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A Review on Classification of Diabetic Retinopathy through Deep Learning

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Abstract: Diabetic retinopathy is certainly a common vision disease and a substantial reason behind blindness in diabetics. It is one of the problems of diabetes that affect the eyes. It is a leading reason behind blindness among adults. If not really treated at an early on stage, then it can cause long term blindness. Early detection of the condition is critical once and for all prognosis.The disease could be detected by examining digital color fundus photographs of retina. Regular screening of fundus pictures along with timely supervision might be the most effective way to handle this condition. Manual analysis of fundus images to investigate lexical modification in microaneurysms, hemorrhages, exudates and blood vessels is extremely time-consuming and monotonous work. The large population of diabetics and their enormous screening requirements have produced interest in a computer-aided as well as fully automated analysis of Diabetic Retinopathy. This comprehensive research work attempts to review classification of diabetic retinopathy by using a variety of techniques. Deep neural systems, however, possess brought many breakthroughs in a variety of tasks in the modern times. Today's effort proposes a means for automatic reorganisation of indicative parameters for DR and uses them deliberately in a framework to quality the severe nature of the condition. The diabetic retinopathy detection has various phases which are pre-processing, feature extraction, segmentation and classification. This work will be ideal for professionals and technological person who desire to exploit the on-going research in this area.
Keywords: fundus image, image processing, deep learning, diabetic retinopathy, blood vessels, feature extraction, Classification.

1. INTRODUCTION

This examination work depends on detecting the diabetic retinopathy from human eyes using technology named as image processing. The images of human eyes are collected from various sources and are processed to identify this disease. The following sections will explain this process in detail.

1.1 Introduction to Diabetic Retinopathy

Retina is a part of human eye which faces a disease commonly termed Diabetic retinopathy (DR). Diabetic patient is undoubtedly more prone to chance of DR. In case if the disease is not cured and it keeps growing, a person might be affected with complete blindness. The under developed nations do not have enough trained ophthalmologists and people are also not aware of such disease. In case if proper treatment and some automated tools have been generated, initial care can be provided to patients furthermore the disease can be prevented from growing to further stage. Some effective solutions have been provided to identify DR from images although they include early diagnosis and continuous monitoring of diabetic patients. DR is diagnosed by evaluating the retinal images of patients captured over time. However, the manual grading of images to define the severity of DR is very time consuming together with resource demanding. The blood flow toward all levels of retina is performed through micro blood vessels. Any congestion in these vessels experienced prospects to a significant eyeball destruction. This major problem can only be noticed when the minute blood vessels contained in the retina begin to damage. This minute blood vessel causes outflow of fluid together with blood from the blood vessels due to which retina become swollen and wet. The symptoms of Diabetic retinopathy comprises of micro-aneurysms(MAs), hemorrhages (HMs),exudates (EXs) as well as the irregular growth of blood veins as shown in Figure-1.Based on the severities, DR is distinguishing as normal, NPDR (non-proliferative DR) and PDR (proliferative DR). NPDR is an earlystage of Diabetic retinopathy which is built with the existence of micro aneurysms. After the disease starts growing to the next level, oxygen enter in between the retina and clouding vision because of the generation of new blood vessels that stage is called PDR. The existence of an automatic or computer based analysis can make it very easy for a specialist to observe the retina of diabetic patients clearly. Even when it is possible to analyze few particular features of retina, a reliable or robust technique has not been derived by researchers yet.

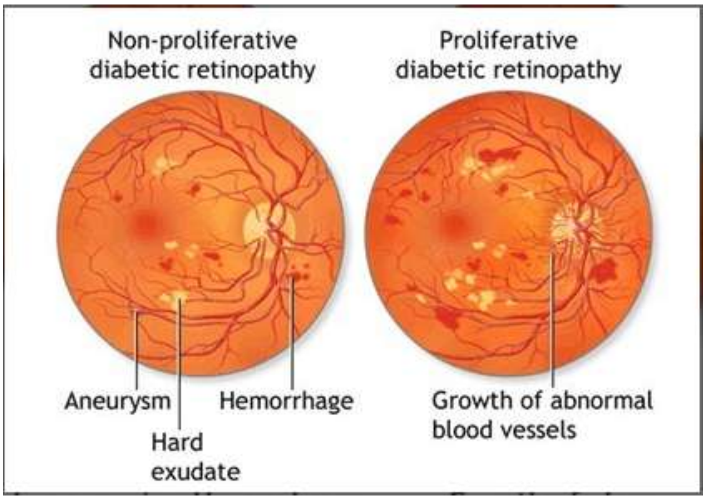

Figure 1: Levels of Diabetic Retinopathy

1.2 General Process of DR

Here is a three-step algorithm which helps in calculating the severity of DR and automatically grades it:-

a. Pre-processing:
The ophthalmic fundus images are used in this automatic process.The pre-processing stage includes few issues such as image blurriness, non-clarity or problems related to image size. In the initial step, the image is resized and then the color space conversion and image restoration steps are performed further. The final stage includes the enhancement of image. In the color space conversion process, the color fundus input image is transformed into HSI (Hue, Saturation and Intensity).

b. feature extraction
The candidate extraction process includes performing different morphological operations for recognizing the micro-aneurysms and exudates features. Feature extraction includes three steps:-

i.Optical disc elimination: Optical disc is the glaring part of a normal eye in the fundus images. The shape of this part is either oval or elliptical. In case of colored fundus picture, the optical disc is presented as a light yellow or white area. The exudates include elevated along with similar intensity values for the optic disc. Therefore, it is very required to exclude the optic disc from the retinal image. The brighter optic disc can be masked and removed with the help of region properties and area recognition processes.

ii. Blood vessels extraction and removal: For the recognition of micro-aneurysms and exudates from the retina images, it is necessary to exclude the blood vessels and optical disc from it since the concentration levels of all these features are same. On an intensity image, dilation is applied so that the high levels contrasts vessels available in blood can be removed. The flat disc shaped structure is applied for removing the optical disc together with blood vessels.

iii. Detection of exudates and micro-aneurysms: After the excretion of blood vessels and optical disc from the image, it is possible to identify the exudates features. Exudates are the bright lesions existing in a retina image.

c. Classification

After recognizing the exudates and micro-aneurysms present in a color image, the features can be extracted from the fundus image. All the features are extracted and different classifiers (such as Convolution Neural Network) are used to which these output values are given as input. This process is described in the figure-2 given below.

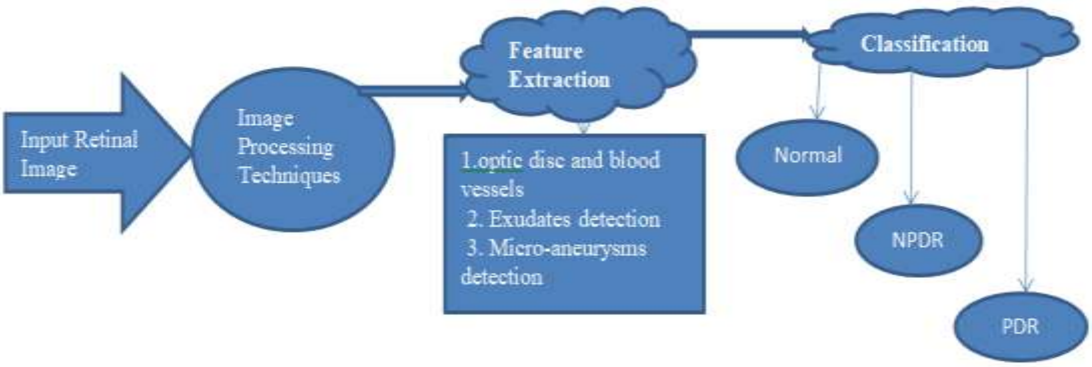

Figure 2: Process of detection and classification of diabetic retinopathy

1.3 **Performance Measures**

In analyzation of the classification,Performance of the classifier is certainly calculated by a confusion matrix. Performance measure includes following parameters and calculated by using the formula given below in Table-1. Here in confusion matrix, 'TP' represents True Positive,'TN' represents True Negative, 'FN' represents False Negative. 'FP' represents False Positive.

Measure	Formula
Accuracy	$\frac{TP + TN}{TP + TN + FP + FN}$

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Misclassification rate (1-Accuracy)	$\frac{FP+FN}{TP+TN+FP+FN}$
Sensitivity(or Recall)	$\frac{TP}{TP+FN}$
Specificity	$\frac{TN}{TN+FP}$
Precision(or positive predictive value)	$\frac{TP}{TP+FP}$

Table 1-Parameters of confusion matrix and their formula

2. LITERATURE SURVEY

AshishIssac, et al. (2018) presented an automatic technique to detect the presence of pathologies which were known to confirm DR. The intensity threshold and anisotropic diffusion were used for identifying the lesions which resulted in rejecting the false positives correctly. The robustness of algorithm was thus, increased here. SVM classifier was applied here along with ten various feature types for rejecting the false positives. To identify the red lesions very accurately, a shade-corrected green channel image was applied. Due to the rejection of false positives with the help of geometrical features, it was possible to minimize the complexity and increase the efficiency of systems [1].

Shailesh Kumar, et al. (2018) designed a noveltechnique to extract the microaneurysm present within the fundus images along with the accurate DR regions. Regular screening of eyes is done for recognizing and handling DR. This approach determined two features which are the number and region of microaneurysm. The pre-processing stage used the previously existing techniques. Further, the microaneurysms were classified efficiently using linear SVM [2].

Enrique V. Carrera, et al. (2017) proposed a novel approach using digital processing to detect the DR from retinal images at initial stage so that it can be controlled. This approach aimed to classify the grade of NDPR in the retinal image in automatic manner. The retinal image which is achieved as output from image processing performed at the beginning was used here to recognize their retinopathy grade by applying SVM. The performance of proposed approach was tested on a database which included 400 retinal images. Based on the 4-grade scale, the images were categorized by this proposed approach. Higher robustness was also achieved by this proposed approach as per the evaluations performed at the end of this research [3].

Nikita Kashyap, et al. (2017) proposed a new technique to identify and retrieve the query image from retinal database. This novel approach mainly included an image retrieval mechanism. The numbers of bins were set in the histogram for designing the retrieval process which helped in extracting the color histogram feature and identifying the feature vector of required size. The similarity among query and database image was checked by calculating the Euclidean distance. The outcomes achieved showed that when color histogram retrieval system was applied in HSV color space, the results achieved were better in comparison to the RGB color space. The proposed approach helped in reducing the tasks performed by professionals while analysing the fundus image[4].

Harini R, et al. (2016) proposed a hybrid approach to detect the Microaneurysms and Exudates from retinal fundus images in which the Fuzzy C-means clustering and morphological processing were combined.The proposed approach helped in segmenting the blood vessel and the morphological operations. A database was generated to implement and test the performance of proposed approach for which images were collected from different hospitals and publically available databases. The images were categorized by applying SVM classifier. This algorithm performed classification on the basis of certain parametric values. Evaluations were performed based on specificity, accuracy and sensitivity which showed that the improvement was of achieved to next higher level [5].

SomchokKimpan, et al. (2017) proposed a new technique for extracting the properties of images. An image retrieval system was applied by extracting the image properties by applying the theory of gravitation proposed by Newton. The center of gravity which includes similar radius was utilized to calculate the force existing among the pixels present within each pixel image. RIFH was applied to extract a unique feature from the image and the outcomes were achieved which showed improvements. Higher numbers of details were provided from retinal DR images to improve the image retrieval so that the doctors could be benefitted for diagnosing DR. Based on the experimental results it was seen that it was possible to detect and retrieve the DR affected images from database efficiently. Thus, this technique provided highly effective outcomes for diagnosing the retinal disorders [6].

Z. A. Omar, et al. (2017) proposed a new algorithm with the objective of improving the accuracy of previously existing approaches such that the DR could be detected more effectively. The methods applied to detect DR features used particular numbers of stages generated by different techniques. The blood vessel and hemorrhages were detected simultaneously due to the similarity in intensity properties. The proposed algorithm was trained and then tested by applying it on 49 and 89 fundus images. Several images from Serdang hospital in Malaysia were collected to be used in training. The images were categorized based on their severity. It was seen through the achieved outcomes that the proposed approach provided highly accurate results for detecting exudates and blood vessels &hemorrhages [7].

V. Mohana Guru Sai Gupta, et al. (2016) proposed a novel approach for discovering the vessels. This approach included various existing approaches which were of less quality and had an estimated locale for the macula position. Based on the results achieved through conducted experiments, it was seen that veins vessels contained less complexity. With the application of Gaussian channel along with morphological administrator, highly efficient results were achieved which had the least computational time. For improving the exactness of proposed technique in future, this work could be extended by generating the edge values which include autonomous image properties [8].

Prof. Dr. S. S. Chorage, et al. (2017) proposed a novel mechanism using which the DR could be detected automatically by using an image database mechanism.A unified framework was used to benchmark the approaches and a clear identification of any kinds of deficiencies present in retina was done here. Thus, when the retinal images were analyzed, it was possible to detect DR very accurately. Based on the severity, a proper treatment could be suggested by the experts and any further growth of this disease could be prevented. Since DR was recognized at initial stages, the automatic DR detection approach could help in preventing the disease to spread [9].

Arisha Roy, et al. (2017) studied the exudates were detected by applying Fuzzy C means and optical disk was detected and removed by applying Convex Hull.The initial processing of fundus images was done for achieving exudates. The optical disk was recognized and its separation from exudates was defined in processing. Further, the fundus images were processed to extract the retinal vessels. Further, the extracted images were trained by applying a two-fold SVM trainer [10].

DevviSarwinda, et al. (2017) presented an investigation of capabilities of texture features found within the fundus images. It aimed to differentiate the images based on their severity level of DR. The LBP method was improved in this paper by calculating the LBP original and magnitude values of fundus images. This study performed four experiments for two different databases. The selection of kernel PCA was done according to the feature selection method and tests were performed for evaluating the performance of proposed method. The binary classification of 100% is achieved for DR-Normal and AMD-Normal images. It was seen that this proposed approach detected the DR successfully by applying diagnosis aid systems [11].

Carson Lam, et al. (2018) demonstrates the utilization of convolutional neural networks (CNNs) on color fundus images for the reorganization activity of diabetic retinopathy setting up. We additionally looked into multinomial classification models, and illustrate that errors generally occur in the misclassification of minor as normal disease mainly due to the CNNs incapability to recognize disease features. They concluded that occurrence of vessel is affecting positively meant for detecting both much more and larger DRs Severity. These types of result advise that the vessel carry information not merely designed for higher DRs Severity but in addition for cheaper severity. Earlier DR, an alteration in vessel is normally already happen, which is normally invisible to naked eyes, leading blood vessels to produce micro-aneurysm [12].

Yuji Hatanaka, et al. (2018) proposed a great automatic MA detector that combines three existing types of detectors: thedouble-ring filter, shape index based on the Hessian matrix, and Gabor filter. They proposed technique which is set up using a two-step DCNN and three-level perceptron along with 72 features just for false positives (FPs) reduction. In the two-stage DCNN, the first DCNN is for primary MA realization and the second DCNN is for FPs decrease. By applying the proposed strategy to the DIARETDB1 database, the proposed technique shows top-quality performance.General performance of the proposed technique was superior to other methods. The method could be further upgraded by changing the network architecture and adding a post-processing technique [13].

ZHENTAO GAO, et al. (2019) designed a dataset of DR fundus pictures containing 4476 images with 4 degree of DR and deployed the models on the cloud processing platform and provided pilot DR analysis services for a lot of hospitals inside the clinical evaluation. They proposed a novel dataset that is moderate in dimensions and annotated with a new marking scheme that may be more useful for clinical practice. They used the Inception-V3 network and a proposed modification of it mainly because our diagnostic models and evaluated the performance of those with multiple mainstream CNN models. The overall performance of the system in the medical evaluation displays the efficiency of this job. In the future, data from additional equipment will be included, and a larger pilot review will be launched. The stored data will probably be further used to improve the consistency of the units [14].

A.B. Aujih, et al.(2018)research U-Net model performance in segmenting retinal vessel based on a settings of dropout and batch normalization and utilize it to investigate the result of retina vessel in DR category. Pre-trained InceptionV1 network utilized to classify the DR severities. Two value packs of retinal images, with and without the presence of vessel, had been created from MESSIDOR dataset. The vessel removal process was done making use of the best trained on U-Net in DRIVE dataset. Final analysis demonstrated that retinal vessel is actually a good characteristic in classifying both serious and early on cases of DR level. They concluded that presence of vessel is affecting positively with detecting equally lower and higher DRs Severity. On early DR, a change in vessel is already happen, which is not visible to naked eye, causing vessel to generate micro-aneurysm. However, it is worthy of to note that, these studies were completed on a more compact dataset. Even more analysis has to be done about bigger dataset before illustrating any further decision [15].

ArkadiuszKwasigroch, et al.(2018)purpose a deep learning method to automated the screening of diabetic retinopathy. Consequently, we take advantage of CNN networks todiagnose the diabetic retinopathy and current stage, based onresearch of the photographs of retina. The made use of models were trained using dataset incorporating over 88000 retina photos, labelled by specialist clinicians. To evaluate classification ability of employed units we applied standard detail metrics and quadratic weighted Kappa get that is counted between the predicted scores and scores delivered in the dataset. The special aim for coding technique was proposed to include the information about relative between forecast and accurate level of disease. Using this method enhanced the classification exactness of the examined systems [16].

AvulaBenzamin,et al.(2018) presents a deep learning algorithm that detects hard exudates in fundus pictures of the retina. Hard Exudates that happen to be present in the DR infected fundus image have been found using the deep learning model developed in this work. In the instance of Diabetic retinopathy disease, recognition of hard exudates is necessary to detect the existence of disease in an automated method. We want to enhance the accuracy on the model with 2 proposing solutions. First way is to range the size of the image patch. Therefore we can find the effect of image patch on the exactness of prediction. Second methodology is to use a great ensemble of convolutional neural networks. They now have not forecast the pixels at the perimeters of the photo i. e. first and last fourth there's 16 pixels of each row and column are not predicted [17].

Xiaoliang Wang, et al.(2018)associates Diabetic Retinopathy (DR) pictures have been aggregated into five categories based on the expertise of ophthalmologist. A grouping of deep Convolutional Neural Network methods had been employed for Diabetic Retinopathy stage category. State-of-the-art clarity result is actually achieved simply by Inception Net V3, which illustrates the effectiveness of making use of deep Convolutional Neural Systems for DR image analyzation. Even more advanced CNN based image classification models could be implemented to further improve DR categorization clarity. CNN based photo segmentation, e.g. cotton wool; strategy may be investigated to implement fine-grained DR level classification [18].

BalazsHarangi,et al.(2018) utilized deep convolutional neural network (DCNN) founded technique.However, they coordinate them right into a super network having a fusion based

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approach. As a most important application domains with good clinical commitment, the methods was analysed for image-level classification. In this paper, they proposed an ensemble-based neuralnetwork structure for the recognition of MAs in fundus images. It connects unique individual DCNNs to allow their coexisting training. The diversity on the selected DCNNs allows the proposed buildings to respond more flexibly towards the variability of fundus pictures thus expectedly improves the classification effectiveness. Moreover, they have confirmed how this method can be configured to justclose environment[19].

P. Khojasteh,et al.(2018) proposed a novel framework with respect to the convolutional neural network architecture simply by *embedding a pre-processing part followed by the first layer of convolutional to enhance the efficiency of the classifier. Two image advancement techniques i. e. 1- Contrast Advancement 2- Contrast-limited adaptive histogram equalization was separately set in the suggested layer as well as the results were contrasted. Through this study, a novel CNN architecture was proposed by embedding a PPL mainly because the first layer of your network just for enhancing input images. Three CNN architectures were examined in this job: 1- without PPL 2- with the PPL implemented simply by CLAHE and 3- with PPL enforced by CE. In contract to the CLAHE, the CE was found far better for diagnosis of Diabetic retinopathy signs [20].

ShoravSuriyal,et al.(2018)targets on detection facets of a mobile application developed to accomplish DR examining in real time. The training and testing is done on 16, 798 fundus images. These photos are pre-processed to remove sound and put together them to come to be fed in to neural network. After pre-processing the input dataset is feasted into the neural network. The convolutional sensory network model used in this project is certainly MobileNets, which is often used for mobile devices. The neural network possesses 28 convolutional layers after each covering there is certainly batch norm and ReLU nonlinear function with the exception of at the finallayer. Through transfer learning, one can retrain such a model with its unique image dataset. The application was currently developed to be working for Android units but one could use this model in a windows or Linux operating system along with the help Python programming words. This established application can serve as a useful examining tool meant for Diabetic Retinopathy [21].

Description and performance measure is illustrated in the table-2 given below:-

Reference Number	**Dataset**	**Description of Dataset**	**Accuracy (%)**	**Sensitivity (%)**	**Specificity (%)**
[1]	DIARETDB1 MESSIDOR	Total images= 89 NPDR=84 (Capturedby using a fundus camera with field of view=50 degree. Total images=1200 (captured by using a fundus camera with	91.13 84.00	92.85 86.03	80.00 79.69

		FOV=45 degree FOV)			
[2]	DIARETDB1	Training sample=58, Testing sample =52 images	-	96%	92%
[3]	400 retinal images labelled according to 4 grade scale of NPDR	Total images=400 Images of retina labelled as 4-grade scale of NPDR. .	85%	95%	-
[5]	DIARETDB0 DIARETDB1	Total images=75 training images=45 , normal images=9 and abnormal images=36 testing images =30, normal =6 and abnormal =24	96.67	100	95.83
[7]	DIARETDB1 -Vessel and hemorrhages -Exudates	Training images =49,testing=89	80.65 86.21	63.97 72.54	97.32 99.88
[10]	DIARETDB0 STARE dataset	*Total images*=130 With DR=110 Normal=20 *Total images=154* With DR =66 Normal=40	91.46 68.77	92.72 -	89 -
[11]	100 fundus images.60 are normal images rest are abnormal	Total images=100 normal images=60 abnormal images=40.	96.23	-	-
[12]	Kaggle Dataset	35,000 images having 5-class labels (normal, mild, moderate,	2ary-74.5 3ary-68.8	-	-

	Messidor-1 dataset	severe, end stage) 1,200 color fundus images with 4-class labels (normal, mild, moderate, severe)	4ary-57.2		
[13]	DIARETDB1	28 training images,61 test images	-	84	-
[14]	Novel dataset of fundus images	4476 images with 4 degree ofDR	88.72 with inception@4 model	94.84 with inception@4 model	-
[16]	Dataset provided by EyePACKS organization	88000 images. Training=35000, validation=1000 and testing =1000 Images.	82	89.5	50.5
[17]	IDRiD dataset	200000 images of 32×32 dimensions out of which 100000 images belongs to background class, 100000 images belong to exudate class.	96.6	98.29	41.39
[18]	Kaggle Dataset	Total=166 images. No DR= 31, Mild NPDR= 30, Moderate NPDR =50, Severe NPDR= 31, Proliferative DR =24	AlexNet=37.43 VGG16=50.03 InceptionNet V3=63.23	-	-
[20]	DIARETDB1 dataset	Total images=89 fundus images contains healthy subjects=5 and the rest contain Mild-non-proliferative	87.6%	-	-

		=84.			
[21]	Kaggle's Database	Total images=16,798 fundus images. DR=26% and no DR=74%	73.3	74.5	63

Table 2: Description and Performance of publically available Dataset

3. Conclusion

This research work is based on the diabetic retinopathy. The diabetic retinopathy detection has various phases which are pre-processing, feature extraction, segmentation and classification. The huge population of diabetics and the prevalence of DR included in this study have fostered an excellent demand in automated DR diagnosing systems. Up to now, a lot of achievements have already been produced and satisfactory results have already been achieved in lots of sub complications like vessel segmentation and lesion recognition.
This paper gives a quick summary of a lot of recently published papers based on classification of diabetic retinopathy. However, these achievements are obtained insmall datasets and so are steps away from real life applications relatively. For clinical application, systems that may give DR intensity are more favourable and practical directly. However, current outcomes for multi-class intensity grading aren't good enough for clinical program.

In this on-going function, we investigated the automated grading of DR using deep neural systems.Automated recognition and screening provides a distinctive opportunity to prevent a substantial proportion of vision reduction in the population effected by diabetic. In the previous research work, the optical disc segmentation was applied with SVM classifier for the detection. To improve accuracy of diabetic retinopathy detection, SVM classifier can be replaced with Convolutional Neural Network (CNN) classifier. The two-level DWT decomposition will be used for feature extraction. The proposed method will be implemented in MATLAB and results will be compared with the existing technique in terms of accuracy, precision, recall and execution time.

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