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Recent Development and Application in Deep Learning for Diabetic Retinopathy Image Classification

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Abstract

The Diabetic Retinopathy Poses a significant risk of vision loss if not detected early. Deep learning has made Substantial strides in classifying Diabetic Retinopathy images, enhancing screening accuracy and efficiency The paper review the current advancement and application in deep learning for Diabetic Retinopathy image classification. Convolutional Neural Network, transfer learning have demonstrated notable improvement in identifying Diabetic Retinopathy stages. This review emphasizes the importance of collaborative efforts and innovative technologies in creating robust, interpretable and clinically relevant solution for early detection and management of Diabetic Retinopathy. By harnessing these advanced techniques, health care providers can better manage the increasing burden of Diabetic Retinopathy, ultimately enhancing patient care and reducing the risk of vision Loss

Keywords: *Diabetic Retinopathy; Deep learning; Image Classification; Early detection; Medical Imaging*

1. Introduction

Diabetic Retinopathy is a common Complication of diabetics that can lead to significant vision loss. Traditional screening method, although effective are labor -intensive and prone to human error. To evaluate the level of Disabilities, the ophthalmologist has determined most effective treatment by acquiring high resolution retinal images. Color fundus photography (CFP). Optical Coherence tomography (OCT), fluorescence [1-10] Angiography are used in clinical Practice to obtain retinal images. For early detection, pre-diagnosis, these modalities of images are excellent. Deep learning has emerged as a powerful tool for automating DR image classification, offering increased accuracy and scalability. Diabetic retinopathy is a medical disorder when diabetes mellitus damages the retina. [11] It is a common problem which causes due to diabetes particularly develops by damage of blood vessels in the retina. In developed nations, it is the main cause of blindness. Approximately 80%age of people who have type 1 and type 2 diabetes for more than 20 years develop diabetic retinopathy. Treatment and eye surveillance could prevent as least 90% of new cases from progressing to more aggressive forms of sight-threatening retinopathy and maculopathy. It is noted that if treatment of diabetes is not received, it may result in blindness or blurred vision. As a result, people with diabetes are recommended to undergo frequent consultations and a biennial or annual follow-up for retinal screening. An individual's risk of diabetic retinopathy increases with the length of time they have the disease. In the India, 15% of new cases of blindness are caused by diabetic retinopathy each year. It is also the main cause of blindness in those between the ages of 20 and 64 years. Diabetic retinopathy images may show neovascularization, hemorrhages, micro aneurysms, and liquid exudates. A diagnostic imaging method called CFP is used to capture finely precise images of the retina, optic disc, macula, and blood vessels in the back of the eye. It is an essential diagnostic and monitoring technique in ophthalmology used to diagnose and track a variety of eye conditions, including glaucoma, age-related macular degeneration, diabetic retinopathy, and retinal vascular occlusions. In the present work exhaustive review of literature has been conducted

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and explore the new future direction for the new researcher in the field of diabetic retinopathy image classification based on deep learning

2. Advances in Deep Learning for DR Classification

According, classification system based on CNN architecture or machine learning, features are taken from original and pre-processed images in the various related studies for the diabetic retinopathy images. Several machine learning-based standard classification systems have been developed by various research communities for the purpose of early detection of diabetic retinopathy disease. Convolution and pooling layers can be used to automatically extract information, hence eliminating the feature engineering step. A Brief review of literature of diabetic retinopathy Fundus images using CNN algorithms is shown in Figure 1.

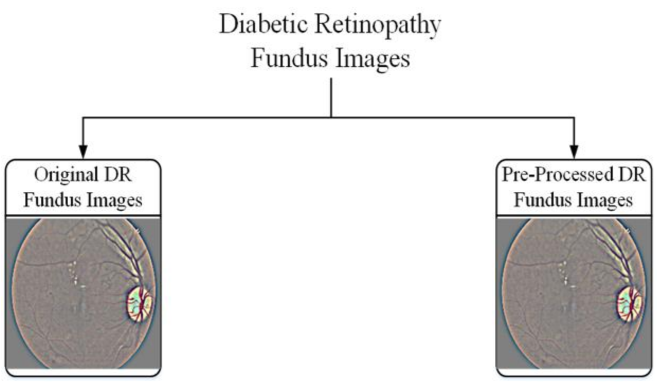

Figure 1 A Brief Review of Literature of Diabetic Retinopathy Fundus Images Using CNN Algorithms

2.1 The Exhaustive Review of Literature of Classification of Original Diabetic Retinopathy Images Using CNN Architecture

Convolutional Neural Network (CNN) has revolutionized image classification including Diabetic retinopathy. These networks automatically learn and extract features from retinal images. [26-30]

Note: LTD- Local Taiwanese, QBB- Dataset, Qatar Biobank, HMC-Hamad Medical Corporation, IDRiD-Indian Diabetic Retinopathy Image Dataset and the Diabetic Retinopathy Detection

From Table 1, it is observed that APTOS 2019 dataset used in most of the studies with five class and pre-trained network. It is concluded that highest accuracy has been achieved as 100% by Shoaib, M. R. et al [11]. It is noted that interpretability of pre-trained networks improves the classification accuracy and explain ability of DR detection. It is also observed that very few pre-trained networks has been used as feature extractor and SoftMax layer has been used for classification accuracy. It is observed that SVM, KNN and PNN classifier has been used to classify feature extracted by CNN architecture. It is also observed that very few self-design CNN architectures used for classification of diabetic retinopathy images. It is noted that very few studies have been observed with binary class classification. [12-18]

2.2 Transfer Learning

Transfer learning has been Crucial in improving deep learning model performance, especially with limited data. Fine tuning pre-trained models on specific DR data set has yield impressive classification accuracy.Number of studies investigate classification with number of classes and type of classifier is shown in Table 2. [19-20] A biennial or annual follow-up for retinal screening. An individual's risk of diabetic retinopathy increases with the length of time they have the disease. In the India, 15% of new cases of blindness are caused by diabetic retinopathy each year. It is also the main cause of blindness in those between the ages of 20 and 64 years.Diabetic retinopathy images may show neovascularization, hemorrhages, micro aneurysms, and liquid exudates.[21-25] A diagnostic imaging method called CFP is used to capture finely precise images of the retina, optic disc, macula, and blood vessels in the back of the eye. It is an essential diagnostic and monitoring technique in ophthalmology used to diagnose and track a variety of eye conditions, including glaucoma, age-related macular degeneration, diabetic retinopathy, and retinal vascular occlusions. In the present work exhaustive review of literature has been conducted Practice to obtain retinal images. For early detection, pre-diagnosis, these modalities of images are excellent. Deep learning has emerged as a powerful tool for automating DR image classification, offering increased accuracy and stability.

Table 1 **The Exhaustive Review of Literature of Classification of Original Diabetic Retinopathy Images Using CNN Architecture**

Investigator(s)	Year	Dataset Name	No. of Images	DL Based Pre-Trained Model	Performance Parameter
Abràmoff et al [25]	2016	MESSIDOR-2	1748	DCNN : ML-RF	Sen.-96.80%
Colas et al [26]	2016	EyePACS	-	DCNN	Sen.-96.20%
Wong et al [27]	2016	EyePACS & MESSIDOR-2	-	DCNN	Sen.-90%
Takahashi et al [28]	2017	University Jichi Data	-	Modified GoogleNet	Acc.-81.86%
García, G. et al. [9]	2017	EyePACS	35126	Self-Design architecture	Acc.-83.86%
Kwasigroch, A. et al [24]	2018	Public Dataset	88000	CNN networks	Acc.-82%
Levenkova et al [28]	2018	Ultra wide field	-	DCNN + SVM	AUC-0.80
Arcadu et al [31]	2019	RIDE and RISE Dataset	-	Inception v3	Sen.-66%
Bellemo et al [32]	2019	Kitwe central Hospital dataset	-	VGGNet and ResNet	Sen.-92.25% & 99.42%
Gulshan et al [33]	2019	Aravind Eye Hospital	-	DCNN	Sen.-88.9% & 92.1%
Hua et al [34]	2019	Kyung Hee Hospital	-	DCNN	Acc.-90.60%
Li, et al [35]	2019	IDRiD and MESSIDOR-1	-	ResNet50	Acc.-92.6% and 91.2%
Ruamviboonsuk et al [36]	2019	Thailand National Dataset	-	DCNN	Sen.-96.8%
Sayres et al [37]	2019	EyePACS	-	DCNN	Acc.-88.40%
Bodapati, J. D. et. Al [1]	2020	APTOS-2019	3662	Blended (VGG16-fc1, VGG16-fc2 and Xception)	DNN (Acc-80.96%)
Wang et al [38]	2020	Shenzhen hospital data	-	DCNN	AUC-0.80
Alcalá-Rmz, V. et al [16]	2020	IDRiD	4 Class	VGGNet	Acc.-81%
Sheikh, S. et al [17]	2020	APTOS 2019	3662	4 Pre-Trained	Sensitivity-90%

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Skouta, A. et al [19]	2020	Public	2000	Self-Design Architecture	Acc.-95.5%
Bora et al [39]	2021	EyePACS	-	Inception v3	AUC-0.79
Bodapati, J. D. et. al [2]	2021	APTOS-2019	3662	Pre-Trained networks	DNN (Acc-82.54%)
Angel Ayala et al. [7]	2021	APTOS-2019 & MESSIDOR	5406	DenseNet121	Precision-0.96
Rodriguez-Leon, C. et al [20]	2021	EyePACS	56,839	MobileNetV2	-
Mule, N et al. [8]	2021	APTOS-2019	3662	Dense Net, ResNet 50, and VGG16	Acc.-77.49%
Dai, L. et al [12]	2021	Local Dataset	666,383	DeepDR	AUC- 0.972
He et al [40]	2021	DDR, MESSIDOR & EyePACS	-	MobileNet	Acc.-92.1%
Saeed et al [41]	2021	MESSIDOR & EyePACS	-	ResNet	Acc-99.73%
Wang et al [42]	2021	EyePACS and Hospital Data	-	Inception v3	Sen.-90.60%
Bala, R. et al [18]	2022	APTOS 2019	3662	Lightweight Pre-Trained Models	-
Yadav, Y. et al [21]	2022	APTOS 2019	3662	4 Pre-Trained	-
Kanakaprabha, S et al [22]	2022	-	-	6 Pre-Trained	-
Bagadi, L et al [23]	2022	APTOS 2019	3662	CNN architecture Networks	-
Bajwa, A. et al. [3]	2023	SIOVS	57625	Self-Design	Acc.- 93.72%
Ratna, K. et al [39]	2023	APTOS 2019	3662	ResNet	-
Zulaikha Beevi, S et al [47]	2023	-	-	SqueezeNet and DCNN	Acc.-0.911
Al-Absi et al [28]	2024	QBB & HMC	15,011	DiaNetv2	Acc.-92%
Rao, S.B. et al [30]	2024	-	-	Self-Design Architecture	Specificity-95.5%
Durairaj, S. et al [34]	2024	APTOS-2019	3662	Self-Design Architecture	Acc.-98.5%
Shoaib, M. R. et al [35]	2024	ODIR dataset	4070 (2 Class)	DiaCNN based on ResNet-20	Acc.-100%
Dai, L. et al [37]	2024	Local Dataset	717,308	Deep DR Plus	-
Biswas, A. et al [38]	2024	EyePACS	56,839	advanced deep learning models	97.55% (binary) & 78%

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Table 2(a) – Number of Studies Investigate with Number of Classes and Type of Classification System

Dataset Type	Publicly Available dataset	Online Dataset	Hospital Dataset
Training dataset	80%	80%	70%
Validation set	10%	10%	20%
Testing Dataset	10%	10%	10%

Table 2(b) – Type of Learning with Type of Classifier

Type of Feature extracted method	Learning	Number of classes	Type of Classifier
Handcrafted Features	Machine learning	Five and two classes dataset used	ML based classifier
Deep Learning Based Features	Deep learning	Five and two classes dataset used	Deep learning based classifier named as softmax layer
Fusion of handcrafted and Deep Features	Machine Learning	Five and two classes dataset used	Five and two classes dataset used

Table 2(c) – Labels of The Type of Images Present in The Dataset

Diabetic Type	Type of Illness	Type of Lesion	Binary Class
DR-0	No Lesion present or healthy eye	No abnormalities	Healthy Eye
DR-1	mild DR	Micro-aneurysms only	Unhealthy or affected with DR disease
DR-2	Moderate DR	More than micro-aneurysms but less than NPDR	
DR-3	severe DR	red and yellow lesions	
DR-4	Proliferative DR	Neovascularization/ Vitreous/preretinal haemorrhage	

From Table 2(a, b & c), it is concluded that most of the researchers used five class datasets in their study and it is noted that pre-trained network based transfer learning has been achieved prominent accuracy in the field of ophthalmologist or DR images [31-35].

3. Results and Discussion

The researchers used original or pre-processed as highlights in table 1,2 of diabetic retinopathy images for classification using deep learning. The deployment of deep learning models for the classification of diabetic retinopathy images has led to significant achievements in the field of medical image analysis. Continuously monitor and update the model to adapt to new data and improve performance. It is concluded that pre-trained networks with SoftMax layer, Support Vector method, KNN, PNN, ANN, and are the most widely used to classify diabetic retinopathy images. Here some key advancements and achievements are as follow [36-38]

a) For original images of diabetic retinopathy, Shoaib, M. R. et al [11] achieved an accuracy of 100% using Dia CNN based on ResNet-20 pre-trained network. It is also noted that binary classification has been achieved using SoftMax layer.
b) Deep learning models, particularly pre-trained network, have demonstrated superior performance in diabetic retinopathy classification compared to traditional machine learning methods.

c) Pre-trained models achieve high accuracy and sensitivity in detecting diabetic retinopathy lesions, such as microaneurysms, exudates, hemorrhages, and neovascularization, from retinal images.[39-42]

Conclusion

It is also concluded that pre-trained models accurately detect the diabetic retinopathy disease and its severity, facilitating timely intervention and treatment to prevent vision loss. Pre-trained models has been deployed on scalable computing platforms, allowing for efficient processing of large data of retinal images. These models integrated with existing healthcare systems and telemedicine platforms, enabling remote screening and diagnosis of diabetic retinopathy in rural regions. Automated classification of diabetic retinopathy images using deep learning reduces the need for manual grading by ophthalmologists, leading to cost savings and increased efficiency in healthcare delivery. It also helps alleviate the burden on healthcare providers and reduce waiting times for patients. It provides insights into the progression and severity of diabetic retinopathy for individual patients, enabling personalized treatment planning and monitoring.By analyzing longitudinal retinal image data, pre-trained models can predict disease progression and guide clinicians in determining the most appropriate course of action for each patient. Deep learning-based classification models has been integrated with clinical decision support systems to assist ophthalmologists in interpreting retinal images and making informed diagnostic decisions. These systems provide real-time feedback and recommendations based on the analysis of retinal images, enhancing diagnostic accuracy and consistency across different healthcare settings. Deep learning models implement large-scale diabetic retinopathy screening programs, reaching a broader population of diabetic patients and facilitating early detection and intervention. These screening programs help identify individuals at risk of vision loss due to diabetic retinopathy and refer them for further evaluation and treatment as needed. Deployment of deep learning models for diabetic retinopathy classification has spurred further research and development in the field of medical image analysis and computer vision. Ongoing advancements in deep learning techniques and model architectures continue to improve the accuracy, efficiency, and interpretability of diabetic retinopathy classification models.Overall, the deployment of deep learning models for the classification of diabetic retinopathy images has revolutionized the diagnosis and management of the disease, leading to improved patient outcomes, reduced healthcare costs, and increased accessibility to screening services.

Results should include the rationale or design of the experiments as well as the results of the experiments. Results can be presented in figures, tables, and text. The Results should include the rationale or design of the experiments as well as the results of the experiments.

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