images is clinically significant. The algorithm is based on mixture models to dynamically threshold the images in order to separate exudates from background. A post processing technique, based on edge detection is applied to distinguish hard exudates from cotton wool spots and other artifacts. We prospectively assessed the algorithm performance using a database of 80 retinal images with variable color, brightness, and quality. The algorithm obtained a sensitivity of 90.2% and a positive predictive value of 96.8% using a lesion-based criterion[6].

Gwenole Quellec et al., "A Multiple-Instance Learning Framework for Diabetic Retinopathy Screening" proposed a novel multiple-instance learning framework, for automated image classification. Given reference images marked by clinicians as relevant or irrelevant, the image classifier

is trained to detect patterns, of arbitrary size, that only appear in relevant images. After training, similar patterns are sought in new images in order to classify them as either relevant or irrelevant images. Therefore, no manual segmentations are required. As a consequence, large image datasets are available for training. The proposed framework was applied to diabetic retinopathy screening in 2-D retinal image datasets: Messidor (1200 images) and e-optha, a dataset of 25,702 examination records from the Ophdiat screening network (107,799 images). In this application, an image (or an examination record) is relevant if the patient should be referred to an ophthalmologist. Trained on one half of Messidor, the classifier achieved high performance on the other half of Messidor (Az ¼ 0:881) and on e-optha (Az ¼ 0:761). We observed, in a subset of 273 manually segmented images from e-optha, that all eight types of diabetic retinopathy lesions are detected [7].

Atul Kumar et al., "A Segment Based Technique for Detecting Exudates from Retinal Fundus Image" detected exudates using a segment based technique. Here, classification into various stages of NPDR is based on their pixels intensity and frequency from the retinal fundus image. A series of experiments for extracting the feature is performed with the use of effective image processing techniques. To get these feature value from fundus retinal image various techniques like morphological preprocessing, image boundary tracing, adaptive threshold using Otsu methodology, Optic disk localization are implemented. The SVM classifier uses features extracted by combined 2DPCA instead of explicit image features as the input vector Combined 2DPCA is proposed and then for acquiring higher accuracy of classification we can use virtual SVM. Experimental evaluation on the publicly available dataset DRIVE demonstrates the improved performance of the proposed method for automatic detection of Exudates. These automatically detected exudates are validated by comparing with expert hand-drawn ground-truths. The overall sensitivity of proposed method is 97.1% for the classifier and the specificity is of 98.3%. So, by using this tool Specialist gets support in screening a detection of early changes causing Diabetic Retinopathy and hence timely intervention leading to reduced DR related blindness [8].

Table 3: Comparative Analysis of Various Methodologies

Methodology	Issues	Merits	Demerits
Marker Controlled watershed segmentation	Average filtering Contrast adjustment	High sensitivity in extraction of contours of optic disc and exudates	Poor noise removal
Split and Merge algorithm based segmentation	Local variation for coarse segmentation. Adaptive thresholding, Split & Merge tech for fine segmentation	High specificity Ratio	No noise removal
Noise map distribution	Morphological operators & adaptive thresholding	Good for contrast changes and non-uniform illumination	Low accuracy rate
Region based segmentation	Adaptive thresholding, Morphological gradient processes	Highly sensitivity in achieving performance	Time consuming
Error boost feature selection method	Extraction of pixels that falls in color range of spots	Highly accurate in achieving performance	No noise removal

Mathematical morphology operations	Top hat and bottom hat reconstruction	Higher rate of sensitivity in detecting exudates	Low accuracy rate
Novel statistical atlas based segmentation	Statistical retinal atlas used for coordinate atlas	Highly accurate in achieving performance	Noise effect
Region of interest	Image binarization	High accuracy	Noise effect
Circular hough transform & bit plane slicing	Slices into different planes for detection of exudates	High speedup	High time consuming
Projection based algorithm	Projection values of image slice used	Decrease false positive cases	Noise effect
Markovian segmentation model method	Exact contour detection & region wise classification of exudates	Provides better description of edge information	Low speed
Adaptive median thresholding	Median thresholding	High speedup	Noise effect
K-mean clustering method	Hough transform used for hard and soft exudates	Noise removal	Low accuracy
Ant colony optimization Technique	Thresholding Region Growing, Morphology, Supervised method	High accuracy, sensitivity and specificity	High Time consuming

Huiqi Li et al., "Automated feature extraction in color retinal images by a model based approach" introduced an automated feature extraction in color retinal images using model based approach. Color retinal photography is an important tool to detect the evidence of various eye diseases. Novel methods to extract the main features in color retinal images have been developed in this paper. Principal component analysis is employed to locate optic disk. A modified active shape model is proposed in the shape detection of optic disk. A fundus coordinate system is established to provide a better description of the features in the retinal images. An approach to detect exudates by the combined region growing and edge detection is proposed. The success rates of disk localization, disk boundary detection, and fovea localization are 99%, 94%, and 100%, respectively. The sensitivity and specificity of exudates detection are 100% and 71%, correspondingly. The success of the proposed algorithms can be attributed to the utilization of the model-based methods. The detection and analysis could be applied to automatic mass screening and diagnosis of the retinal diseases [9].

2. Discussion and Future Work

Detected exudates are compared with the ophthalmologists' hand-drawn ground-truth images for verification. Example testing and training performances are shown in Table 1 and Table 2 respectively. Sensitivity (Recall) is the percentage of the actual exudate pixels that are detected, and specificity is the percentage of non-exudates pixels that are correctly. Table 3 shows comparative analysis of various exudates detection methodologies. Future work may aim to develop a better segmentation algorithm to segment the other abnormal signs of the DR including blood vessels and diagnose the abnormality in earlier stage itself. Also, include other extensive tests on other types of fundus images acquired from different digital cameras.

Table 1 Testing Performance

Classifier	SE(%)	SP(%)	Precision(%)	PR(%)	Acc(%)
Mathematical morphology	80	99.46	51.78	65.89	99.29
Naive Bayesian	93.38	98.14	47.51	70.45	98.05
Support Vector Machine	92.28	98.52	53.05	72.67	98.41

Table 2 Training Performance

Classifier	SE(%)	SP(%)		PR(%)	Acc(%)
Naive Bayesian	94.53	89.19	89.74	92.13	91.86
Support Vector Machine	92.06	94.92	94.77	93.41	93.49

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