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Deep Learning-Based Automated Systems For Detection And Grading Of Diabetic Retinopathy Using Retinal Fundus Images: A Review

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Abstract —
One of the most common eye conditions that, if ignored, can cause blindness and vision loss is diabetic retinopathy (DR). Retinal fundus image analysis is extensively used for computer-assisted diagnosis and grading of diabetic retinopathy. Several deep learning-based automated algorithms are available for fundus image analysis-based diabetic retinopathy detection and grading. The purpose of this article is to summarise and assess the performance of various deep learning-based diabetic retinopathy detection and grading algorithms. The many types of image processing techniques employed by deep learning-based algorithms, as well as the performance measures employed in the classification process, are also explored. Additionally, the study addresses the retinal fundus datasets for diabetic retinopathy that are currently available and can be utilised for segmentation, classification, and detection tasks. The study also examines research gaps in the domain of DR detection, classification and discusses numerous difficulties that require additional research and examination.

Keywords — *Diabetic Retinopathy, Fundus Image, Deep Learning, Disease Detection, Diabetic Retinopathy Grading*

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I. INTRODUCTION

Diabetes is a very common condition, however it can cause a number of consequences, including eye issues, kidney damage, nerve damage, stroke or heart attack because of blood vessel damage. One of its side effects is that eye issues might develop into eye diseases. Diabetic Retinopathy (DR) is a condition caused by damage to the retina's small blood vessels. It must be detected early in order to prevent blindness caused by diabetes mellitus. Diabetic retinopathy impairs eyesight. The goal of creating automated systems for diabetic retinopathy identification is to reduce the risk of complications by screening patients early. Diabetic Retinopathy has two stages: non-proliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR) [1]. NPDR is a preliminary stage of diabetic retinopathy that can be further classified as mild, moderate, or severe. The more complex stage of DR is called PDR. If DR is not treated in its early stages, it might result in permanent blindness. Blindness can be avoided in 90% of advanced DR patients if the condition is treated before the retina is substantially damaged. In order to treat DR, a fundus image's might be graded.

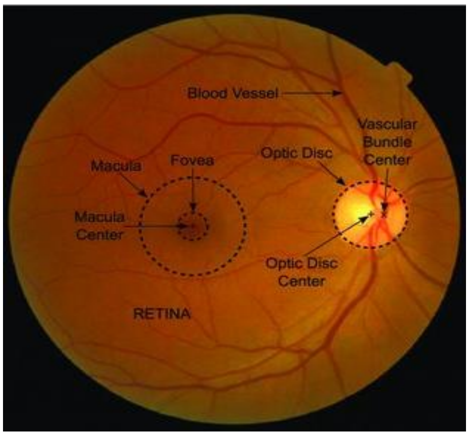

Fig.1. A typical retinal image from the right eye showing blood vessels, optic disk, fovea, vascular bundle and macula

The fundus image is a representation of the inside surface of a human eye that includes important components like the macula, optic disc, and blood vessels, optic cup, and fovea.. These objects can be found in practically every fundus photograph. A typical retinal fundus image from right eye is shown in figure 1.

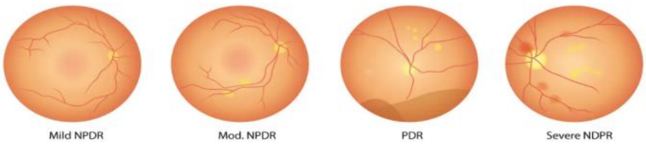

Fig.2, A fundus image with different stages of DR

The different stages of DR is shown in figure 2. However, some abnormalities in the retinal picture may appear as DR progresses. The rupture of the arteries that carry blood in the eye causes the abnormalities. As DR advances, the blood vessel walls weaken. The weak walls rupture because they cannot maintain blood pressure.

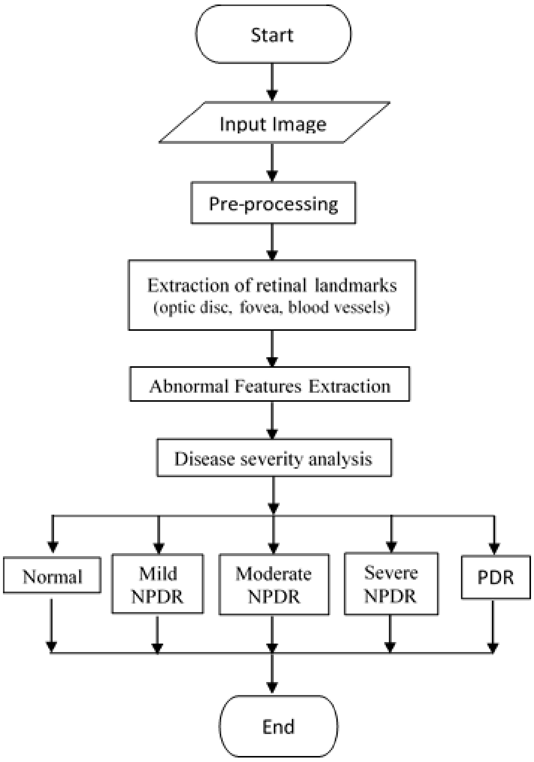

Fig.3, General Flowchart of Detection of Diabetic Retinopathy Using Image Processing Technique

When the barriers burst, lipids or blood are deposited on the retinal surface. Abnormalities such as exudates and red lesions are created when lipids or blood are deposited. The grading system rates the health of the fundus image by taking into account both significant objects and abnormalities, and it aids in determining the severity level of DR. The figure 3 shows the general flow chart of grading diabetic retinopathy using image processing technique

II. LITERATURE SURVEY

This section provides a brief overview of the works proposed for DR severity grading. Researchers have proposed several techniques based on machine learning (ML) for DR grading. ML techniques employ manual features appropriate for image classification problems with a small database. However, the results obtained with one database features often fail in classifying the other database Therefore, automated feature extraction is performed in deep neural networks such as CNN. Different types of deep architectures were proposed by the researchers in DR classification.

Many approaches and strategies utilised to identify and separate the objects and anomalies in the fundus image were explained. These strategies are important for grading a fundus image since the grading is based on the location and distance between the objects and abnormalities in the image. The grading algorithm determines the severity of the condition and assists the patient in avoiding permanent visual loss. In terms of accuracy, the methodologies and procedures outlined in this research produced better results. However, there is a need to increase the accuracy of rating a DR in order to correctly diagnose diabetes patients [1].

The research wok exudates and microaneurysms in the fundus pictures have been used to grade the severity of diabetic retinopathy, i.e., whether it is mild, moderate, or severe. Exudates are graded based on their distance from the macula, whereas micro aneurysms are graded based on their count. Support vector machines and K-Nearest neighbours have the highest accuracy of 92.1% when grading exudates, and decision trees have the highest accuracy of 99.9% when evaluating microaneurysms in terms of disease severity levels [2].

The study describes a deep learning architecture for grading diabetic retinopathy (DR) from fundus images. This research describes a deep learning architecture for grading diabetic retinopathy (DR) from fundus images. The suggested framework is divided into three phases. The fundus image is first pre-processed with intensity normalisation and augmentation. The pre-processed image is then sent into a ResNet Convolutional Neural Network (CNN) model to generate a compact feature vector for grading. Finally, a classification step is performed to detect and grade DR. They have used Indian Diabetic Retinopathy Image Dataset (IDRiD). Data augmentation and data balancing can greatly enhance system performance, according to experimental results. The suggested method outperforms comparable systems using the same data, as indicated by the greatest overall classification accuracy of 86.67% [3]. The diabetic retinopathy grading severity is described in this work they have developed a solution to this problem by image processing followed by ensembling state of the art Convolution Neural Networks (CNNs) and shows that the new strategy surpasses earlier studies in multi-classification by demonstrating its effectiveness on publically available datasets. Metrics, with 5-class accuracies of up to 88.71% and quadratic weighted kappa values of up to 0.9256. These findings provide encouraging evidence for the therapeutic relevance and usability of contemporary CNN designs. An approach for creating such a solution was described in this study, and it made use of a more modern and up-to-date Convolution Neural Network called Effective Net. Solutions for grading the severity of diabetic retinopathy that are automated, portable, and accurate. Two publicly available and well-researched datasets from Kaggle were used in this tests. First is Kaggle 2015 and second is Kaggle 2019 [4].

In order to classify the condition according to severity categories such as mild, moderate, severe, and proliferative, this study compares and evaluates many deep neural networks. On the Kaggle (APTOS) data set, pre-trained architectures like VGG16, EfficientNetB5, and ResNet50 yield accuracies of 76.47%, 90.2%, and 97.2%, respectively. In the future, some productive pre-processing of the data sets and architectural improvements can be implemented to improve the model's efficiency and accuracy. Ensemble techniques can be used to increase system efficiency [5]. In present study, a DR severity classification approach based on Vision Transformer (ViT). To keep location information, the fundus images are originally separated into non-overlapping patches in this work. The flattened patches are then turned into sequences before being subjected to a linear and positional embedding method. The suggested work is tested using the IDRiD and Kaggle databases. The outcomes surpass both state-of-the-art and convolutional neural networks. The proposed model produces an accuracy of 87.41% [6].

This study proposes an autonomous diagnosis technique based on a deep learning algorithm, which would speed up the diagnosis of diabetic retinopathy and improve treatment efficiency. The "AD2Net" convolutional neural network model was developed by them. The network combines the advantages of Res2Net and DenseNet to train multi-scale features while also solving the vanishing gradient problem and improving feature reuse. Simultaneously, this article applies an attention mechanism approach to direct the network's attention to learning relevant information in images, which can improve the network's classification effect to some extent. The model's accuracy and Kappa values on the testing set are 83.2% and 0.8, respectively [7].

The present study uses the fractal dimension to differentiate between patients with diabetic retinopathy based on severity, as well as between healthy individuals and those with the illness. Using the MESSIDOR dataset and Random Forest as a Classifier, researchers discovered that fractal dimensions may distinguish between healthy participants and diabetic retinopathy patients, but not for classifying diabetic retinopathy severity (grade level). Thus, in the future, new parameters such as univariate, multivariate, and other statistical traits should be examined. It must also focus on red lesion detection to understand more about the severity of diabetic retinopathy [8].

This research provides an intelligent ML-based DR grading and classification (IMLDRGC) model based on retinal fundus pictures. The IMLDRGC model's purpose is to autonomously diagnose the DR with high accuracy. The IML-DRGC approach first allows IoT devices to capture the patient's retinal fundus image. The gathered image is then pre-processed using the Gaussian filtering (GF) approach to remove noise from the fundus image. Then, a fuzzy c-means enabled segmentation technique is used to detect impacted areas in the fundus image. Finally, support vector machine (SVM) is employed as a classification model to assign distinct labels to DR. In this investigations, databases such as DRIVE, ROC, and DIARETDB1 were used. The proposed model produces an accuracy of 95.71% [9].

The study shows how to employ the Diabetic Retinopathy convolutional neural network advanced (DR-CNN+) technique on color fundus pictures to detect diabetic retinopathy and classify retinal images as having no DR, mild, moderate, severe, or proliferative DR in. Images of the retinal fundus obtained from Kaggle. When compared to existing techniques, the proposed DR-CNN+-based algorithm has been shown to attain 96% accuracy [10]. In comparison to current methodologies, this study proposes a method for automatic identification and grading of DR that yields more exact findings. They used transfer learning and ensemble learning ideas. The pre-trained models utilized for DR identification are Xception, InceptionV3, and InceptionResnetV2, while the grading models are ResNet-50, DenseNet-201, and DenseNet-169. The proposed model is tested using the IDRiD database and achieves 99.5% DR recognition and 99.6% grading accuracy [11]. In this studyidentify the various lesions, this research provides a two-stage model-Convolutional Neural Network (CNN) and MLP-Conv-NIN (Network-in-Network). The CNN model is used to minimise the size of the input fundus images and extract the various features. To detect the various lesions present in the fundus pictures, the necessary features are supplied into the MLP-Conv-NIN model, which absorbs the non-linear information. In order to improve performance and analyse responses, the proposed model employs a variety of filter widths and a rectified linear unit (RELU) activation function. The suggested model's performance is evaluated using publically available dataset. The proposed model has an accuracy of 87.34% and a kappa-score of 0.81[12]. The study concentrated on categorizing and evaluating diabetic retinopathy photos based on severity levels. They look into an automated grading approach for diabetic retinopathy that employs a machine learning strategy based on spatial local binary patterns and accelerated robust features (SURF). Kaggle databases are used to test the proposed work. A comparison study is carried out with three machine learning classifiers, which are evaluated utilizing optimum performance metrics. Among the classifiers, the artificial neural network obtained the highest classification accuracy of 89.89% [13].

The system in the research work conducts DR classifications using a pre-trained DenseNet-169 CNN model. In this work, they used the publicly available Kaggle APTOS 2019 Blindness Detection dataset. Hype-parameter tuning and data augmentation procedures are employed to achieve adequate classification performance. The model was also compared to two other pre-trained models, DenseNet-121 and ResNet-50. The proposed approach generated a classification accuracy of 96.54% on the test set [14]. The system in the study allows for the classification of DR into normal eyes, moderate, severe, mild, and proliferative DR, which could aid ophthalmologists in making a preliminary diagnosis. They employed pretrained Convolutional Neural Network (CNN) VGG-16 and MobileNet-V2, as well as data gathered by the Asia-Pacific Tele Ophthalmology Society (APTOS) in 2019 to diagnose diabetic retinopathy, which is available on the Kaggle platform, to diagnose diabetic retinopathy. The accuracy rates for estimating the degree of diabetic retinopathy from an image using the pretrained Convolutional Neural Network (CNN) VGG-16 and MobileNet-V2 were 90% and 92%, respectively[15]. This paper [16] provides a new DR intelligent classification model based on the powerful relationship capturing capabilities of graph neural networks. The model is made up of two cascaded networks. The convolutional neural network is used to extract the deep features of the DR picture, and the graph neural network is used to capture the relationship between the convolutional network's deep features. Ultimately, the grading outcome of the complete network is obtained by fusing the two network outputs using adaptive weight. The suggested model is tested using the APTOS2019 and Messidor-2 datasets. On APTOS2019, the suggested model's grading accuracy and F1-score improve by 1.1% and 1.3%, respectively, On Messidor-2, grading accuracy and F1-score improve by 1.4% and 1.8%, respectively.

This study [17] presents the creation of a screening system that uses the Inception V3 model to identify various severity grades on the online dataset. The images are pre-processed using techniques such as computer vision filtering and other filtering methods. At the 190th and 200th iterations, 86.67% accuracy is attained. Cross-entropy loss is used to validate the results. Authors will aim to enhance accuracy in the future by suggesting different CNN models.

The goal of this study is to create and verify a new automated deep learning-based approach for multi-class diabetic retinopathy detection and classification. In this study [18], assess the contribution of the DR features in each colour channel, then select the most significant channels and calculate their principal components (PCA), which are then fed into the deep learning model, and the grading decision is made using a majority voting scheme applied to the output of the deep learning model. The created models were trained using a publically available dataset of roughly 80K colour fundus photos and tested on their local dataset of around 100 images. Their results reveal a significant improvement in DR multi-class classification, with 85% accuracy, 89% sensitivity, and 96% specificity. The authors of this work [19] suggest developing and refining a lightweight convolutional neural network (CNN) to categorise diabetic retinopathy into five groups. The model so created is compared to the pre-trained deep learning architecture Resnet. CNN has an accuracy of 83.51% and Resnet has an accuracy of 76.17%. The results show that CNN outperforms the pretrained model. The research is based on the kaggle APTOS 2019 dataset. The training dataset consists of 3556 photos with severity ratings ranging from 0 to 4. Fusion-based models could be proposed in future work. Deep learning models that are distributed can be utilised to speed up the grading process.

An automated deep learning method for DR grading from retinal fundus pictures is presented in this research [20]. They use Convolutional Neural Network (CNN) designs that have demonstrated cutting-edge performance in image recognition applications. The experimental results show that the best deep learning model has a high sensitivity of 94.3%, a specificity of 95.5% (for DR/no-DR classification), and a quadratic weighted kappa score of 0.88. They utilise the EyePACS and IDRiD dataset for the trials, which both employ the same methodology for rating DR severity.This paper [21] proposes using a deep graph correlation network (DGCN) to automate diabetic retinopathy grading without professional annotations. DGCN is a deep learning system that uses a graph convolutional network to capitalize on correlations between retinal image data learned by a convolutional neural network. To evaluate the DGCN model, this study used the EyePACS-1 and Messidor2 sets to grade outcomes. The algorithm had an accuracy of 89.9% (91.8%), sensitivity of 88.2% (90.2%), and specificity of 91.3% (93.0%) on the EyePACS-1 (Messidor-2) dataset. This research [22] presents an improvement approach to improve the quality of fundus images. It also suggests two architectures for CNN models. The first is a binary classifier that differentiates between normal and abnormal DR images. The second CNN architecture classifies DR severity grades. The pre-trained and suggested CNN models are tested on Messidor1, Messidor2, and Kaggle EyePACS datasets. The suggested binary classifier model achieved F1-scores of 0.9387, 0.9629, and 0.9430 for the Messidor-1, Messidor-2, and EyePACS datasets, respectively. The suggested second model successfully classifies the five classes with F1-scores of 0.9133, 0.9226, and 0.9393 on Messidor1, Messidor2, and Kaggle EyePACS datasets, respectively. The effectiveness and dependability of the newly suggested CNN model in identifying DR and grading its severity in fundus photos have been demonstrated. Using the binary model, preprocessing approaches improved performance by 10.83% in accuracy and 0.13037 in AUC.

DR is a common vision-threatening condition that has recently become more widespread.

This paper [23] proposes an automated early DR diagnostic and rapid grading method. M-CNN and ML classifiers extract relevant features from fundus pictures and identify lesions based on severity levels. The databases MESSIDOR, Kaggle, and IDRiD are used to analyze the model. The experiments make use of Random Forest, J48, and SVM machine learning classifiers. Evaluation is also conducted utilizing the features that are extracted using pre-trained networks. The suggested approach has a K-score of 0.995 and an average validation accuracy of 99.62%. Several tests reveal that the M-CNN features perform the best when used with the J48 classifier. M-CNN and J48 classifiers can predict and grade DR quickly and automatically. Modifying this multipath network can improve retinal health monitoring by predicting more disorders.

This research [24] presents a unique hybrid Strawberry-based Convolution Neural Framework (SbCNF) for detecting and classifying retinopathy disease from retinal pictures. DRIVE datasets are used for the full execution. This research is carried out using the Python platform. Furthermore, this study suggests potential improvements for the retinopathy detection program. The implementation results have been validated using typical classification model approaches such as accuracy, precision, recall, and F-measure. The investigation shows that the suggested algorithm attained the highest accuracy in retinopathy recognition due to its effective advantages, such as reduced computational complexity.

This study [25] introduces a new algorithm based on deep convolutional neural networks (DCNN). The approach differs from typical DCNN by using fractional max-pooling instead of traditional max-pooling. Once the image's metadata and CNNs' features are combined, they train a support vector machine (SVM) classifier to discover the underlying boundaries of each class's distributions. They used Kaggle's publicly accessible DR detection database for the studies. To construct the model, they have used 34,124 training photos and 1,000 validation images. We then evaluated our model with 53,572 testing images. The experimental results demonstrate that the suggested technique can obtain a recognition rate up to 86.17%, which is greater than previously reported in the literature. The proposed DR classifier divides the stages of DR into five categories, each labeled with an integer between zero and four.

III. SUMMARIZED WORK DONE

Table I. compares several approaches employed in the classification of significant objects and abnormalities from fundus images, which plays an important role in assessing the severity of the fundus image impacted by diabetic retinopathy.

TABLE I. Summary of methods and datasets used

Authors	Method used	Database	Result
Avleen Malhi et al (2023)	Machine learning algorithm (SVM & KNN)	Messidor, e-optha and DiaretDb	SVM and KNN has 92.1% accuracy Decision tree has 99.9% accuracy
Doaa K. Elswah et al (2020)	ResNet	IDRiD	86.67% accuracy
Andrew Lee et al (2021)	EffectiveNet	Kaggle2015 and Kaggle2019	88.71% accuracy and kappa values of up to 0.9256
Anitha T Nair et al (2022)	VGG16, EfficientNetB5, and ResNet50	Kaggle (APTOS)	VGG16 has 76.47%, accuracy EfficientNetB5 has 90.2% accuracy and ResNet50 has 97.2% accuracy
N Jagan Mohan et al(2022)	Vision Transformer (ViT)	IDRiD and Kaggle	87.41% accuracy
Zhixiang Qian et al (2021)	AD2Net	Kaggle	83.2% accuracy and Kappa values of 0.8
Farrikh Alzami et al (2019)	Random Forest	MESSIDOR	80.37 %
K. Parthiban et a l (2021)	SVM	DRIVE, ROC, and DIARETDB1	95.71% accuracy
Samiya Majid Baba et al (2023)	DR-CNN+	Kaggle	96% accuracy
Shintu Mariam Skariah et al (2021)	Xception, InceptionV3, andInceptionResnetV2 are the pre-trained models utilised for DR identification. ResNet-50, DenseNet-201, and DenseNet-169 are used for grading	IDRiD	99.5% accuracy for DR recognition and 99.6% accuracy for grading
Praveen Modi et al (2022)	Convolutional Neural Network (CNN) and MLP-Conv-NIN (Network-in-Network).	Publically available dataset	87.34% accuracy and a kappa-score of 0.81
V. Deepa et al (2020)	Artificial neural network (ANN)	Kaggle	89.89 %. accuracy
Most Tahmina Rahman et al (2021)	DenseNet-169	Kaggle APTOS 2019 Blindness Detection Dataset.	96.54% accuracy
Abini M.A et al (2023)	VGG-16 and MobileNet-V2	Kaggle APTOS	VGG -16 has 90% accuracy and MobileNet-V2 has 92% accuracy
MEILING FENG et al (2023)	CNN	APTOS2019 and Messidor-2	84.8% accuracy
Shruti Jain et al (2021) [17]	Inception V3	DRIVE), STARE, and DIARETDB1	86.67% accuracy
Eman Mohamed et al (2021)[19] 18	CNN	Kaggle	85% accuracy, 89% sensitivity, and 96% specificity.
Shantala Giraddi et al (2022) [24] 19	CNN and ResNet	kaggle APTOS 2019	83.51% accuracy is obtained with CNN and accuracy of 76.17% obtained with Resnet.
Sagar B Hathwar et al (2019) 20	CNN	EyePACS and IDRiD	sensitivity of 94.3% specificity of 95.5% and a quadratic weighted kappa score of 0.88

Guanghua Zhang et al [21] 2022	Deep graph correlation network (DGCN)	EyePACS-1 and Messidor-2	89.9% accuracy (EyePACS-1) & 91.8% accuracy(Messidor-2)
Mohamed A. Berbar [22] 2022	CNN (DR2Net& DR5Net)	Messidor1, Messidor2, and Kaggle EyePACS	94.11% accuracy and an F1-score of 0.9226(Messidor2) & 95.06% accuracy and an F1-score of 0.9393 (Kaggle EyePACS)

IV. CONCLUSION

This paper addressed the numerous approaches and procedures utilised for detecting and grading the objects and abnormalities present in the fundus picture. These strategies are important for grading a fundus image since the grading is based on the location and distance between the items and abnormalities in the fundus image. The grading algorithm determines the extent of the illness, aids the patient, and lowers the possibility of irreversible blindness. In terms of accuracy, the methodologies and procedures outlined in this research produced better results. However, there is a need to increase the accuracy of grading a DR in order to correctly diagnose diabetes patients. The accuracy of the grading system can be improved by taking into account more than one irregularity.

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