Diabetic Retinopathy Detection using Image Processing: A Survey

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Abstract
Diabetic retinopathy (DR) is a diabetes related eye disease which occurs when blood vessels in the retina become swelled and leaks fluid which ultimately leads to vision loss. Several image processing techniques including Image Enhancement, Segmentation, Image Fusion, Morphology, Classification, and registration has been developed for the early detection of DR on the basis of features such as blood vessels, exudes, hemorrhages, and microaneurysms. This paper presents a review of latest work on the use of image processing techniques for DR feature detection. Image Processing techniques are evaluated on the basis of their results.

Keywords: Diabetic Retinopathy, Fundus Image, Blood Vessels, Exudes, Hemorrhages, Microaneurysms.

1. Introduction
Image Processing is widely used to diagnose the eye diseases in an easy and efficient manner. It also supports Ophthalmologists to screen their patients and to do clinical study as well[1]. Major eye related diseases that cause blindness worldwide are Diabetic Retinopathy, Glaucoma, and age-related macular degeneration. It is found that in America, almost 950,000 people became blind in 2002 and 2.5 million people have visionary problems due to these diseases[2].

The structure of blood vessels in eye retina gives information about changes followed by these retina related eye diseases [3]. Some of eye features, i.e., vascular blood vessels, fovea, and optic disc (OD) are used to identify diabetic retinopathy (DR) and other eye related diseases. Many screening tools are available to diagnose DR [4],[5]. Digital fundus cameras are used to take the retinal vessel images; therefore, unnecessary brightness, environment, and the process of acquisition of fundus image degrade the image quality to some extent. Hence image enhancement is always required to improve the quality of desired image.

Certain methods are proposed by researchers to enhance the quality of retinal images[6],[7, 8]. Some of the image processing techniques used by researchers in order to diagnose eye diseases including Image Enhancement[9], Registration, Fusion, Segmentation, Feature Extraction[10], Morphology, and Classification [11],[12]. Image registration is used in order to detect changes in medical images. Different images captured from different angles are aligned in a single coordinate system in order to get registered successfully[13]. Image fusion is used to integrate different type of information from different images into a single image. Segmentation[14] is used to divide an image into multiple regions on the basis of color, intensity, and objects. Image Classification is used to label the group of pixels on the basis of grey values or other parameters. Image analysis is used to make the content of image easy to understand[15],[16]. Diabetic Retinopathy is one of the common eye diseases and a reason of blindness in the world[17].

People in developed countries are mostly become the victim of DR due to the lack of treatment and required resources. People with Diabetes are 25% more likely to become the victim of DR[18]. Features of retinal eye which are used for the detection of DR are blood vessels, exudes, hemorrhages, Microaneurysms, and textures[19]. This feature grows when glucose level reaches to maximum limit and destroys capillaries which then leak blood in retina[20].

In this paper, several image processing techniques used for the detection of Diabetic Retinopathy (DR) will be
discussed. Different Lesion detection techniques used for DR are also presented with appropriate results. Image processing methods are evaluated on the basis of these results. In Section II, some of the latest work on the use of image processing techniques in detection of DR is presented; it will provide an overview of these techniques. Section III will finally conclude the paper.

2. Current Challenges, Trends, and Issues

Diabetic retinopathy (DR) is one of the major causes of blindness in the world. It occurs when diabetes affects the circulatory blood system of eye retina and damages the blood vessels in the retina which leads to partial or complete blindness[21]. The effect of blood leakage from these vessels creates certain lesions in eye retina, e.g., Microaneurysms, Hemorrhages, Neovascularisation, Hard exudates, Soft exudates, Cotton wool spots, and venous loops[22]. Nonproliferative DR (NPDR) and Proliferative DR (PDR) are two types of DR. Stages of DR can be classified as Mild NPDR[23], Moderate NPDR, Severe NPDR, and PDR[24]. Bayesian detection algorithm [25] is used to classify the changes in retinal fundus image in order to diagnose the diabetic retinopathy. This method can detect brightness variation, fundus image artifacts, outliers, and segmentation errors. Segmentation of optical disk, blood vessels, and fovea is performed in order to detect variations in the fundus image. The algorithm can successfully detect lesions, e.g., Microaneurysm, Exudates, and Cotton wool spots. The algorithm is failed to analyze vascular changes in the fundus image.

A new hybrid vessel segmentation algorithm [26] having morphological edge detector with TopHat segmentation technique is used to diagnose Diabetic Retinopathy. The algorithm is tested on DRIVE image database having 20 color images. Their algorithm achieves True Positive Fraction (TPF) of 0.8214 and False Positive Fraction (FPF) of 0.0941. The algorithm can’t detect small image region vessels and Neovascularisation.

Color retinal images [27] are segmented by removing background and noise from the image. It is found that noisy regions in image consume more processing time. Therefore, RGB retinal image is transformed to Hue, Saturation, Intensity (HSI) to perform noise segmentation. After it, Morphological operations are used to remove single pixel noise. Diaretdb0 and Diaretdb1 with 219 retinal images are used as retinal image databases to test the proposed algorithm. 92% images are accurately segmented.

2-D Gabor wavelet based vessel segmentation [28] technique is used to enhance the vascular pattern in retinal fundus image. After image enhancement, unsharp filter is used to remove the blurred effect from the enhanced image and to sharpen the vascular edges. Then, Morphological Dilation operator with Canny edge detector is used to get the final Vessel segmentation mask. Technique is tested on DRIVE database, average accuracy is 0.9469 with Standard Deviation of .0053. K-means clustering [29] and color space features are used to segment exudates, a lesion of diabetic retinopathy. Pixel color list data structure is used to enable faster clustering. In first step, unnecessary fundus mask is removed by applying thresholding, after it color transformation constructed two feature spaces, i.e., f1 and f2. The results of clustering confirm that exudates are bright lesions, and there color is yellow. Method is evaluated using DIARETDB1 dataset and sensitivity of 71.96% with PPV of 87% is achieved.

Bright lesions i.e., Exudates and dark lesions, i.e., Hemorrhages with Micro aneurysms (HAM) are detected on the basis of their intensity values [30]. Firstly, 130 images acquired from DIARETDB0 dataset with their masks. After it blood vessels are extracted using morphological techniques[31]. Then, Morphological Closed and Open operations are used to detect exudates and optic disk. Finally, green channel is used to detect HAM. Sensitivity of 93.1% and Specificity of 80.7% is achieved.

In order to segment the optic disc (OD) from retina image [32], Morphological and Circular Hough Transform techniques are used to proposed a new template based method. MESSIDOR database is used to evaluate the results. When algorithm is applied on 1200 images of database, it is found that overlapping is 0.92 as compare to elliptical and deformable models. The main drawback of their technique is that it can’t generate performance results better than Elliptical approach.

Knowledge based rough segmentation algorithm with unsupervised algorithm [33] is used to detect the retinal vessels in eye fundus image. Ensemble learning based segmentation is used to segment large vessels, after it curve fitting technique is used to detect thin vessels. DRIVE database is used to evaluate the results, sensitivity of 0.8854 and specificity of 0.9363 is found. Adaptive thresholding based on pure splitting technique [34] is used in order to detect exudates in retinal images. Coarse segmentation is used to find the local variations in image pixels, i.e., clear border of image candidates. Morphological operation will then refine the results of Coarse segmentation. DIARETDB1 database is used to evaluate results. Sensitivity of 91.2 with specificity of 99.3 is found.
Gradient vector flow (GVF) based segmentation method [35] is used to segment the optic disc in retinal fundus image. Mean shift term is used to improve the accuracy of GVF algorithm. DRIVE database is used to evaluate the results. Experimental results show that proposed methodology outperforms classical GVF snakes and level set segmentation[36] in term of segmentation accuracy. Lin Lin [37] used threshold based image segmentation, inscribed parallelogram, and ellipse equation to estimate pupil center and radius to identify the diabetic retinopathy. Results shows that algorithm accurately measure pupil size under eye corners and eyelid occlusion.

Flux mechanism and Graph Cut method [38] are used to segment the blood vessels in the retina fundus image. Adaptive Histogram Equalization and Pruning is used to enhance the blood vessels in first step. After it, Graph Cut method is used to perform segmentation. DRIVE and STARE are used as databases to evaluate the technique. True Positive Rate (TPR) of 89.51% on STARE and 77.6% on DRIVE is found.

2-d Gradient Filter with Intensity Adjustment enhancement technique [39] is used to detect and segment Exudates in order to diagnose Retinoblastoma (Rb) and Diabetic Retinopathy (DR). After statistical analysis, Mean and Std Dev of 0.0388 and 0.1877 for Retinoblastoma with Mean and Std Dev of 0.0388 and 0.1790 for Exudative Maculopathy are found.

Rule based classifier with morphological operations [40] is used to detect red lesions from retina fundus images. Median filter is used to increase the visual contrast in pre-processing step[41]. After it, Morphological technique is used for Red Lesion detection. Then, Morphological Closed operation is used to detect blood vessels. Finally, Rule based Classifier[42] will classify red lesion candidates. DIARETDB1 database gives sensitivity of 98% and specificity of 86%. Their method fails to detect red lesions inside fovea during refining process.

Blood vessel and hemorrhage detection algorithm is proposed in [43]. It classifies the stages of DR into three different classes, i.e., normal, moderate, and non-proliferative diabetic retinopathy (NPDR). Blood vessels are detected using Guassian filter; whereas, Hemorrhage candidates are detected using density analysis, and classification is perform at the end. Normal cases are found to be 90% accurate and NPDR were 87.5% accurate.

K.Narasimhan [44] proposed two algorithms consist of filtering operations, i.e., morphological transformation, and region growing methods for the detection of lesions, i.e., MicroAneurysms, Haemorrhages, and Exudates. Accuracy of 95% is achieved for DIARETDB1 database and 92% for a hospital database. Bayessian Neywork with Support Vector Machine (SVM) is used to classify images.

Classification rate of 95% for SVM and 90% for Bayessian is achieved.

M. Usman Akram [45] used Two dimensional Gabor Wavelet[46] with multilayered thresholding technique to proposed a methodology for vessel segmentation to detect neovascularization, a sign of Proliferative diabetic retinopathy (PDR). Gabor Wavelet is firstly used for Vessel enhancement, after it multilayered thresholding is used to create binary mask for vessel segmentation. DRIVE and STARE databases are used to evaluate the proposed technique. Average accuracy of 95% and Std deviation of 0.03 is found.

Parisut Jitpakdee [47] presents a survey on Hemorrhage detection to diagnose diabetic retinopathy from retinal images. Their work review the latest work on common methods used for detection of hemorrhages, e.g., Morphological processing, Neural Network[48], Classification, Region Growing, and Inverse method. Comparison of available methods is conduct on three basis, i.e., Image based, Lesion based, and Pixel based. It is observed Image based and Lesion based have high sensitivity but low specificity.

Extreme Learning Machine (ELM) [49] approach is used to proposed a new methodology for blood vessel detection in retinal images. The output of pixel classification is given to ELM. It calculates grey level and fixed moment features to represent pixels. DRIVE and STARE databases are used to evaluate the results of proposed method. Accuracy of 90% is achieved.

Feature Extraction [50] method is also used to diagnose Diabetic Retinopathy. Adaptive histogram approach is used to extract features. Binary thresholding follows by morphological operation is used to remove small and irrelavent objects from the image. After it, boundary tracing technique is used to detect the optical disk (OD) boundary. DRIVE and DIARETDB1 databases are used to evaluate the results on the basis of area, and centroid of OD.

3. Conclusion

In diabetic retinopathy (DR), retina blood vessels are damaged due to fluid leakage from these vessels. Different lesions, i.e., Exudes, hemorrhages, microaneurysms, and textures are used to detect the stage of DR. In this paper, use of several image processing techniques for DR lesion detection are discussed and evaluated. It is found that early diagnosis of DR can reduce the chance of vision loss upto 50%. Image processing techniques discussed in this paper can detect the DR accurately. Hybrid methodology should be used in order to get better result in terms of accuracy and efficiency for DR detection.

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References


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