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A Review on Recent Techniques For grading the Severity of Diabetic Retinopathy in Retinal Colour Fundus Images

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ABSTRACT

Diabetic retinopathy (DR) is an eye disease, which is caused by the development of retinal microvascularization following diabetes. It is a problem of diabetes mellitus, which produces lesions in the surface of the retina due to which eye vision gets affected. Severe, uncontrolled cases of diabetic retinopathy will result in blindness. Since DR cannot be reversed, it can lead to blindness, and only early treatment maintains vision. Early diagnosis and treatment of DR can significantly reduce The risk of losing the vision. Fundus images are manually examined for morphological changes in retinal lesions such as micro aneurysms, exudates, blood vessels, hemorrhages. They are a tedious and time-consuming job. It is often easily accomplished with the help of a computer-assisted system. The identification and classification of the severity of diabetic retinopathy requires adequate segmentation of the retinal lesions. In this article, various techniques for detecting retinal lesions are discussed for the final detection and classification of nonproliferative diabetic retinopathy. Blood vessel detection techniques for diagnosing proliferative diabetic retinopathy are also discussed. In addition, the available datasets for the fundus colored retina were also examined. This work will be useful for researchers and technicians who wish to use ongoing research in this area. Several challenging topics are also discussed that require further investigation.

Keywords : Diabetic Retinopathy, exudates, hemorrhages, micro aneurysms, Blood vessels.

I. INTRODUCTION

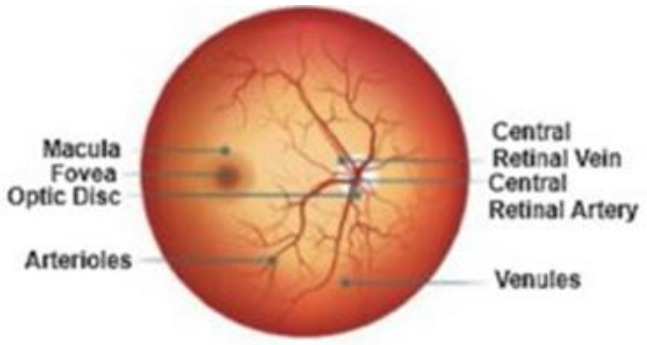
In the field of health, treatment is most effective for diseases that are detected in their early stages. Diabetes is a disease caused by a lack of insulin which increases the amount of glucose in the blood. Worldwide, more than 450 million adults are affected by diabetes. Diabetes affects the retina, heart, nerves and kidneys [1].

Diabetic retinopathy (DR) is a disease caused by the uncontrolled blood sugar level resulting from diabetes that causes blood vessels in the retina to swell and fluid and blood to lose. DR in its advanced stage can cause vision loss. Worldwide, DR causes 2.6% of

blindness [3]. The effect of DR is enhanced for diabetic patients who suffer from the disease for an extended period. Regular retinal screening tests are highly necessary for diabetic patients to diagnose and treat DR at an early stage to avoid the risk of blindness. DR is detected by the appearance of different types of lesions on a retinal image.

These lesions are micro aneurysms (MA), Haemorrhages (HM), soft and hard exudates (EX) [4].

The first sign of DR that appears as small round red dots on the retina due to the swelling of the vessel walls is called micro aneurysms (MA). These are very small in size, less than 125 microns with a sharp margin. Haemorrhages (HM) appear as larger spots on the retina, where their size is greater than 125 μm with an irregular margin. Hard exudates look like bright yellow spots on the retina caused by plasma leaks. These bright yellow spots have sharp edges and are found on the outer layers of the retina. Soft exudates, also called cotton spots, appear as white spots on the retina caused by inflammation of the nerve fiber. The shape is oval or round. Microaneurysms and haemorrhages are called red lesions, and hard and soft exudates are often referred to as shiny lesions. Figure 1 shows the image of the normal retina and the retina affected by diabetic retinopathy.



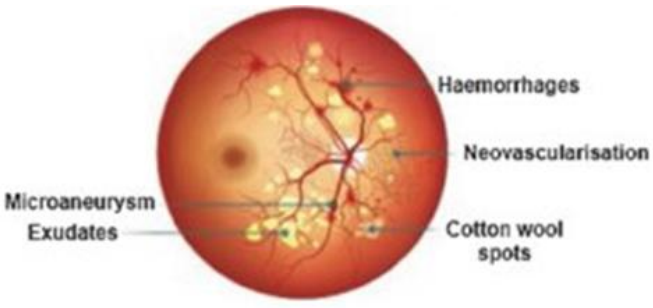


Fig 1. Normal Retina and Diabetic Retinopathy Retina

Non-proliferative DR has three phases, namely, mild DR, moderate DR, severe DR. Therefore, the detection of DR is classified into five classes, no DR, mild DR, moderate DR, severe DR and proliferative DR as indicated in Table 1. A sample of stage images is provided in Fig. From DR.

Table 1:Levels Of DR With Its Associative Lesions

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Classes	DR Severity Level	Abnormalities
Class 0	No DR	No visible lesions and abnormalities.
Class 1	Mild non-proliferative DR	Only Micro aneurysms.
Class 2	Moderate non-proliferative DR	Extensive Micro aneurysms, Haemorrhages and hard exudates.
Class 3	Severe non-proliferative DR	Cotton wool spots, Extensive Haemorrhages, Venous beading, Venous reduplication
Class 4	Proliferative DR	Neovascularisation, vitreous Preretinal haemorrhages.

Automated methodologies for detecting diabetic retinopathy save time and money and are more efficient than manual diagnosis [5]. A manual diagnosis is prone to misdiagnosis and requires more effort compared to automatic methods.

Detecting and classifying DR at an early stage is a challenging task due to the small size of the microaneurysms and point bleeds. This requires an adequate segmentation technique to detect abnormalities in the retina. This article examines the different cutting-edge methods of segmentation technologies by considering 35 articles.

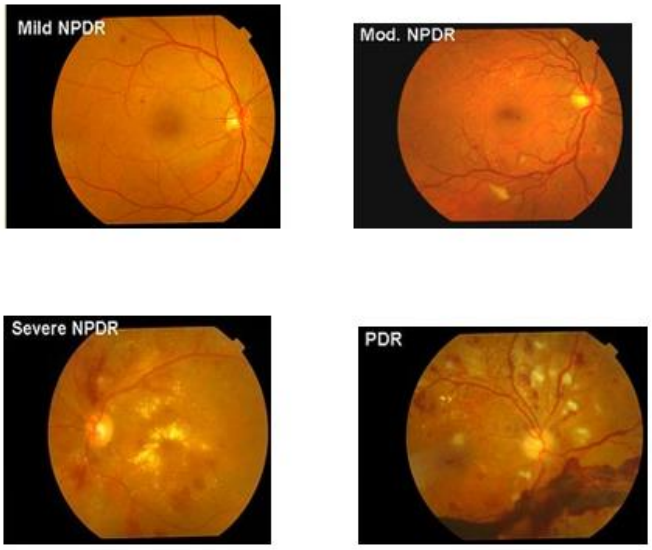

Fig 2. Stages of Diabetic Retinopathy

This paper is organized as follows: Section 2 includes several publicly available datasets of retinal fundus images. Section 3 examines the different image processing methods used for segmentation of retinal lesions. Section 4 presents the various performance measurements. Section 5 presents a discussion section and a summary in section 6.

II. RELATED WORK

There are many publicly available data sets for the retina to detect DR and detect retinal lesions. These datasets are often used to train, validate and test systems and also to compare the performance of a system with other systems. Color fundus imaging and Optical Coherence Tomography (OCT) are types of images of the retina. Effective lesion segmentation improves the detection and severity classification of diabetic retinopathy. But very few researchers have focused on segmenting all types of retinal lesions. Many studies have focused only on the segmentation of one or two retinal anomalies and have used this result to detect the classification of DR. This section examines the different types of lesion detection methodologies used.

The work of authors [27] highlights a novel method for Bifold classification of DR and concentrated on the detection of EX,MA and HM with DBN and SVM using DIARET DB1. Sensitivity,Specificity achieved is 0.99 and 0.96.

Table 3 : Summary of Recent Works With Performance

Studies	Year	Abnormalities considered in DR detection	Database Used	Methodology	Graded DR	performance
Gharaibeh et al. [10]	2018	Detection of HM, EX and MA	DIARETDB1	Deep Belief network (DBN) and SVM	DR binary classification	SEN 99%, SPE 96%, and ACC 98.4%.
Sundaram et al. [11]	2019	BV segmentation	DRIVE, CHASE, HRF	Morphological operations and adaptive thresholding	No	In DRIVE, SEN 0.69 , SPE 0.94 ACC 0.93
Zago et al. [12]	2020	Localization of Red lesions	DIARETDB1, MESSIDOR	CNN	No	AUC 91.2%, SEN 94%

Studies	Year	Abnormalities considered in DR detection	Database Used	Methodology	Graded DR	performance
Biran et al.[13]	2016	Segmenting HM and EX	DRIVE, STARE	Gabor filter and CHT followed thresholding	No	-
Safitri et al.[14]	2017	Segmenting BloodVessel	MESSIDOR	Box counting and KNN	DR binary classification	ACC 89%
Fadafen et al.[15]	2018	Segmentation of EX	DIARETDB1	Morphological operations	No	AUC 90.12%
Atlas and Parashuraman[16]	2018	Segmentation of HM	MESSIDOR	Region growing, GLCM, GLRLM, SURF for feature extraction, Binary classification by ANFIS	DR binary classification	HM segmentation-ACC=92.56%,DR detection 63%
Abdelmaksoud et al.[17]	2020	EX, MA,BV,HM segmentation	DRIVE, STARE,MESSIDOR,IDRiD	MLSVM	Yes	ACC-89.2%, AUC-85.2%SEN-85.1%, SPE-85.2%,PPV-92.8%,DSC-88.7%

The authors [10] uses the vessel segmentation using Morphological operations and used thresholding which is adaptive in nature.They got the sensitivity as 0.64 and specificity as 0.94.

In 2020 Zago et al.[12]considers the identification of red lesions using CNN techniques.They have achieved a sensitivity of 0.94.

The paper [13] putforward a method for classication without considering the grading of DR.HM and Ex are segmented using Machine learning Techniques.

Safitri et al.[14] shown the novel method for bifold classification of DR by considering blood vessels using KNN algorithm and achieved an accuracy of 89%.

In paper[15],a methodology is proposed using Morphological operations to find the exudates in the retina.An AUC of 0.9012 is obtained.

III. RESULTS AND DISCUSSION

This study examines 50 articles. Fundus images have been observed to have poor contrast, noise and artifacts, leading to imprecise detection of some signs of DR in images, such as EX. Most DR diagnostics can be applied to a single data set. Furthermore, most of the studies used ML datasets [36] for binary classification (presence / absence of DR) resulting in misclassification. Advanced1or severe stages of DR can be diagnosed by changes in BV, but early signs may not be definitive after vessel removal.In addition, some studies were limited to segmentation of a single pathological feature (i.e. BV EX, HM or MA) and most studies have detected DR without diagnosing its grades, which is essential in the treatment of DR.

Most studies used data augmentation to increase the number of images and overcome overfitting in the training phase.

One of the limitations of using deep learning for segmentation of retinal lesions is the size of the data sets required to train DL systems, as DL requires a large amount of data. The results of DL systems depend to a large extent on the size of the training data, as well as on the quality and balance of the classes. Therefore, the size of the current public datasets must be increased, while the large sizes, such as Kaggle1's public dataset, must be refined to remove low quality data.

It is observed that most of the studies treated here (80%) classified only the fundus entrance image as DR

and non-DR, while 20% classified the entrance to one or more stages as shown in Fig. 3 On the other hand, 75% of current studies did not detect the affected injuries while 25% of them detected the affected injuries. Of these, only 5% of the studies were able to classify the images and detect the type of lesion affected in the retained image, as shown in Figure 4.

In addition, they fall into overfitting. Many state-of-the-art systems have diagnosed DR grades without segmenting and visualizing different DR variations for ophthalmologists. Most studies ignored pre-processing steps, while noise and low contrast affect the accuracy of segmentation and classification. Therefore, it is necessary to segment all both bright and red lesions for efficient detection by DR.

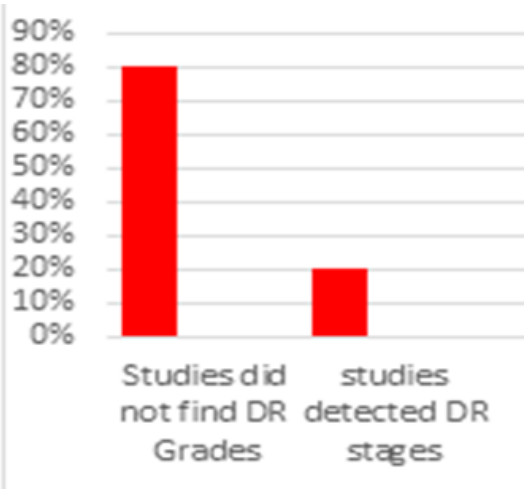

Fig. 3. The percentage of studies that detected DR stages.

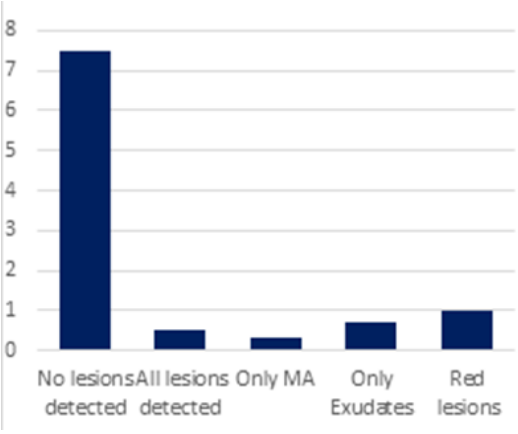

Fig. 4. The percentage of studies that detected DR lesions

IV. CONCLUSION

From the previous review of the current literature utilized conventional methods and DL architectures, we can conclude their main limitations1 in diagnosing DR grades from color fundus images as follows:

Most studies focused on1 detecting the DR presence/absence and1 ignored the DR grades. On the other hand, the studies which focused1 only on segmenting the DR signs, satisfied1with segmenting only one or two of DR pathological variations (EX, HM, BV, and MA).Some studies proposed the DR grades1 diagnosis. These models were conservative, and1 they were not applicable in the real world because of the insufficient and imbalanced datasets. Besides, they fall into1overfitting.A lot of state-of-the-art1 systems diagnosed the1 DR grades without1segmenting and visualizing the different variations of DR for the ophthalmologists. Most studies ignored pre-processing steps, while the noise and low contrast affect the1 segmentation and classification accuracy. So there is need to segment all the lesions both red and bright for the efficient detection of DR grades.

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