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A Survey for Automatic Detection of Non-Proliferative Diabetic Retinopathy

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ABSTRACT: Diabetic Retinopathy (DR) is a common symptom of diabetes which is one of the world's leading causes of blindness. There are many techniques and algorithms that helps to diagnose DR in retinal fundus images. This paper reviews, classifies and compares the algorithms and techniques previously proposed in order to develop better and more effective algorithms.

Keywords: Diabetic Retinopathy, Segmentation, Microaneurysms, Haemorrhaeges, Exudates

I. INTRODUCTION

DR is an eye disease that is associated with persons who are having diabetes more than five years. It is a major cause of poor vision. Recent statistics from Vision 2020: The Right to Sight reported that DR is responsible for 4.8% of the 37 million cases of blindness due to eye diseases throughout the world. The proportion of blindness due to diabetic retinopathy ranges from close to 0% in most of Africa, to 3–7% in much of South-East Asia and the Western Pacific, to 15–17% in the wealthier regions of the Americas, Europe and the Western Pacific. About 50% of persons with diabetes were unaware that they have the condition, although about 2 million deaths every year were attributable to complications of diabetes. After 15 years, about 2% of persons with diabetes will become blind, and about 10% will develop severe visual loss. After 20 years, more than 75% of patients will have some form of DR.

Retinal fundus image consists of a network of blood vessels and an optic disc. The initial stage of DR is NPDR. In this stage, the blood vessels in the retinal become thin and leak fluids, leading to microaneurysm and hemorrhage in case of blood leakage, and exudates in case of fat or protein leakage. Microaneurysm and hemorrhage are red in color while exudates are yellow. Moreover, blood vessels can swell and become fluffy white patches called cotton wool spots. The later stage of DR is Proliferative Diabetic Retinopathy. In this stage, due to circulation problem, the blood vessels in the retina receive inadequate oxygen causing the blood vessels to grow in order to maintain adequate oxygen level. These newly grown vessels are weak and prone to leakage which decreases the vision. Ophthalmologists diagnose DR by either mere eye observation or using computerized systems with complex detection algorithms.

There are varieties of approaches for automatic detection of Microaneurysms (MAs), Haemorrhaeges (HAs), and Exudates in fluorescein angiography retinal fundus images. These approaches are explained in the next section.

II. REVIEW OF METHODS

Meysam Tavakoli et al [1] presented a novel and different algorithm for automatic detection of MAs in fluorescein angiography (FA) fundus images, based on Radon transform (RT) and multi-overlapping windows. Top-hat transformation and averaging filter are applied to remove the background for pre-processing. After pre-processing, the whole image is divided into sub-images. Optic nerve head (ONH) and vessel tree are then detected and masked by applying RT in each sub-image. After detecting and masking retinal vessels and ONH, MAs are detected and numbered by using RT and thresholding. The proposed method is evaluated on three different retinal images databases, the Mashhad Database with 120 FA fundus images, Second Local Database from Tehran with 50 FA retinal images and apart of Retinopathy Online Challenge (ROC) database with 22 images. Results achieved a

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sensitivity and specificity of 94% and 75% for Mashhad database and 100% and 70% for the Second Local Database respectively.

Fangyan Nie et al [3] proposed a novel two-dimensional variance thresholding scheme to improve image segmentation. One drawback of 1D thresholding methods is that only the distribution of the gray levels of an image is considered, whereas the spatial information is ignored. To overcome this problem, 2D variance-based techniques using spatial as well as pixel information have been proposed. This scheme uses 1D summation. It is almost as fast as the original 1D variance-based algorithm. In this scheme, the gray levels of the pixels and the local average gray level of the neighbourhood pixels form a 2D histogram. This 2D parameter space is reduced to a 1D histogram, while assigning equal weights to both variables. Experimental results on bi-level and multilevel thresholding for synthetic and real-world images demonstrate the proposed image thresholding scheme performs well compared with the Otsu method, 2-d Otsu method and the minimum class variance thresholding method.

M. Usman Akram, Shehzad Khalid, Shoab A.Khan [4] proposed a three-stage system for early detection of Mas using filter banks. The proposed system extracts all possible candidate regions for Mas present in retinal image. A feature vector for each region depending upon certain properties, i.e. shape, color, intensity and statistics is formed to classify a candidate region as MA or non-MA. A hybrid classifier which combines the Gaussian mixture model (GMM), support vector machine (SVM) and an extension of multi-model mediod based modelling approach in an ensemble is presented to improve the accuracy of classification. The true MA regions are selected and classified using a hybrid classifier which is a weighted combination of multivariate m-Mediods, GMM and SVM. The proposed system has achieved higher accuracy which is better than previously published methods.

Istvan Lazar and Andras Hajdu [5] proposed a method for retinal MAs Detection through Local Rotating Cross-Section Profile Analysis. This approach recognizes MA detection through the analysis of directional cross-section profiles centered on the local maximum pixels of the pre-processed image. Peak detection is applied on each profile, and a set of attributes regarding the size, height, and shape of the peak are calculated subsequently. Attribute values are used as the orientation of the cross-section changes. These values constitute the feature set that is used in a naïve Bayes classification to eliminate false candidates. The final score of the remaining candidates can be thresholded further for a binary output. The proposed method has been tested with the Retinopathy Online Challenge and proved to be competitive with the existing approaches. The proposed method has achieved higher sensitivity at low false positive rates, i.e., at 1/8 and 1/4 False Positives/image.

Bob Zhang et al [6] have proposed a new method to detect MA based on Dictionary Learning (DL) with Sparse Representation Classifier (SRC). In addition to MA detection, Retinal blood vessels are also extracted using SRC. This method consists of two phases. First all possible MA candidates are identified with the help of Multi-scale Gaussian Correlation Filtering (MSCF). The second step is to classify these candidates with Dictionary Learning (DL) via SRC. Two dictionaries are used in this proposed approach: one for the MA and other for the non-MA. Experimental results on the ROC database show that the proposed method can well distinguish MA from non-MA objects. With the learned MA and non-MA dictionaries, SRC is then applied to the candidates to distinguish MA objects from non-MA objects. Vessel extraction is based on Multi-scale Production of Matched Filter (MPMF) and SRC. First, vessel center-line candidates are extracted using Multi-scale Matched Filtering, scale production, double thresholding and center-line detection. Then, the candidates which are center-line pixels are classified using SRC. Two dictionary elements of vessel and non-vessel are used in the SRC process. The proposed approach is experimented on ROC dataset. Results show that the proposed method is effective and efficient for MA detection.

Cemal Kose et al [7] developed an approach called inverse segmentation method to detect DR. Direct segmentation techniques gives poor results in some of the cases. The proposed system exploits the homogeneity of healthy areas rather than dealing with varying structure of unhealthy areas for segmenting bright lesions (hard exudates and cotton wool spots). This system first generates the reference or extended background image from a retinal image. Healthy parts of the retinal image except for vessel and OD areas are used in the calculation of this reference image. Next the retinal image is divided into two parts as low and high intensity areas based on the intensities of the background image. Background image is used as the dynamic threshold value for segmenting high intensity and low intensity degenerations in the image. Both degenerations are segmented separately by using the inverse segmentation method and dynamic thresholding. The performance of the system is over 95% in detection of the optic disc (OD), and 90% in segmentation of the DR. Therefore, the method provides high segmentation and measurement accuracy. In some cases, the image lighting artifacts may affect segmentation performance negatively, which could also be considered as an issue.

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A two-phase decision support framework [8] is proposed for the automatic screening of digital fundus images. Pre-screening is the first step in which images are classified as severely diseased (highly abnormal) or to be forwarded for further processing. The second step of the proposed method detects regions of interest with possible lesions on the images that previously passed the pre-screening step. These regions will serve as input to the specific lesion detectors for detailed analysis. The computational performance of a screening system is increased due to pre-screening process. Experimental results show that there is a decrease in the computational burden of the automatic screening system.

An Ensemble-Based System [9] is developed for Microaneurysm Detection and Diabetic Retinopathy Grading. This approach has proved its high efficiency in an open online challenge with its first position. Our novel framework relies on a set of <pre-processing method, candidate extractor> pairs. A search algorithm is used to select an optimal combination. Since the proposed approach is modular, further improvements can be done by adding more preprocessing methods and candidate extractors. The DR/non-DR grading performance of this detector in the 1200 images of the Messidor database have achieved a 0.90 ± 0.01 AUC value, which is competitive with other existing methods.

Anderson Rocha et al [10] presented a common approach for identifying both red and bright lesions in DR images without requiring specific pre- or post-processing. The proposed approach requires pinpointing the location of each lesion to allow the specialist to evaluate the image for diagnosis. It constructs a visual word dictionary representing points of interest (PoIs) located within regions marked by specialists. Fundus images are classified as normal or DR-related pathology based on the presence or absence of these PoIs. Area under the curve (AUC) of 95.3% and 93.3% is achieved for white and red lesion detection using fivefold cross validation. The visual dictionary is robust for DR screening of large, diverse communities with varying cameras and settings and levels of expertise for image capture.

Marwan D. Saleh, C. Eswaran [2] provides an automated decision-support system for non-proliferative diabetic retinopathy disease based on MAs and HAs detection. The proposed system extracts some foreground objects, such as optic disc, fovea, and blood vessels for accurate segmentation of dark spot lesions in the fundus images. Dark object segmentation approach is used to locate abnormal regions such as MAs and HAs. Based on the number and location of MAs and HAs, the system evaluates the severity level of DR. A database of 98 color images is used to evaluate the performance of the developed system. Experimental results show that the proposed system achieves 84.31% and 87.53% values in terms of sensitivity for the detection of MAs and HAs respectively. In terms of specificity, the system achieves 93.63% and 95.08% values for the detection of MAs and HAs respectively.

Reliable detection of retinal hemorrhages is important in the development of automated screening systems. Li Tang et al [11] proposed a novel splat feature classification method with application to retinal hemorrhage detection in fundus images. Retinal color images are partitioned into non-overlapping segments covering the entire image. Each splat contains pixels with similar color and spatial location. Features are extracted from each splat relative to its surroundings, employing responses from a variety of filter bank, interactions with neighboring splats, and shape and texture information. An optimal subset of splat features is selected by a filter approach followed by a wrapper approach. Given splats with their associated feature vectors and reference standard labels, a classifier can then be trained to detect target objects. A classifier is evaluated on the publicly available Messidor dataset. An area under the receiver operating characteristic curve of 0.96 is achieved at the splat level and 0.87 at the image level.

Luca Giancardo et al [12] introduced a new methodology for diagnosis of Diabetic macular edema (DME) using a novel set of features based on colour, wavelet decomposition and automatic lesion segmentation. The method proposed for the DME diagnosis is based on the classification of single feature vector generated for each image. The feature vector is based on three types of analysis: Exudate probability map, Colour Analysis and Wavelet Analysis. These features are employed to train a classifier able to automatically diagnose DME through the presence of exudation. The proposed algorithm obtained an AUC between 0.88 and 0.94 depending on the dataset/features used.

Haniza Yazid, Hamzah Arof, Hazlita Mohd Isa [13] presents a new approach to detect exudates and optic disc from color fundus images based on inverse surface thresholding. The proposed approach involves many techniques such as fuzzy c-means clustering, edge detection, otsu thresholding and inverse surface thresholding. It does not depend on manually selected parameters. The proposed method has achieved 98.2% in sensitivity and 97.4% in specificity for DIARETDB1 database and 90.4% in sensitivity and 99.2% in specificity for the National University Hospital of Malaysia (NUHM), respectively. This method outperforms methods based on watershed segmentation and morphological reconstruction.

Atul Kumar, Abhishek Kumar Gaur, Manish Srivastava [14] implements a method that segment the exudates from the image using feature based segmentation. The methodology is composed of morphological operation with the SVM

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algorithm. Image pre-processing is the first step to enhance the image for better analysis. Then morphological operation is implemented to localize the optic disk from the retinal fundus image. Features are extracted using combined 2DPCA for classification. The SVM classifier uses these extracted features for classifying the exudates. The results of the algorithm is compared with expert hand-drawn ground-truths. The proposed method has achieved sensitivity and specificity as 97.1% and 98.3% respectively.

C.JayaKumari, and R.Maruthi [15] have presented contextual clustering algorithm to detect the presence of hard exudates in the fundus images. After the pre-processing stage, the proposed algorithm has been applied to segment the exudates. Features extracted from the segmented regions are like the standard deviation, mean, intensity, edge strength and compactness. These extracted features are given as inputs to Echo State Neural Network (ESNN) to discriminate between the normal and pathological image. A dataset consists of a total of 50 images have been used to find the exudates. Out of 50, 35 images consisting of both normal and abnormal are used to train the ESSN and the remaining 15 images are used to test the neural network. The performance of the proposed algorithm has obtained 93.0% sensitivity and 100% specificity in terms of exudates based classification.

III. CONCLUSION

Early signs of DR can be diagnosed by the presence of microaneurysms and hemorrhages in fundus images. The need for effective detection algorithms is inevitable. There are several detection algorithms that have already been developed and proposed which perform satisfactorily. This paper can act as a resource for the future researchers interested in automated detection of abnormal signs of DR and help them to get an overview of this field in order to develop more efficient algorithms.

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