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Machine Learning for Diabetic Retinopathy Detection using Image Processing

Ujwala W. Wasekar, R. K. Bathla

***Abstract:** The disorder of Diabetic Retinopathy (DR), a complication of Diabetes that may lead to blindness if not treated at an early stage, is diagnosed by evaluating the retina images of eye. However, the manual grading of images for identifying the seriousness of DR disease requires many resources and it also takes a lot of time. Automated systems give accurate results along with saving time. Ophthalmologists may find it useful in reducing their workload. Proposed work presents the method to correctly identify the lesions and classify DR images efficiently. Blood leaking out of veins form features such as exudates, microaneurysms and haemorrhages, on retina. Image processing techniques assist in DR detection. Median filtering is used on gray scale converted image to reduce noise. The features of the pre-processed images are extracted by textural feature analysis. Optic disc (OD) segmentation methodology is implemented for the removal of OD. Blood vessels are extracted using haar wavelet filters. KNN classifier is applied for classifying retinal image into diseased or healthy .The proposed algorithm is executed in MATLAB software and analyze results with regard to certain parameters such as accuracy, sensitivity, and specificity. The outcomes prove the superiority of the new method with sensitivity of 92.6%, specificity of 87.56% and accuracy of 95% on Diaretdb1 database.*

***Keywords:** Classification, Diabetic Retinopathy, KNN, Lesions, Optic Disk segmentation*

I. INTRODUCTION

Diabetic retinopathy (DR) is a severe condition of diabetes that causes harm to the retina and can even makes a person blind. This disease damages the blood vessels in the retinal tissues. The damaged blood vessels leak fluid and pervert eyesight. Retinal tissue gets blood supply through the vasculature of retina. The retinal tissue should maintain the blood glucose level with the continuous blood flow. An abnormal state of glucose levels in the retina's blood vessels gives rise to microaneurysms (MAs). MA is an early symptom of diabetic retinopathy [1]. Generally, MAs are circular shaped, small sized and darkish in nature. Afterward, anomalous retinal blood vessels may rupture into a micro-vascular network, known as retinal neo-vascularization. Diabetic retinopathy also comprises other irregularities, such as cotton wool spots, Haemorrhages (HA), exudates. All these irregularities cause permanent sightlessness and visual disability. Regular eye check-up and diabetes control can protect one's vision from this condition. An automated screening system for DR not only reduces the chances of complete vision loss, but also the work load of ophthalmologists. For DR screening, a computer-aided diagnostic (CAD) system is developed that can differentiate a retina with possible DR from a normal retina. A general process of DR detection based on image processing includes several stages. These stages are input image, pre-processing, dark object segmentation, spot lesions classification, rule-based grading. Input image refers to the color image of human retina. Image acquisition causes non-uniformly illuminated, noisy or poor contrast images. Fundus camera analysis gives better results than optical coherence tomography [6]. Pre-processing helps in the preparation of retinal fundus image for segmentation. Segmentation helps in analyzing the image pattern [2]. Some commonly employed pre-processing methods are green-channel extraction, optic disc removal, and background normalization. Green channel creates maximal local contrast among the values of image pixels with the components of color image (i.e., red, green, and blue). In optic disk removal, optic disc is removed from the image of retina. Optic disc occurs in the middle of the image because of the location of the image capturing device [3]. Median filter is a popular filtering approach, used for noise removal. MAs and HAs come in the category of dark spot lesions. Dark lesion segmentation involves h-maxima transformation, thresholding and ultimately, feature extraction. The h-Maxima transformation step applies h-maxima transform for the processing of images attained from the pre-processing step [4]. Thresholding is a commonly used image segmentation approach. The thresholding process results in the occurrence of blood vessels and some redundant pixels as false positives. Proper blood vessel segmentation technique can enhance the performance [7]. Feature extraction process is concerned with applying certain post-processing methods for refining the image and holding the required objects [5].

A number of researchers have presented many classification algorithms for the classification of a disorder on the basis of its risk level. Some commonly employed classification algorithms are Support Vector Machine (SVM), k Nearest Neighbor (kNN), Decision Tree, etc. SVM model refers to a supervised machine learning model [35]. This model has been successfully used for classification and regression issues. However, it is most commonly used in a classification problem. The main idea of SVM is to discover a hyperplane that can clearly classify the data.

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* Correspondence Author
Ujwala W. Wasekar*, Department of Computer Science, Desh Bhagat University, Mandi Gobindgarh, India. Email: ujwalazade@rediffmail.com
R. K. Bathla, Department of Computer Science, Desh Bhagat University, Mandi Gobindgarh, India. Email: dr.bathla@gmail.com

Hyperplane refer to as decision boundaries. These help in the classification of the data points. Decision tree is a very popular classification approach. In this configuration, each internal node refers to a test on a feature. All branches of this tree represent the tested outcomes.

Also, a class label is assigned to every leaf node. This node is known as terminal node. The partitioning of source set is performed into subsets on the basis of a feature value test for tree learning. This process is repeated again and again on all resultant subsets. This process is referred as recursive partitioning. The recursion is finished after the subset at a node get the value same as the target variable, or when partitioning no longer inserts value to the predictions. There is no need of any domain knowledge or parameter setting for generating this classifier. Generally, DR can be classified into five categories. They are Normal, Mild Non Proliferative Diabetic Retinopathy (NPDR), Moderate NPDR, Severe NPDR, and Proliferative Diabetic Retinopathy (PDR). Fig. 1 depicts the normal and abnormal retina [31].

This paper presents an approach to maximize the DR detection rate. Selection of features of lesions and classifier has been done carefully to classify images accurately and minimize the execution time. Rest of the paper is organized as follows: section II represents the literature review of the works done in the past. Section III represents the research methodology adopted in the proposed work. Section IV manifests the experimental results obtained after implementation of the algorithm. Section V concludes the work.

II. LITERATURE REVIEW

Researchers have reported some technical work in the computer-aided detection of diabetic retinopathy based on image processing. Kumar and Kumar [8] suggested an enhanced DR detection system for exact region and numerous MA were extracted from color fundus images. Deperlıoğlu and Kose [9] emphasized on implementing the image processing and DL process for the diagnosis of DR from retinal fundus images. Arora and Pandey [10] intended a DL algorithm that was capable of recognizing the pattern and classifying the retina images into one of the five-class based in automatic way. Qiao, Zhu and Zhou [11] recommended PMNPDR in which Deep Convolutional Neural Networks were developed for segmenting the fundus images semantically. The fundus image was classified as non-infected or infected using the semantic segmentation algorithm that assisted in maximizing the efficacy and precision. Ekatpure and Jain [12] introduced a technique to automatic detect the DR with eye fundus image. The blood vessels were extracted through Gaussian filter while detecting the red lesions. Trisha and Ali [13] introduced an Optic Disk detection algorithm based on intensity for non-invasive observation. For the analysis purpose, the detection of regions of the retina that was geometrically imperative had required. Nursel, Alver and Uluhatun [14] suggested an approach based on DL to detect the DR from the retinal images. Gautam, Jana and Dutta [15] developed a software-based algorithm for

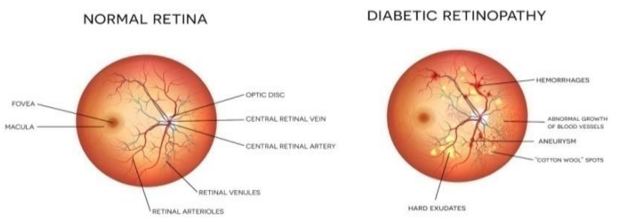

Fig. 1: Normal and abnormal retina [31]

diagnosing the DR at initial phase. The developed method was capable of detecting the diabetic retinopathy earlier without the assistance of any physician due to which time and money was saved. Chakrabarty and Chatterjee [16] recommended an Image processing boosted Hybrid DL-ML approach in order to diagnose the DR. The FF-CNN-SVM Hybrid approach had employed the processed images to determine whether the patient was suffered from diabetes or not. Karami and Rabbani [17] established a DL based technique in order to detect the Diabetic Retinopathy automatically in digital fundus image. This technique was planned on the basis of learned dictionaries through K-Singular Value Decomposition algorithm. Chen, Sun, Zhang, Cao and Liu [18] presented a LFPN for preserving more image details so that the mini lesion instance was detected. The outcomes of experiment depicted that presented technique outperformed the traditional FPN and RCNN. Zeng, Chen, Luo and Ye [19] intended a DL algorithm based on CAD for automatic diagnosing the referable DR. Palani, Venkatalakshmi, Jabeen and Ram [20] established an efficient segmentation technique in which modified FCM clustering was integrated with spatial features and IWPSO to detect the DR. A number of parameters were employed such as TPR, TNR and FPR for analyzing the performance of these techniques. Kajan, Goga, Lacko and Pavlovičová [21] aimed at detecting and classifying the symptoms of DR automatically with the implementation of CNN which was pre-trained. A data set of retinal images was employed and split into 5 kinds on the basis of the grade of retinal damage. Khan, Patel, Meemai and Shukla [22] stated that the DL approach was deployed which assisted in detecting the DR in patients through their retina fundus images. The obtained accuracy was computed 73% that was higher in comparison with the earlier work. Sugasri, Vibitha, Paveshkumar and Bose [23] designed a super-pixel algorithm so that different phases of Diabetes Retinopathy lesions such as exudates, HAs and MAs were detected. The skin locus method was implemented to segment the image and the phases of Diabetic Retinopathy were categorized using SVM classification algorithm along with linear kernel. Hua, Huynh-The and Lee [24] recommended a Convolutional Neural Network based on DRAN for leveraging the learnable integration of channel-wise attention at multi-level attributes within a pre-trained network so that spatial representations of significant Diabetes Retinopathy-oriented factors were included in an unambiguous manner.

Eladawi et al. [25] suggested a CAD system which had potential for diagnosing the early symptoms of Diabetic Retinopathy. Jayakumari, Lavanya and Sumesh [26] suggested an automated system for detecting and classifying DR. To achieve this, ImageNet model was utilized so that a superior accuracy was obtained. The performance of suggested algorithm was compared and analyzed on the public dataset named Kaggle that included retinal images. Nazir, Javed, Masood, Rashid and Kanwal [27] developed an automated model for extracting the anatomy independent attributes and the training of Support Vector Machine algorithm was done for diagnosing various phases of diabetic retinopathy. The performance of the developed technique was quantified on Kaggle DR-data. Pour, Seyedarabi, Jahromi and Javadzadeh [28] recommended a novel DR monitoring model for which CLAHE technique was utilized for the enhancement of image quality and equalization of intensities uniformly as the pre-processing stage. Afterward, the classification was carried out with the deployment of EfficientNet-B5 model. Palavalasa and Sambaturu [29] presented a new technique for detecting hard exudates acquiring high accuracy with regard to lesion level. At first, the BGS technique was applied for detecting the possible candidate exudate lesions in this technique. Carrera, Gonzalez and Carrera [30] introduced a computer-assisted diagnosis planned on the basis of the digital processing of retinal images for assisting people in the earlier detection of DR. This approach aimed at classifying the grade of NPDR on any retinal image in automatic manner.

III. RESEARCH METHODOLOGY

The proposed work is an improvement over the existing work [33]. Fig. 2 illustrates the methodology used in the implementation of this work.

A. *Optic disc elimination*

The optic disc (OD) is the brightest part of the fundus image in a normal eye. This part is always elliptical or oval in shape. In the colored fundus images, the bright yellowish or white area reveals the optic disc. Exudates resemble optic disc in terms of intensity and brightness. Therefore, it is essential to eliminate the optic disc from the retinal image. The image is converted into gray scale and median filtering is applied in order to remove noise from the image. The image is formed and inverted to produce the mask image. For this purpose, the logical black and white function is implemented. This procedure involves the generation of mask image and its elimination from the edge detected image. Disk shaped structuring element was used for the morphological processing. Figure 3 shows the process of optic disc detection.

B. *Blood vessels extraction and removal*

The elimination of blood vessels and OD is very crucial for detecting the microaneurysms (MAs) and exudates. The reason behind this is the similarity of their concentration levels. Green channel of the image is extracted as it gives the maximum contrast. The image contains small holes that need to be removed in order to smooth the background. The structuring elements exist in various shapes. The flat disk

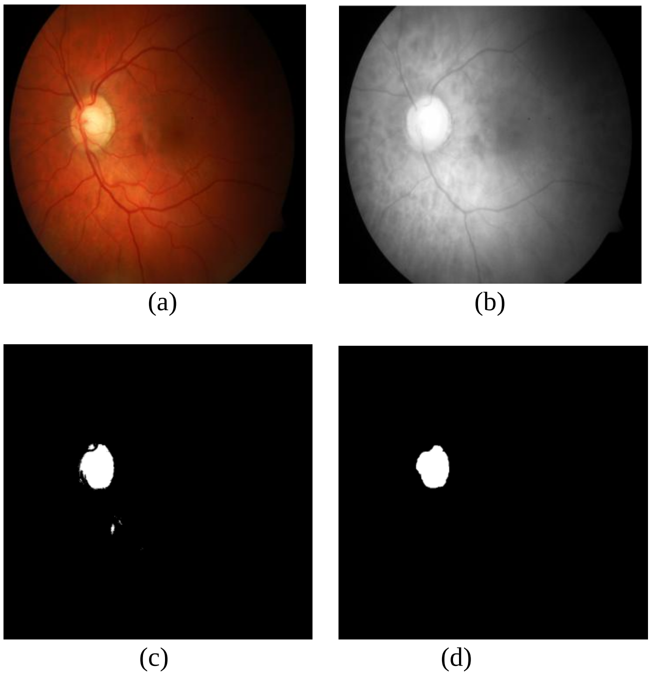

Fig. 3: (a) original image (b) candidate for disc extraction (c) binary disc image after thresholding (d) morphological processed image

shaped structure is executed to eliminate the blood vessels. The image is then gray thresholded and binarized for morphological operations. Haar wavelet transform, upto the level of three, is used to improve the resolution and better analysis. Figure 4 represents the process of blood vessel extraction.

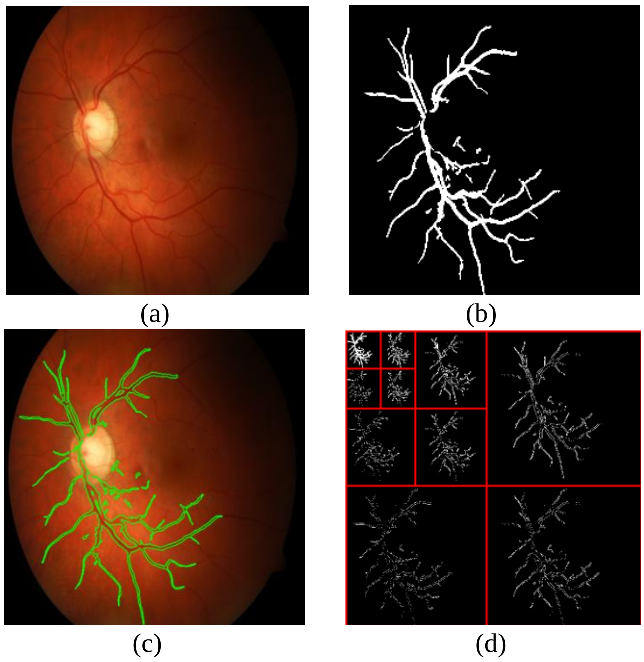

Fig. 4: Blood vessel extraction (a) input image (b) vessels extracted image (c) boundaries detected (d) wavelet transformed image using Haar wavelet

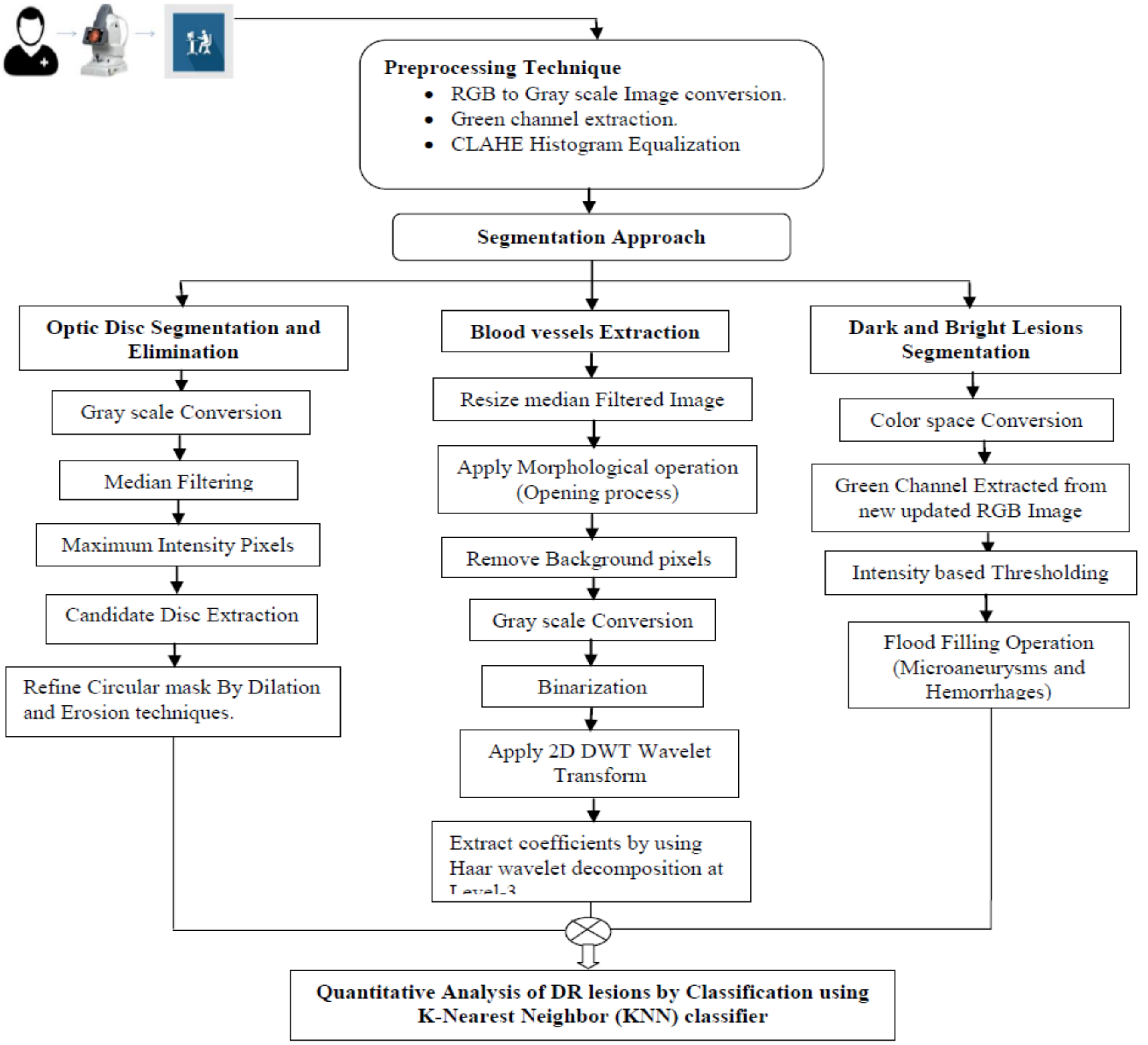

Fig. 2: Building block representation of proposed system for detection of Diabetic Retinopathy (DR)

C. *Detection of exudates and micro-aneurysms*

When the removal of blood vessels and OD from the image is done, the recognition of attributes of exudates is taken place. The bright lesions of retina image are called the exudates. These kinds of attributes are found using the morphological closing operation. This operation is useful for the eroded fundus image. Figure 5 shows the segmented image after removal of optic disc and blood vessels.

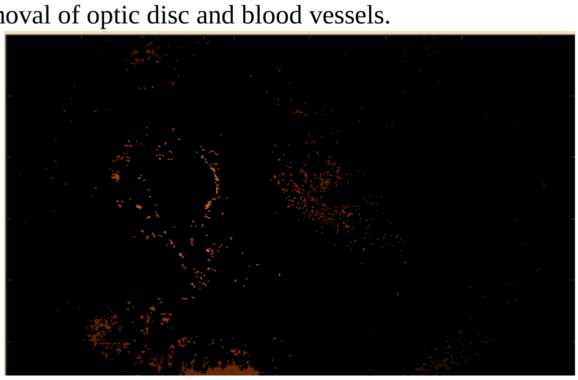

Fig. 5: segmented image

D. *Classification*

The issues related to classification and regression can be easily tackled with the implementation of K-Nearest Neighbor. This algorithm assists in dealing with the classification problems extensively. It is simple and easy to implement [36]. The value of KNN is computed on the basis of Euclidean distance. It is the distance between the test sample and the particular training samples. The Euclidean distance between sample x_i and x_j (i, j=1, 2,…, p) is calculated using the below mentioned equation:

$$d(x_i, x_j) = \sqrt{(x_{i1}-x_{j1})^2 + (x_{i2}-x_{j2})^2 + \cdots + (x_{ip}-x_{jp})^2} \quad (1)$$

$$Ri = \{x \in R_p : d(x, x_i) \leq d(x, xm), \forall i \neq m\} \quad (2)$$

The Voronoi cell is utilized to encapsulate all the neighborhood points which are available nearer to every sample. In the equation, the Voronoi cell is denoted by Ri for sample xi. The x is used to reveal all the points which possibly exist in the Ri. Figure 6 shows the classified images.

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IV. EXPERIMENTAL RESULTS

The MATLAB is employed to deploy the proposed research. The performance evaluation is done on diaretdb1 database [32]. It is a publically available database containing 89 high quality images (in png format) out of which 84 are representative or abnormal images (having at least one sign of DR) and 5 are normal images. Images were taken at 50º field of view using digital fundus camera. Some amount of imaging noise exists in the images. 28 and 61 images were used for training and test purpose respectively. Database contains the ground truth for red as well as bright lesions with annotations labeled by the medical experts. Messidor [34] is also a publically available database consisting of 1200 images in TIFF format. Images were taken using a color video 3CCD camera with 45º field of view. 1200 images are divided into set of 3, which is again subdivided into 4 sets containing 100 images each. The database consist the diagnoses of each image but not annotations as in case of Diaretdb1 database.

The performance of suggested method is compared with the existing method [33] concerning the widely used performance measures accuracy, sensitivity and specificity on both Diaretdb1 and Messidor databases. The results show the efficacy of the proposed work. Specificity, specificity and accuracy are defined as follows:

$$\text{Sensitivity} = \frac{TP}{TP+FN} \quad (3)$$

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (4)$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (5)$$

Where, TP = Correctly classified lesions, TN = Correctly classified non-lesions, FN = Incorrectly classified non-lesions, FP = Incorrectly classified lesions.

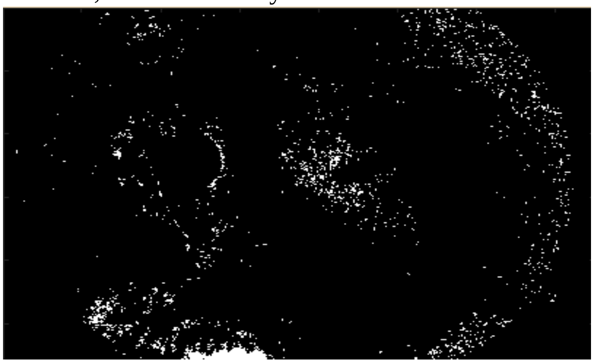

Fig. 6: classified image

Feature extraction is one of the most important steps in the identification of DR as it helps in eliminating the false positives. Four relevant statistical features used in this work are:

- **Contrast**: Contrast is the difference between the intensities of an object and background in an image.
- **Correlation**: Correlation is a quantity measuring the extent of the interdependence of variable quantities.
- **Energy**: Energy is used for optimization purpose.
- **Homogeneity**: Homogeneity gives the statistics related to the change of intensities of an area in the image.

A. *Comparison with Diaretdb1 database*

The proposed work attained the accuracy of 95% as against the existing 92.13%. Specificity of 87.56% as against was achieved as against the existing 80%. Sensitivity of 92.6% was gained which is slightly less than the existing 92.85%. Accurate and less number of features led to less execution time. The system took 32.6 seconds to execute the algorithm.

B. *Comparison with Messidor database*

The proposed work achieved the sensitivity, specificity and accuracy of 92.6%, 87.56% and 95% respectively as against the existing 86.03%, 79.69% and 84% respectively. Execution time of 32.6 seconds is much lesser than the existing 45±0.341 seconds. The obtained results are far better than [33] on Messidor database. Fig. 7 and Fig. 8 indicate the performances of the suggested and the existing algorithm using dissimilar set of images with regard to accuracy and specificity respectively. This reveals that the proposed work provides better results in comparison with the existing work. Table 1 depicts the comparison of the performance measures.

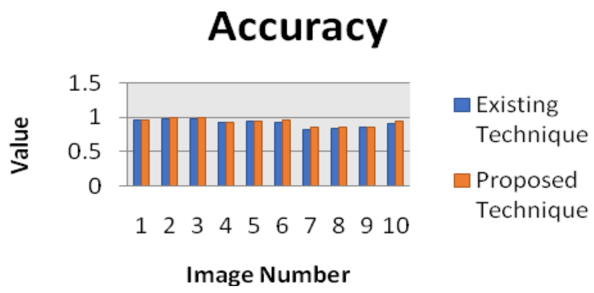

Fig. 7: Performance comparison in terms of Accuracy on Diaretdb1 database

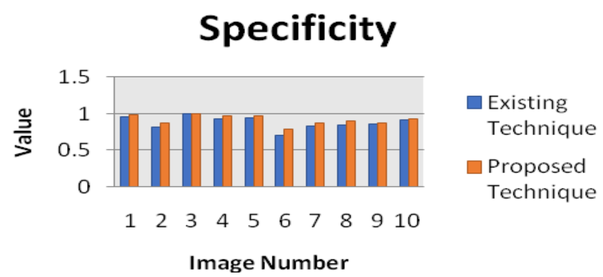

Fig. 8: Performance comparison in terms of Specificity on Diaretdb1 database

Table I: Comparison of performances of the proposed work and existing method [33]

Performance Measure	Performance Comparison		
	[33] on Diaterdb1 database	*[33] on Messidor database*	*Proposed work on Diaretdb1 database*
Accuracy (%)	92.13	84	95
Sensitivity (%)	92.85	86.03	92.6
Specificity (%)	80	79.69	87.56
Total elapsed time (s)	33±0.499	45±0.341	32.6

V. CONCLUSION

The Diabetic retinopathy (DR) is a disease due to which the retina present in a human eye is affected. The permanent loss of sight can be occurred to the affected person in case, the earlier treatment of the disease is not initiated. Earlier, many researchers worked towards the betterment of the performance of the automated systems. However, improvement was needed to build the robust system that can accurately diagnose the problem. The work presented in this paper put forward a method that is capable of identifying true lesions and rejecting false ones. Different preprocessing techniques were used and features were extracted. Evaluation of the algorithm is done on the publically available Diaretdb1 database. The use of k-Nearest Neighbor (kNN) classifier resulted in the achievement of sensitivity, specificity and accuracy of 92.6%, 87.56% and 95% respectively. It is observed that the suggested technique provides better results in comparison with the state of the art technique. In future, the efficacy of performance can be enhanced by using hybrid approach.

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AUTHORS PROFILE

Ujwala W. Wasekar received M.Sc. degree in Computer Science from Nagpur University, Nagpur, Maharashtra in 2003, MCA degree from Maharshi Dayanand University, Rohtak, Haryana in 2009. She cleared University Grant Commission (UGC) National Eligibility Test (NET) in 2018. Currently, she is pursuing Ph.D. in Computer Science from Desh Bhagat University, Mandi Gobindgarh, Punjab. Her area of interest is Machine learning and image processing . She has published many papers in reputed journals.

Dr. R.K. Bathla working as Professor and Head of Department in Computer Science & Applications at Desh Bhagat University, Mandi Gobindgarh, Punjab. He has more than 18 years of experience in the field of Computer Science and Information Technology. He has guided more than Sixteen Ph.D Research Scholars and more than 60 Scholars of M.Tech/M.Phil in Computer Science. He has more than 100 Publications in International Journals in repute. He has served as Dean Engineering and Technology and Dean Research Department. He is an active Panelist of the Research Degree Committee. He is also an active Nodal Officer of SWAYAM/MOOCs.