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Diabetic Retinopathy Detection Techniques: A Review

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Abstract: The information that is stored within the pixels of images is processed through image processing technology. For detecting different kinds of diseases, the medical image processing Based approach is applied. The diabetes patients might suffer from a disease in which certain spots are created on the eyes of patients. The approach through which this disease known as diabetic retinopathy can be detected is based on image processing. There are two phases in which the diabetes retinopathy can be detected through image processing. Feature extraction is the initial phase of this approach. Classification is applied in the second phase of this technique. In this paper, various diabetic retinopathy detection techniques will be reviewed in terms of various parameters

Keywords: *Diabetic Retinopathy, Feature Extraction, Classification, Segmentation*

1. Introduction

1.1 Diabetic Retinopathy

Diabetic retinopathy is major cause of impaired vision worldwide. At the primary phases of DR, several abnormalities in the fundus of the eye affect the microvasculature of the retina. These anomalies include microscopic aneurysms, signs of vascular hyperperme ability, exudates and capillary closure. The lesions of this disease are generally considered to be reversible and retinopathy may progress slowly in the early stages of the disorder. Detecting and treating DR at an early stage is crucial due to its progressive disorder and its severity is occurred according to the number and type of lesions in the fundus imagery. This disease has 2 levels: PDR and NPDR [1]. Non-proliferative diabetic retinopathy is known as a background of DR. The diabetes weakens the blood vessels within retina which causes this disease as the blood is leaked out at the surface of retina. This leakage leads to diminish the sensitivity of the retina when it becomes wet and swollen. Computerized detection of diabetic retinopathy assists in saving much time and effort. Several image pre-processing techniques have also been proposed in order to detect DR.

1.1.1 Diabetic Retinopathy Detection Process

The screening of Diabetic Retinopathy is done using easily using a CAD system which is capable of differentiating a diseased retina from the normal one. A general procedure to detect the Diabetic Retinopathy is planned on the basis of image processing consisted of various phases in which image is pre-processed, dark object is segmented, spot lesions are classified and Rule-based grading is performed. Figure 1 depicts the procedure to detect the Diabetic Retinopathy.

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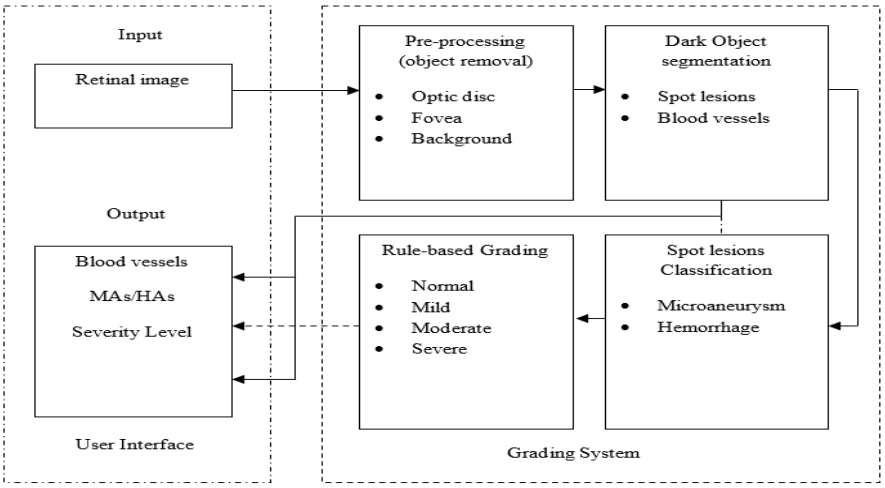

Fig 1: Diabetic Retinopathy Detection Process

Following are the stages involved in the detection of diabetic retinopathy disease:

a. Input image: It is the colour picture of human retina. Generally, a fundus camera is used to click the image of eye retina. The output is the binary image. This image indicates that the MAs and/or Has are present and the severity of diabetic retinopathy disease [2].

b. Pre-processing: This phase is executed to prepare the retinal fundus image so that the disease was segmented. For example, sometimes, image capturing takes place under some complex conditions. This creates non-uniformly illumination, noise or poor contrast in pictures. These types of images generally affect the efficacy of the segmentation algorithm. Therefore, it is essential to apply several image pre-processing methods. Some extensive techniques used to pre-process the images are defined as:

- Green-channel extraction: In this process, the colored test images are partitioned into 2 parts according to their size. Then, green-channel assists in creating the maximal local contrast among the values of image pixels through the components of color image. Firstly, the extraction of green-channel I_G is performed from the color image due to the uniqueness of micro aneurysms and hemorrhages features.
- Optic disc removal: In this stage, the important attributes of retina are removed from the photograph of retina. Typically, Optic disc (OD) has some features. These features depict its correct position within the photograph. Few opaque artifacts may occur in this part of the eye [3]. Sometimes, these objects may be mistakenly identified as MAs or HAs. Hence, extraction of the OD contributes significantly in the elimination of these puzzling objects. Owing to the placement of the camera, the position of OD is found in the middle third of the photograph. Hence, the methods for optic disc removal generally consider the middle third part of the green intensity photograph f_G as the required area. After it, a filtering approach is employed to process the image of eye retina. Median filter is used for the preprocessing of retinal image as a filtering method.
- Background Extraction: The fundamental goal here is to eliminate background discrepancies in brightness from a photograph. This process simplifies the analytic process of forefront artifacts. At first, it is essential to improve the contrast of the mage contrast so that an optimized converted image for the forthcoming image analysis processes can be obtained. There are various factors that make the image contrast poor. With the time, researchers have presented several methods for improving the contrast of captured images. Some commonly used methods are AHE, HE, CLAHE and so on.

c. Dark spot segmentation: In this process, different steps are implemented to segment the dark spot lesions in competent way. The steps involved have been explained below:

- h-Maxima transformation: The strategy of H-maxima transformation is applied in this stage to the processing of the pictures obtained from the preceding stage. This key objective of this step is to lower the amount of brightness levels. 'I' being an intensity photograph, all the maxima in it are suppressed using the H-maxima transform. This key objective of this step is to lower the amount of brightness levels. This image now has values below a set threshold h. This is denoted as:

$$\mathrm{H}_h(\mathrm{I}) = R_I^{\delta}(I - h)$$

In the above formula, R_I^{δ} denotes the morphological reconstruction using image dilation I. in general, all images have different quality level. The quality of an image depends on the condition in which it is captured [4].

- Thresholding: This step applies thresholding approach on the intensity image H_h for segmenting both MAs and HAs. The key purpose of this approach is to create a

binary image with pixel value. On the other hand, the existing thresholding approaches are not able to give precise outcomes for all images. In this approach, a multilevel thresholding process is applied on the images before converting these images into black& white. This process simplifies the process of threshold value selection. This sort of thresholding decreases the number of intensity levels so that a gray-scale image can be transformed into an indexed image.

- Feature extraction: The output of thresholding step are blood vessels and few irrelevant pixels as false positives in the achieved binary picture. Consequently, certain post-processing methods must be applied for the image refinement with the required artifacts. These objects generally include MAs (Micro aneurysms) and HAs (Hemorrhages).

d. Dark spot classification: It is possible to classify a number of spot lesions using important features. The research community has classified diabetic retinopathy disorder based on the extent of seriousness through various classification algorithms. The most common algorithms applied to classify this disorder include NB (Naive Bayes), SVM (Support Vector Machine), DT (Decision Tree), K Nearest Neighbor etc. [5].

e. Severity level grading: There are generally four scales in which the risk level of diabetic retinopathy disorder can be classified. The severity level of this disorder increases as the scale increases. The first level is denoted as "normal" or "no apparent retinopathy". This level signifies the normalcy of the eye retina. The next level is represented as "mild NPDR". This level indicates the presence of just MAs (Micro aneurysms) in the retina of eye. The next level is denoted as "moderate NPDR," This level indicates the substantial growth in the severity level. The last level of "severe NPDR" is the riskiest level of DR (Diabetic Retinopathy) disorder.

1.1.2 Classification algorithms

Once the valuable features from the retina image are extracted, the next step is to implement a classification algorithm on these features so that the disease can be classified on the basis of risk level. The values achieved by measuring all extracted features are given to different classifiers. Following are the some commonly used classification algorithms:

a. Support Vector Machines: SVMs are usually employed for classification purpose. This algorithm has the ability to handle many continuous and categorical variables in competent way. In this approach, a hyperplane is generated in the multidimensional space so that all classes can be separated from each other. This hyperplane is generally used to minimize the errors. This algorithm works on the theory of exploring a maximal marginal hyperplane (MMH). This hyperplane can optimally divide the dataset into classes. In this algorithm, support vectors denote the data points, nearest to the hyperplane. These points compute margins so that the separating line can be described more efficiently. The role of these points is quite significant in the development of a classifier. These data points separate the given dataset in the best manner [6].

b. K Nearest Neighbor: KNN (K-Nearest Neighbors) is a commonly used popular ML (Machine Learning) algorithm. Different purposes such as intrusion detection, data mining and pattern recognition can be served using this algorithm. This algorithm does not assume anything regarding the allocation of data. This algorithm makes use of some already existing data. This data performs the classification of coordinates into groups, identified by a feature. This algorithm is utilized to compute the distance between data points. This distance is referred as Euclidean Distance. Below is the formula using which the distance between data points can be measured:

$$d(p,q) = d(q,p) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \cdots + (q_n - p_n)^2}$$

$$= \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2}$$

In this formula, variable 'n' represents the number of dimensions or features in machine learning. According to the assumption, the data point located at the minimal distance from the test point belongs to the same class that a test point has. This formula does the same in n number of dimensions. Therefore, this formula can be easily implemented with n number of features.

c. Decision tree: Decision tree is a very popular approach which is generally used for classification and prediction. Every internal node in a DT is the representative of a test on an attribute. The output of tests, on the other hand, is presented by each twig of this configuration. Also, each leaf node is assigned a class label. This node is called the terminal node. For tree learning, the source set is divided into subsets depending on the feature value test. This operation is iterated over all the resulting subsets. This classification framework can be built without any domain knowledge or parameter setting. This classifier is able to handle the huge volume of data and generally produces very accurate outcomes.

2. Literature Review

Yash S. Boral, et.al (2021) suggested an algorithm in which an enhanced technique of detecting DR (Diabetic Retinopathy) was incorporated in order to boost the efficacy [7]. The TL (transfer learning) technique was established to customize the diverse function of Inception V3 utilized to classify the image. SVM (Support Vector

Machine) algorithm was utilized to classify the input images as DR affected and no-DR images. The outcomes obtained in experiments depicted that the suggested algorithm was useful to detect the DR and offered higher accuracy.A cost-effective computer-aided screening system was projected by Md. Mahmudul Hasan Sabbir, et.al (2020) using which DR (Diabetic Retinopathy) was detected from color fundus images [8]. An Ensemble Learning (EL) model was presented for increasing the efficiency with the integration of various frameworks. Moreover, the texture attributes generated through GLCM were adopted for the training these models due to their efficiency of determining the patterns from any images. The experiments were conducted on MESSIDOR dataset. The outcomes revealed that the voting-based EL technique had yielded the sensitivity around 97.20% and 78.60% specificity in comparison with individual model. A DL (Dictionary Learning)-based scheme was investigated by Narjes Karami, et.al (2017) for detecting DR in automatic way in images [9]. The learned dictionaries of K-SVD algorithm were utilized with regard to the best atomic representation of fundus images. These dictionaries had potential for discriminating the images as normal and the diabetic classes. The results confirmed that the introduced technique was capable of detecting the DR at 70% accuracy for normal images and 90.2% accuracy to detect the diabetic images.A new and hybrid technique was intended by Anas Bilal, et.al (2021) to detect and classify the DR (Diabetic Retinopathy) [10]. The distinctive models were integrated for the robustness of procedure of detecting DR when the classification was carried out on the basis of the majority voting technique. The images were pre-processed to enhance the abnormality presence. The adequate attributes were obtained in the feature extractions stage and three classifiers namely SVM, KNN and BT were utilized to classify the images. The accuracy obtained from the intended technique was calculated 98.06%, sensitivity was 83.67% and specificity was 100%. An automatic system was presented by Elaouaber Zineb Aziza, et.al (2019) for detecting the DR from the color fundus images [11]. This system was relied on segmenting the blood vessels and focused on extracting the geometric attributes so that DR was detected at primary phases. The blood vessels were segmented using Hessian matrix, ISODATA algorithm and active contour. In the end, the DT model was adopted with the purpose of classifying the images as DR and no-DR.DRIVE and Messidor datasets were employed for testing the presented system. Finally, the obtained outcomes confirmed the efficiency of the presented system while detecting Diabetic Retinopathy at higher accuracy in contrast to the traditional techniques. A computer based technique was designed by Arwa Gamal Eldin, et.al (2020) which was able to overcome the limitations of SVM (Support Vector Machine) algorithm to perform the classification [12]. For this, this algorithm was incorporated in NNs (Neural Networks) so that the DR (Diabetic Retinopathy) was detected from fundus images. The major goal of the segmentation methods was to process the fundus images for detecting the attributes namely blood vessel area, MA (micro aneurysms) and texture. IDRiD database was utilized in the testing of the designed technique. This database was consisted of 516 images using which testing and classification was done into three classes: healthy, DR affected and MA. The designed technique offered optimal outcomes with accuracy of 96%, sensitivity of 98% and specificity of 67%.A new and automatic technique was established by Pan Junjun, et.al (2018) to detect the DR with the implementation of DCNN (Deep Convolutional Neural Networks) [13]. The ROIs (region of interests) were recognized using an attention mechanism to assign score to particular region called RSM (regions scoring map). This approach was assisted in scoring diverse areas of retina image for highlighting the discriminative ROIs with regard to image severity level. The experiments were performed on 5000 images for quantifying the established technique. The results depicted that the established technique performed more efficiently with RSM for locating the discriminative areas of the input image.A novel automatedHPTI-v4 (Hyper parameter Tuning Inception-v4) mechanism was investigated by K. Shankar, et.al (2020) for detecting and classifying the DR from color fundus images [14]. The pre-processing phase adopted the CLAHE model to improve the contrast level of the fundus image. Moreover, the adequate attributes were extracted from the segmented image using the investigated mechanism. The MLP (Multilayer Perceptron) was implemented to classify the images with regard to the extracted attributes. MESSIDOR dataset was utilized in the experimentation for computing the investigated mechanism. The results proved that the investigated mechanism outperformed the existing algorithms. An innovative technique was suggested by Tahira Nazir, et.al (2020) on the basis of Faster RCNN (Region-based Convolutional Neural Network) for tackling the issues related to techniques which were employed to detect the DR (Diabetic Retinopathy) lesions and precisely detecting the early symptoms [15]. First of all, the images were pre-processed and the abnormalities of DR such as MA (micro aneurysms) and hemorrhages etc. were localized later on. Diaretdbl and Messidor datasets were applied to validate the suggested technique. The suggested technique provided 95% accuracy and 94% IOU (Intersection over Union). Moreover, the outcomes generated from this technique were found superior to existing methods. A CAD (computer-assisted diagnosis) was introduced by Enrique V. Carrera, et.al (2017) based

on the digital processing of retinal images so that DR was detected at initial phase [16]. This approach was adaptable for the categorization of the grade of NPDR at any retinal image automatically. The attributes were extracted by isolating the blood vessels, MA, etc. in the primary phase of image processing. The SVM (Support Vector Machine) utilized these attributes for recognizing theretinopathy grade of each retinal image. A dataset, containing 400 retinal images at which labels were assigned in accordance with a 4-grade scale of NPDR, was utilized in the testing of introduced approach. The outcomes revealed that the introduced approach provided the sensitivity up to95% and a predictive capacity around 94%. An automated system was presented by C. Jayakumari, et.al (2020) for detecting and classifying the DR (Diabetic Retinopathy) on the basis of Image Net model so that superior accuracy was obtained [17]. The presented system was quantified and analyzed on public dataset Kaggle. The presented system performed well and detected and classified DR effectively. This system provided the accuracy up to 98.6% in training phase. The presented system was trained with more number of images to increase the accuracy. Navoneel Chakrabarty, et.al (2019) emphasized on constructing an Automated System for differentiating the diseased eyes from normal eyes on the basis of HRFI of the Retina [18]. The images were processed using diverse methods such as Greyscale Conversion, Thresholding and Binarization. A hybrid of FF-CNN-SVM (Feedforward Convolutional Neural Network-Support Vector Machine) had employed these images for their classification as DR and no-DR. The outcomes proved that the constructed system provided an accuracy of 100% as compared to traditional techniques. Dinial Utami Nurul Qomariah, et.al (2019) discussed that the severity of DR (Diabetic Retinopathy) was prevented by detecting it in advance [19]. A DL (deep learning) technique was implemented to extract the attributes and classify the disease via SVM. CNN algorithm had generated high-level attributes of last fully connected layeron the basis of TL (transfer learning) which were utilized for input in SVM to perform the classification. The CNN was capable of mitigating the computation time. Messidor database with base 12 and base 13 was applied for testing the presented approach. The experimental outcomes validated that the presented approach had acquired the accuracy of95.83% for base 12and 95.24% for base 13.

Comparison Table

Author/Year	Technique Used	Dataset	Advantages	Disadvantages
Yash S. Boral, et.al. 2021	Hybrid Neural Network	Kaggledatabase	The suggested algorithm was useful to detect the DR and offered higher accuracy.	This algorithm was not able to deal with the effect of unstable image
Md. Mahmudul Hasan Sabbir, et.al. 2020	A cost-effective CASS	MESSIDOR dataset	The voting-based EL technique had yielded sensitivity around 97.20% and 78.60% specificity.	This system was ineffective in application of soft majority voting
Narjes Karami, et.al (2017)	Dictionary Learning-based algorithm	Kaggle database	The introduced technique was capable of detecting the DR at 70% accuracy for normal images and 90.2% accuracy to detect the diabetic images.	This algorithm was not bal to classify the diabetic images in different categories.
Anas Bilal, et.al. 2021	A new and hybrid technique	IDRiD	The accuracy obtained from the intended technique was found higher for detecting the DR	This hybrid technique had provided poor performance in some scenario when the complex data was present.
Elaouaber Zineb Aziza, et.al. 2019	An automatic system	DRIVE and Messidor databases	The efficiency of the presented technique was confirmed for detecting Diabetic Retinopathy at higher accuracy	This technique was found inapplicable to screen the disease using other attributes with retinal vessels.

Arwa Gamal Eldin, et.al. 2020	A computer based technique	IDRiD database	The designed technique offered optimal outcomes while detecting DR with regard to accuracy, sensitivity and specificity.	The recall obtained from the technique was found lower.
Pan Junjun, et.al. 2018	DCNN (Deep Convolutional Neural Networks)	EyePACS	The established technique performed more efficiently with RSM for locating the discriminative areas of the input image.	The severe class imbalance problem was not resolved using this technique.
K. Shankar, et.al. 2020	A novel automatedHPTI-v4(Hyper parameter Tuning Inception-v4) mechanism	MESSIDOR dataset	Theinvestigated mechanism was employed as an automated diagnostic tool to detect the DR images.	This mechanism was not adaptable in the application of classification models.
Tahira Nazir, et.al (2020)	Faster RCNN (Region-based Convolutional Neural Network)	Diaretdbl and Messidor datasets	The suggested technique provided 95% accuracy and 94% IOU (Intersection over Union).	This technique was not useful to detect other retinal image diseases such asCataract, Age-related MacularEdema degeneration
Enrique V. Carrera, et.al. 2017	CAD system	Messidor database	The introduced approach provided the sensitivity up to95% and a predictive capacity around 94%.	The soft exudates, besides hard exudates were not effectively detected by this approach.
C. Jayakumari, et.al. 2020	An automated system	Kaggle	The presented system performed well and detected and classified DR effectively. This system provided the accuracy up to 98.6%.	This system was not performed well when more images of all categories were present.
Navoneel Chakrabarty, et.al. 2019	A hybrid of FF-CNN-SVM (Feedforward Convolutional Neural Network-Support Vector Machine)	High Resolution Fundus (HRF) Image Database	The outcomes proved that the constructed system provided an accuracy of 100% to detect DR.	This system was incapable to work with larger datasets.
Dinial Utami Nurul Qomariah, et.al. 2019	DL (deep learning) technique	Messidor database	The presented approach had acquired the accuracy of95.83% for base 12and 95.24% for base 13.	The efficiency of this approach was mitigated in case of a huge amount of data and classes.

3. Conclusion

Diabetic Retinopathy is considered one of the main health problems. In the diabetes patients, the bloods vessels of retina are damaged and the DR disease takes place. The people who have uncontrolled high blood sugar levels and the persons who suffer from the diabetes of 1 or 2 type are easily affected by this disease. Only mild vision loss issues occur at the starting of this disease. But at the last stage complete a patient can face blindness. The major cause of vision loss is the uncured DR in the United States, as per the report provided by National Eye Institute. Early stage detection and constant screening are the most

effective ways to prevent this disease. Various techniques for detecting DR are reviewed and it is analyzed that machine learning methods are maximum efficient in terms of various parameters.

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