Computer Aided Diagnosis of Diabetic Retinopathy: A Survey

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ABSTRACT *Diabetes mellitus (DM) is defined as a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion or insulin action or both. It is a disease that affects 65 million people in India. Diabetic retinopathy (DR), the most common ocular complication of DM affects one out of every 10 persons with diabetes and is the leading cause of blindness in the working age population. As majority of patients with DR remain asymptomatic till late stages, by the time disease is detected it might be too late for effective treatment. Regular screening of all diabetic patients for timely detection and treatment of DR is therefore necessary to prevent or reduce the risk of visual loss. This paper presents a survey of various computer aided diagnosis techniques for detection of DR.*

Keywords: *Diabetic Retinopathy; Hard Exudates; Proliferative; Non-proliferative.*

Introduction

In today's world due to more workload and stress people don't maintain a proper diet, lack of sleep and working with the system the whole day and immediately using mobile phones just by sitting in the same place for more than eight hours without any physical activity causes increase high blood glucose level. Stress is also one of the major reasons in the increase blood level within the body where the growth of the hormone and cortisol level rise, which causes body tissues (muscle and fat) to be less sensitive to insulin. As a result, more glucose is available in the blood stream. Diabetic retinopathy is caused by prolonged high blood glucose levels. Over time, high sugar glucose levels can weaken and damage the small blood vessels within the retina. This may cause hemorrhages, exudates and even swelling of the retina. This then starves the retina of oxygen, and abnormal vessels may grow. It is broadly categorized into Non-Proliferative Diabetic Retinopathy (NPDR) or Proliferative Diabetic Retinopathy (PDR) based on the absence or presence of new blood vessels emanating from the retina (neovascularization). The early stage of this disease is called non-proliferative diabetic retinopathy. In this stage blood vessels swell and sometimes bulge or take the shape of a balloon (aneurysm). The vessels may leak fluid that can build up in the retina and cause swelling. This condition is called macular edema, and it changes the vision of individuals with the disease. The blurriness is sometimes compared to trying to look through water. PDR is the advanced stage where there is no proper supply of oxygen and nutrients to the blood vessel where many new blood vessels emerge from the retina to the vitreous humor. This paper involves various techniques proposed by various researchers and it would be easy for the beginners to get a clear insight about various techniques proposed in their research work. This paper is very effective for the beginners as they can easily understand the method which is used to diagnose the diabetic retinopathy. The rest of the paper is organized as follows. Section 2 provides the literature review. Section 3 describes the image datasets available for DR. Section 4 gives the conclusion of this paper.

Literature Review

Ravindraiah et al have demonstrated a framework to detect hard exudates in Retinopathy images. Their paper proposes Laplacian kernel which is induced into kernel spatial FCM clustering algorithm to segment the retinal fundus images [1]. Since FCM and KFCM are sensitive to noise and other imaging artifacts because it doesn't have spatial information. To overcome this problem Laplacian Kernel spatial FCM which include the spatial information and the fuzzy membership functions are used. A total of 30 color images from retinopathy patients were selected for their study.

The images were taken by Topcon TRC-50 IX mydriatic camera [2]. The morphological function was applied on intensity components of hue saturation intensity (HSI) space. To detect the exudates regions, thresholding was performed on all images and the exudates region was segmented. To optimize the detection efficiency, the binary morphological functions were applied.

Maher et al have proposed a CAD system for the detection and differentiation of hard exudates, cotton wool spots in retinal images for Diabetic retinopathy detection and support vector machine (SVM) for classifying images [3]. It was evaluated on a large dataset containing 130 retinal images. The obtained sensitivity was 96.9%, specificity 96.1% and 97.38 accuracy.

Jaya et al, have proposed an expert decision making system using a fuzzy support vector machine [FSVM] to detect hard exudates in fundus images [4]. The optic disc is been segmented to avoid false alarm using morphological operations based on Circular Hough transform. To discriminate between the exudates and non-exudate pixels, color and texture features are extracted from the images and 200 retinal images is been collected from Diabetic Retinopathy Screening programmes.

Renato et al, give an overview of the types of lesions that may appear as biomarkers for both the eye and non-eye diseases [5]. To extract the components and lesions in color fundus photographs several state-of-the-art procedures are been presented. By fusing the output of individual detector algorithms the performance of image processing based systems have been improved.

Sreeparna et al, have proposed a decision support system to classify these abnormalities. The process involves combination of contextual information with images obtained from the database. Decision tree where proposed as they can combine contextual information with images [6]. Fuzzy C Mean Clustering was used for generating three different clusters. Images are pre-processed and segmented to obtain the regions of interest for the individual manifestations in each of these diseases.

Ibrahim et al, have proposed an ophthalmic B- Scan Ultrasonography to determine the causes of low vision among Sudanese patients with Diabetic Retinopathy, where a total of 100 patients with Diabetic Retinopathy at different grades were recruited from ultrasound unit which has been used to determine the causes of low vision in diabetic patients according to their glycated haemoglobin and early treatment of Diabetic Retinopathy scale severity levels [7]. It is a noninvasive imaging technique to reduce the discomfort in ophthalmological practice.

Saiprasad et al, have developed methods to automatically detect all the features such as blood vessels, exudates, microaneurysms and hemorrhages using different morphological operations [8]. They propose a new constraint for the optic disc detection where the major blood vessels are first detected and then they use the intersections to find the location of the optic disk which is further localized using color properties. Extensive evaluation of algorithm on a database of 516 images with varied contrast yields 97.1% success rate for optic disk localization, Sensitivity and specificity of 95.7% and 94.2%, for exudate detection 95.1% and 90.5% for microaneurysms/ hemorrhage detection.

Biran et al, have proposed an automated algorithm to extract hemorrhages and exudates form retinal fundus images using different image processing techniques including Circular Hough Transform, Contrast limited Adaptive histogram equalization, Gabor filter and thresholding [9]. The presented method is tested on fundus images from STARE and DRIVE databases. STARE database consist of Structured analysis of the retina and DRIVE database consist of digital retinal images for vessel extraction.

Saheb et al, have proposed a novel approach to automatically detect diabetic Retinopathy from digital fundus images of DIARETDB0 dataset [10]. The fundus images is segmented employing morphological operations to identify the regions such as hard exudates, soft exudate and red lesions such as microaneurysms and hemorrhages. A fuzzy set is formed with the color space values and fuzzy rules is been derived based on fuzzy logic reasoning for the detection of Diabetic Retinopathy.

Akara et al, have proposed a Fuzzy C Mean Clustering to automatically detect exudates from low contrast digital images of retinopathy patients with non-dilated pupils [11]. Contrast enhancement preprocessing is applied on four features such as intensity, standard deviation on intensity, hue and a number of edge pixels, these features are then extracted as input parameters using FCM Clustering method. The detection results are validated by comparing with expert ophthalmologists.

Faisal et al, have proposed Cascading Decision Tree for filtering out most of the non- candidate blobs [12]. A simple and fast method is implemented for detection of Diabetic Retinopathy. Pre-processing of grey-scale images is done to find all components in an image such as hemorrhages, exudates, vessels and optic disk. Then constraints such as compactness, area of blob, intensity and contrast are applied for screening the Diabetic Retinopathy.

Filter based approach with a bank of Gabor filters is used to segment the vessels [13]. The frequency and orientation of Gabor filter are tuned to match that part of a vessel to be extracted in a green channel image. To classify the pixels into vessels and non-vessels entropic thresholding based on gray-level co-occurrence matrix is applied. The performance of the method is evaluated by two publicly available retinal databases with hand labeled ground truths.

Ahmed et al, proposed a new algorithm for the extraction of features from fundus images based on marker controlled watershed segmentation [14]. The proposed algorithm makes use of average filtering and contrast adjustment as pre-processing steps. The marker is mainly used to modify the gradient before the watershed transformation is applied. A comparison of the available techniques for diagnosis of DR is given in Table I.

Table I: Techniques available in the literature of diagnosis of DR

S. No	Authors	Techniques used	Classified structures
1.	R. Ravindraiah, S. Chandra Mohan Reddy and Rajendra Prasad,	FCM, KFCM, LKSFCM	Hard Exudate
2.	Mahsa Partovi , Seyed Hossein Rasta, Alireza Javadzadeh	Median filter, Gray scale top-hat operator.	Exudate
3.	Raju Maher, Sangramsing Kayte, Suvarnsing Bhable and Jaypalsing Kayte	Support Vector Machine	Hard Exudate
4.	T. Jaya, J. Dheeba, N. Albert Singh	Circular Hough Transform, Fuzzy Support vector machine	Exudates
5.	Renato Besenczi, Janos Toth, Andras Hajdu	Spearman's rank correlation coefficient, detector algorithms	Exudates
6.	Sreeparna Banerjee, Amrita Roy Chowdhury	Decision tree, Fuzzy C Mean Clustering, Naive Bayes and SVM	Microaneurysms,Cotton wool spot, Hard exudate
7.	Saiprasad Ravishankar, Arpit Jain, Anurag Mittal	Open and Close operation, Morphological filters	Blood vessels, Exudates, Microaneurysms and Hemorrhages
8.	A. Biran, P. Shobe Bidari, K. Raahemifar	Gabor Filter Circular Hough Transform, Contrast limited Adaptive histogram equalization, Gabor filter and thresholding	Exudates and Hemorrhages
9.	S. Saheb Basha, Dr. K. Satya Prasad	Dilation and erosion, Fuzzy logic	Exudate, red lesions
10.	Akara Sopharak, Bunyarit Uyyanonvara, Sarah Barman	Decorrelation stretch, Entropy feature, Fuzzy C-mean	Exudate
11.	Faisal Ghaffar, Sarwar Khan, Bunyarit Uyyanovara, Chanjira Sinthanayothin, Hirohiko Kaneko	Cascading Decision Tree, Adaptive Histogram Equalization, Top hat filtering, Bottom hat filtering, Morphological opening & close	Exudate, Hemorrhage, Microaneurysm
12.	Jaspreet Kaur, Dr. H. P. Sinha	Gabor Filter, Morphological techniques	Blood Vessels
13.	Ahmed Wasif Reza, C. Eswaran, Kaharudin Dimyati	Morphological operations, Marker-controlled Watershed Transformation	Optic disk and Exudate

DATASETS AVAILABLE FOR DIABETIC RETINOPATHY

In this section, we list several publicly available databases that are generally used.

Retinopathy Online Challenge (ROC) is a worldwide online competition dedicated to measure the accuracy of MA detectors. The ROC database consists of 50 training and 50 test images having different resolutions (768 × 576, 1058 × 1061 and 1389 × 1383 pixels), 45◦ field-of-view (FOV) and JPEG compression. For objective comparisons of the MA detector algorithms, a test set is provided, where the MAs are not given.

The DIARETDB0 database contains 130 lossless compressed color fundus images with a resolution of 1500 × 1152 pixels and 50◦ FOV. 110 images contain abnormalities, like hard exudates, soft exudates, MAs, hemorrhages and neovascularization. For every fundus image, a corresponding ground truth file is available containing the OD/macula centers and all lesions appearing in the specific retinal image

The DIARETDB1 v2.1 database contains 28 lossless compressed training and 61 test images, respectively with a resolution of 1500×1152 pixels and 50◦ FOV. As ground truth, an expert in ophthalmology marked the OD/macula centers and the regions related to MAs, hemorrhages, and hard/soft exudates.

The HEI-MED database consists of 169 images of resolution 2196 × 1958 pixels with a 45◦ FOV, among which 54 images are classified manually by an ophthalmologist as containing exudates.

The Messidor database consists of 1200 lossless compressed 24-bit RGB images with 45◦ FOV at different resolutions of 1440 × 960, 2240 × 1488, and 2304 × 1536 pixels. For each image, a grading score is provided regarding the stage of retinopathy based on the presence of MAs, hemorrhages and neovascularization.

The DRIVE database contains 40 JPEG-compressed color fundus images of resolution 768 × 584 pixels and 45◦ FOV. For training purposes, a single manual segmentation of the vessel system is available for each image. For the test cases, two manual segmentations are available; one is used as ground truth, the other one is to compare computer-generated segmentations with those of an independent human observer.

The STARE database consists of 397 fundus images of size 700 × 605 pixels. STARE contains annotations of 39 possible retinal distortions for each image. Furthermore, the database includes manual vessel segmentations for 40 images, and artery/vein labeling for 10 images created by two experts. Ground truth for OD detection is provided for 80 images, as well.

The HRF database contains high-resolution fundus images for vessel segmentation purposes. It consists of 45 JPEG-compressed RGB images of size 3504 × 2336 pixels and the images are divided to three sets of equal sizes, namely, healthy, glaucomatous and DR ones. This database contains the manual annotations of one human observer.

CONCLUSION

The key to diabetic vision loss is to prevent it through early detection and treatment. In many of the research papers they have included the optic disk as a feature. In many cases the optic disc too is considered as exudates. Exudates are the primary stage to detect diabetic retinopathy. Since optic disk is included, it detects the optic disk as exudate where a person who does not suffer from diabetic retinopathy will be recognized under the category of diabetic retinopathy. In this paper an overview of Diabetic Retinopathy is given, methodologies available in the literature for diagnosis of DR are listed to give a clear insight for the new researchers.

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