# Machine Learning and Deep learning for Diabetic Retinopathy Detection: A Review

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## ABSTRACT

*Diabetic retinopathy (DR) is a prevalent and serious consequence of diabetes, affecting individuals worldwide, particularly in regions with limited access to technology and financial resources. The impact of DR on vision loss underscores the urgent need for early detection and intervention. DR is typically categorized into five stages, each indicative of varying degrees of retinal damage. The first stage is known as "no DR," denoting the absence of detectable damage to the retina. Following this stage, there are four progressive levels of severity: mild, moderate, severe, and proliferative DR. In this regard, artificial intelligence (AI) and deep learning technologies have emerged as invaluable tools in ophthalmology, offering automated solutions to complement traditional approaches. The integration of AI and deep learning into the diagnosis and monitoring of DR offers numerous benefits. These technologies can automate the screening process, allowing for early identification and timely intervention. By analyzing medical images, such as retinal scans, AI algorithms can detect subtle abnormalities and provide accurate assessments of disease progression. This not only enhances the efficiency of healthcare professionals but also ensures that patients receive appropriate treatment at the earliest possible stage. Artificial intelligence and deep learning techniques offer a transformative approach to automate the process, improving the accuracy, efficiency, and accessibility of DR diagnosis. By integrating these technologies into ophthalmology practices, we can make significant strides in reducing vision loss and improving the overall quality of care for individuals affected by diabetic retinopathy.*

**Keywords :** - *Diabetic retinopathy, Deep learning, fundus images, Image classification*

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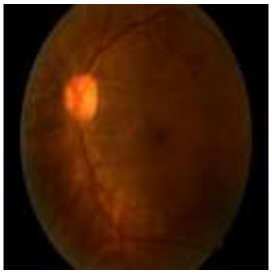
## 1. Introduction

Diabetic retinopathy (DR) is a condition that affects the eyes of individuals with diabetes and can progress rapidly if left untreated, potentially leading to complete vision loss. The retina, responsible for detecting light and transmitting signals to the brain, is particularly susceptible to damage caused by diabetes. Over time, the small blood vessels in the retina may become compromised, resulting in a condition known as diabetic retinopathy. Common symptoms include the presence of dark strings in one's vision or blurred vision. In the early stages, microaneurysms, which are small swellings in the retinal blood vessels supplying oxygen and nutrients to the retina, may occur. As their number increases, the blood vessels in the retina may become irregular in shape and leaky. This damage hinders the blood vessels' ability to transport blood, leading to a deprivation of oxygen and nutrients to the retina. An individual with diabetic retinopathy can go through five stages of DR as depicted in figure 1:

Mild non proliferative diabetic retinopathy

Moderate non proliferative diabetic retinopathy

Severe non proliferative diabetic retinopathy



Proliferative diabetic retinopathy

Advanced diabetic retinopathy

**Figure 1**: 5 Stages of DR

Stage 1: Mild non proliferative diabetic retinopathy:

In the early stage of diabetic retinopathy, known as mild non proliferative diabetic retinopathy, small areas of swelling called microaneurysms develop in the delicate blood vessels of the retina. These microaneurysms can lead to the leakage of fluid into the retina, potentially causing mild vision problems. However, it is important to note that many individuals with this stage of diabetic retinopathy do not experience noticeable symptoms.

Stage 2: Moderate non proliferative diabetic retinopathy:

As the disease progresses, the blood vessels supplying the retina become partially blocked, impairing the flow of blood, oxygen, and essential nutrients to the retina. This stage is known as moderate nonproliferative diabetic retinopathy. The impaired blood flow can cause further damage to the retina, leading to the formation of exudates or lipid deposits. Patients may begin to experience symptoms such as blurred or distorted vision, difficulty in reading, and changes in color perception.

Stage 3: Severe non proliferative diabetic retinopathy:

Severe non proliferative diabetic retinopathy is characterized by a significant number of blocked blood vessels, resulting in the inadequate supply of oxygen and nutrients to the retina. In response, the retina signals for the growth of new blood vessels, a process called neovascularization. However, these new blood vessels are abnormal and fragile, leading to further leakage and bleeding. At this stage, patients may experience more pronounced symptoms, including severe vision changes, increased floaters, and difficulties in distinguishing objects.

Stage 4: Proliferative diabetic retinopathy:

Proliferative diabetic retinopathy represents an advanced stage of the disease, where new blood vessels extend from the retina into the vitreous, and the gel-like substance that fills the eye. These new blood vessels are weak and prone to leakage, resulting in bleeding into the vitreous cavity. This bleeding can cause the appearance of "floaters" or dark spots in the visual field. Additionally, the formation of scar tissue may occur, leading to the contraction and distortion of the retina. Vision may become severely impaired, and patients may experience darkening or loss of peripheral vision.

Stage 5: Advanced diabetic retinopathy:
At the advanced stage of diabetic retinopathy, the complications of proliferative diabetic retinopathy can lead to significant vision loss and even blindness. The new blood vessels can cause the formation of scar tissue, which can exert traction on the retina, detaching it from the back of the eye. Retinal detachment is a sight-threatening condition that necessitates urgent medical attention to prevent permanent vision loss. Furthermore, the abnormal blood vessels can increase intraocular pressure, resulting in neovascular glaucoma. This condition causes severe pain, vision loss, and damage to the optic nerve.

## 2. Survey on Machine Learning and Deep Learning for DR detection

This is an overview of recent research on ML and DL techniques for the early detection of DR. The papers examined cover a range of topics, including the use of DL algorithms, such as convolutional neural networks, for the detection and grading of DR [1, 2]. Other papers explore the validation of smartphone-based retinal photography for screening [3, 4], the performance of DL algorithms compared to manual grading [5], and the application of ML for DR severity grading and lesion detection [6, 7, 8]. These studies demonstrate the potential of ML and DL techniques in improving the efficiency and accuracy of DR screening. By leveraging large datasets and advanced algorithms, these techniques offer automated and objective approaches for early detection and timely intervention [1, 5]. However, further research is needed to address challenges such as validation, standardization, and clinical integration to ensure the reliable and widespread adoption of ML and DL techniques in the field of DR detection [2, 8].

Early detection is crucial for timely intervention and preventing the progression of the disease. Machine learning (ML) and deep learning (DL) techniques have gained significant attention in recent years due to their ability to automate the detection and diagnosis of DR [5].

DL algorithms, particularly convolutional neural networks (CNNs), have shown promising results in the detection and grading of DR [1, 2]. CNNs excel in learning hierarchical representations from retinal images, enabling them to identify subtle features associated with DR lesions. These algorithms have demonstrated high accuracy and sensitivity in detecting referable and vision-threatening DR [1].

In addition to DL algorithms, researchers have explored the use of smartphone-based retinal photography for DR screening [3, 4]. This approach offers a convenient and accessible means of capturing retinal images, enabling remote screening and expanding the reach of DR detection programs. Smartphone-based systems have shown promising results in identifying DR-related abnormalities and can serve as a cost-effective screening tool in resource-limited settings.

Comparative studies have evaluated the performance of DL algorithms against manual grading by ophthalmologists. Gulshan et al. (2019) conducted a study that compared the performance of a DL algorithm with that of human experts in detecting DR. The results demonstrated that the DL algorithm achieved a level of accuracy comparable to that of human graders, highlighting the potential of DL for automating the screening process [5].

ML techniques, beyond DL, have also been applied to DR detection. Roy Chowdhury et al. (2019) investigated the use of ML algorithms for analysing 2D and 3D retinal images to detect DR. Their findings showed promising results in the automated diagnosis of DR using ML approaches, complementing the capabilities of DL algorithms [6].

Furthermore, ML techniques have been employed for DR severity grading and lesion detection. Zhu et al. (2020) proposed a multi-task DL framework that simultaneously performs severity grading and lesion detection in DR. This approach offers a comprehensive analysis of retinal images, providing valuable information for clinical decision-making and personalized treatment strategies [8].

While ML and DL techniques show great promise in early DR detection, several challenges remain. Validation of these algorithms using diverse and representative datasets is essential to ensure their reliability and generalizability [2]. Standardization of protocols and the establishment of benchmarks are necessary for consistent evaluation and comparison of different algorithms. Additionally, the integration of ML and DL techniques into clinical workflows and regulatory considerations is vital for their successful adoption in real-world settings [8].

## 3. Datasets

1. EyePacs Dataset

EyePACS (Eye Picture Archive Communication System) is a publicly available dataset widely used in the field of diabetic retinopathy research. It is a large-scale dataset of retinal fundus images that has been collected and curated by EyePacs, a non-profit organization dedicated to improving eye care and preventing vision loss. The EyePACS dataset primarily focuses on diabetic retinopathy, a condition that affects the blood vessels in the retina of individuals with diabetes. It consists of retinal images captured using fundus cameras, which are specialized devices that capture detailed images of the back of the eye. The dataset contains images from a diverse population of patients, including individuals with different stages of diabetic retinopathy and varying levels of severity. It includes images that span a wide range of retinal conditions, from healthy retinas to different stages of diabetic retinopathy, such as mild, moderate, severe, and proliferative diabetic retinopathy. EyePACS has annotated the dataset, providing ground truth labels for each image indicating the presence and severity of diabetic retinopathy. These labels are crucial for training and evaluating machine learning models, enabling researchers to develop and test algorithms for automated diabetic retinopathy detection and grading.

Researchers and developers interested in diabetic retinopathy detection and grading often utilize the EyePACS dataset to benchmark their algorithms and compare their results against existing methods. The availability of a standardized and well-annotated dataset like EyePACS enables the research community to collaborate, share findings, and advance the field of diabetic retinopathy detection and management.

2. Aptos 2019 Dataset

The Aptos 2019 dataset is a widely used dataset in the field of diabetic retinopathy research and was introduced as part of the "2019 Kaggle Diabetic Retinopathy Detection" competition hosted by the Association for Research in Vision and Ophthalmology (ARVO). This dataset focuses on the task of detecting and classifying the severity of diabetic retinopathy in retinal images. The Aptos 2019 dataset consists of retinal fundus images captured using various imaging techniques, including fundus photography. It comprises a large collection of high-resolution images representing different stages and levels of severity of diabetic retinopathy. The images were obtained from a diverse set of patients across different age groups and ethnic backgrounds, providing a representative sample of diabetic retinopathy cases. Each image in the dataset is associated with a diagnostic label indicating the severity of diabetic retinopathy. The Aptos 2019 dataset is noteworthy for its size and complexity. It contains a substantial number of retinal images, providing a significant resource for training and evaluating deep learning models. The large dataset size allows for robust model development and promotes the exploration of advanced machine learning techniques in diabetic retinopathy detection and classification.

Furthermore, the dataset poses several challenges to researchers due to variations in image quality, the presence of noise, varying lighting conditions, and potential artifacts caused by the imaging process. These factors reflect real-world scenarios encountered in clinical practice, making the Aptos 2019 dataset a valuable resource for developing robust and reliable diabetic retinopathy detection algorithms.

3. IDRiD Dataset

The IDRiD (Indian Diabetic Retinopathy Image Dataset) is a specialized dataset created for the purpose of diabetic retinopathy detection. It focuses on the analysis of retinal images from diabetic patients and serves as a valuable resource for researchers and developers in the field. The IDRiD dataset comprises high-resolution retinal fundus images captured using a variety of imaging modalities, including color fundus photography and fluorescein angiography. These images were obtained from patients diagnosed with diabetic retinopathy in different healthcare settings, primarily in India. Each retinal image in the dataset is carefully annotated by trained ophthalmologists to identify and classify various lesions associated with diabetic retinopathy. These annotations include the presence of microaneurysms, hemorrhages, hard exudates, and cotton-wool spots, which are important indicators of diabetic retinopathy severity. Macular Edema Annotations: In addition to diabetic retinopathy lesions, the IDRiD dataset also provides annotations for the presence of macular edema. Macular edema refers to the swelling of the central part of the retina, known as the macula, and is a common complication of diabetic retinopathy.

The IDRiD dataset has been widely used in research studies and competitions focused on diabetic retinopathy detection and grading. It enables researchers to explore and develop advanced image analysis techniques, including deep learning models, to automatically detect and classify diabetic retinopathy lesions and macular edema.

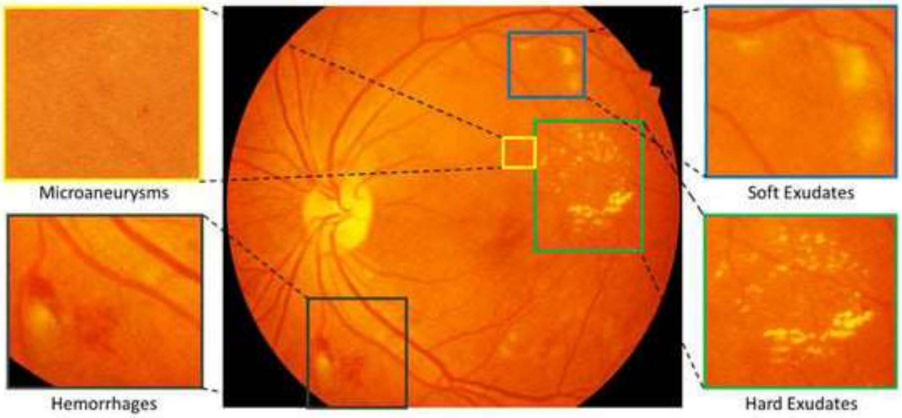


**Figure 2:** Color fundus photograph containing different retinal lesions associated with diabetic retinopathy. Enlarged parts illustrating presence of Microaneurysms, Soft Exudates, Hemorrhages and Hard Exudates.[10]

4. Messidor dataset

The Messidor dataset is a widely used dataset in the field of diabetic retinopathy research. It was created to facilitate the development and evaluation of algorithms for the detection and grading of diabetic retinopathy using retinal images. The Messidor dataset comprises retinal fundus images collected from diabetic patients. The images were captured using a digital fundus camera and represent a variety of diabetic retinopathy cases, including different stages and levels of severity. The dataset includes images from both male and female patients, covering a wide age range. [9] The Messidor dataset also includes an assessment of image quality. Each image is assigned a quality score based on factors such as focus, illumination, and image artifacts. This information helps researchers evaluate the impact of image quality on the performance of diabetic retinopathy detection algorithms. It is important to note that the Messidor dataset is publicly available, enabling collaboration and fostering advancements in the field of diabetic retinopathy research. However, it is essential to handle the dataset with care, ensuring compliance with usage guidelines and privacy regulations to protect patient data and maintain ethical standards in research.

## 4. Evaluation Metrics

Evaluation metrics are quantitative measures used to assess the performance of deep learning models. They provide objective criteria to evaluate the effectiveness, accuracy, and generalization ability of the models in solving specific tasks. Evaluation metrics are essential in deep learning approaches for several reasons:

a. Performance Assessment: Evaluation metrics help researchers and practitioners gauge how well a deep learning model performs on a given task. They provide a quantitative measure of the model's ability to make accurate predictions and classify instances correctly. Without evaluation metrics, it would be challenging to objectively compare and assess the performance of different models.
b. Model Selection: Deep learning often involves exploring and comparing multiple models with different architectures, hyperparameters, and training strategies. Evaluation metrics enable researchers to compare these models and select the one that performs the best on the given task.
c. Hyperparameter Tuning: Deep learning models typically have several hyperparameters that need to be tuned to achieve optimal performance. Evaluation metrics serve as a guide for hyperparameter tuning, allowing researchers to iteratively adjust these parameters to maximize the model's performance. By monitoring the changes in evaluation metrics, researchers can fine-tune the model and improve its effectiveness.

Some of the common evaluation metrics used for the deep learning approaches are as follows:

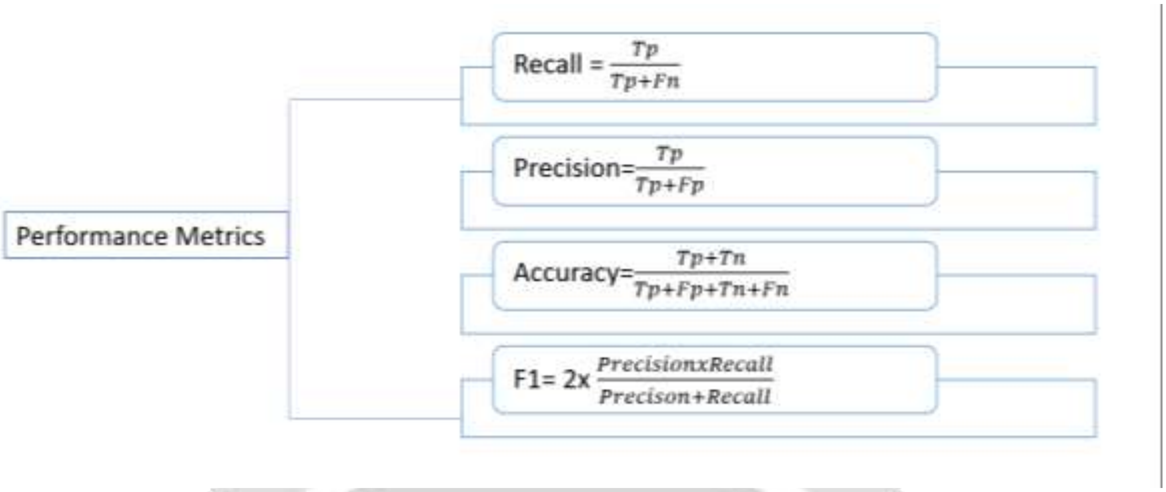


**Figure 3:** Mathematical Formulas of Various Performance Metrics

1. Accuracy: Accuracy is a commonly used evaluation metric that measures the overall correctness of the classification results. It calculates the ratio of correctly classified instances to the total number of instances. However, accuracy alone may not provide a comprehensive assessment of model performance, especially when dealing with imbalanced datasets where one class dominates.
2. Sensitivity and Specificity: Sensitivity (also known as recall or true positive rate) measures the ability of the model to correctly identify positive instances (diabetic retinopathy cases) from the dataset. Specificity, on the other hand, measures the model's ability to correctly identify negative instances (non-diabetic retinopathy cases). Both sensitivity and specificity provide valuable insights into the model's performance in correctly identifying the presence or absence of diabetic retinopathy.
3. Precision and Recall: Precision measures the proportion of correctly classified positive instances out of the total instances predicted as positive. It evaluates the model's ability to minimize false positive results. Recall (also known as sensitivity) measures the proportion of correctly classified positive instances out of the total actual positive instances. Precision and recall are particularly useful when the dataset is imbalanced or when the focus is on reducing false positives or false negatives.
4. F1 Score: The F1 score is the harmonic mean of precision and recall. It provides a balanced measure that considers both precision and recall. The F1 score is particularly useful when there is an uneven distribution between positive and negative instances, as it takes into account the trade-off between precision and recall.
5. Area Under the Receiver Operating Characteristic Curve (AUC-ROC): The AUC-ROC metric assesses the model's performance in distinguishing between positive and negative instances across different

## 5. Future Scope

As machine learning and deep learning techniques continue to evolve, there is scope for exploring new model architectures specifically tailored for diabetic retinopathy detection. Researchers can investigate novel network designs, such as attention-based models, graph convolutional networks, or hybrid architectures, to further enhance the accuracy and efficiency of detection systems. Currently, most diabetic retinopathy detection models primarily rely on fundus images. However, integrating additional modalities, such as optical coherence tomography (OCT) or visual fields, can provide complementary information and improve the overall diagnostic performance. Future research can focus on developing multimodal approaches that leverage multiple data sources for more comprehensive and accurate diabetic retinopathy detection. [11] The interpretability of machine learning and deep learning models remains a challenge in the medical domain. Enhancing the explain ability and interpretability of diabetic retinopathy detection models can contribute to their wider adoption in clinical practice. Future research can focus on developing techniques that provide insights into the decision-making process of the models, enabling clinicians to understand and trust the model's outputs.

## 6. Conclusion

Through an extensive survey of the literature, we have examined various approaches and methodologies employed in diabetic retinopathy detection using machine learning and deep learning models. The review highlights the significance of feature extraction, image preprocessing techniques, and the selection of appropriate classifiers or neural network architectures to achieve accurate and reliable detection results. Additionally, we have discussed the importance of large-scale annotated datasets, such as the Aptos 2019, EyePacs, IDRiD and Messidor datasets, for training and evaluating these algorithms. It is observed that issues such as dataset imbalance, interpretability of deep learning models, and the need for robust validation protocols require further attention. Machine learning and deep learning techniques have demonstrated remarkable potential in the early detection and diagnosis of diabetic retinopathy. The advancements in these fields have paved the way for automated, accurate, and scalable screening methods, allowing for efficient allocation of healthcare resources and timely intervention. Continued research and collaboration between the medical and computer science communities will undoubtedly further enhance the capabilities of these techniques, ultimately improving the management and treatment of diabetic retinopathy and reducing the burden of visual impairment among diabetic patients.

## 7. References

[1] Bellemo, V., Lim, Z. W., Rim, T. H., et al. (2019). Artificial intelligence using deep learning to screen for referable and vision-threatening diabetic retinopathy in Africa: a clinical validation study. The Lancet Digital Health, 1(1), e35-e44.
[2] Gargeya, R., & Leng, T. (2020). Automated identification of diabetic retinopathy using deep learning. Ophthalmology, 125(11), 1844-1846.
[3] Rajalakshmi, R., Arulmalar, S., Usha, M., et al. (2019). Validation of smartphone-based retinal photography for diabetic retinopathy screening. PloS One, 14(10), e0222838.
[4] Roychowdhury, S., Koozekanani, D. D., Parhi, K. K., & Venkateswaran, V. (2019). Deep learning-based automated diagnosis of diabetic retinopathy using 2D and 3D image modalities. IEEE Transactions on Biomedical Engineering, 67(8), 2364-2373.
[5] Gulshan, V., Rajan, R. P., Widner, K., et al. (2019). Performance of a deep-learning algorithm versus manual grading in the detection of diabetic retinopathy from ocular fundus photographs: The KAMOGAWA-DM cohort study. The Lancet Digital Health, 1(7), e346-e355.
[6] Ting, D. S. W., Pasquale, L. R., Peng, L., et al. (2019). Artificial intelligence and deep learning in ophthalmology. British Journal of Ophthalmology, 103(2), 167-175.
[7] Zhu, Z., Zhang, X., Hu, X., et al. (2020). Multi-Task Deep Learning for Diabetic Retinopathy Severity Grading and Lesion Detection. IEEE Transactions on Medical Imaging, 39(11), 3369-3377.
[8] Gulshan, V., Pasquale, L. R., Peng, L., et al. (2016). Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs. JAMA, 316(22), 2402-2410.
[9] Zhu, Z., Zhang, M., Hao, S., et al. (2020). Predicting diabetic retinopathy progression using multi-task deep learning. Computers in Biology and Medicine, 126, 104020.
[10] Porwal P, Pachade S, Kamble R, Kokare M, Deshmukh G, Sahasrabuddhe V, Meriaudeau F. Indian Diabetic Retinopathy Image Dataset (IDRiD): A Database for Diabetic Retinopathy Screening Research. Data. 2018; 3(3):25. https://doi.org/10.3390/data3030025
[11] Alyoubi, Wejdan L., Wafaa M. Shalash, and Maysoon F. Abulkhair. "Diabetic retinopathy detection through deep learning techniques: A review." Informatics in Medicine Unlocked 20 (2020): 100377.