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Systematic Study on Recent Automatic Microaneurysm Detection for Diabetic Retinopathy

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Abstract - One of the most common causes of vision loss in people with diabetes is diabetic retinopathy (DR), a chronic illness characterised by damage to the retina as a result of tiny vessel damage brought on by the disease. "The scientific community has spent the better part of the last several years focusing on the issue of microaneurysyms (MA) segmentation since it is essential for the early identification of DR. In this study, the diagnostic utility of automated MA detection and segmentation for early DR diagnosis is investigated using a comprehensive literature analysis. In particular, we analyse the benefits and drawbacks of currently available early DR diagnostic approaches. Our research is confined to colour fundus photography since it is the most often used method for early diagnosis. The development of completely automated, user-friendly early DR diagnosis and grading systems has a great deal of room to grow, despite the fact that much progress has been made in these three categories of early DR diagnosis."

Keywords - Automatic Microaneurysyms, Diabetic Retinopathy, medical, deep learning

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INTRODUCTION

"Tiny red spots inside the eye, encircled by yellow rings caused by vascular leakage, are a common symptom of micro aneurysms, an eye disorder. Diabetic retinopathy is characterized by a chronic expansion of the venous end of a retinal capillary. Visual impairment is not a symptom of a micro aneurysm, and vice versa [1]."

A visual depiction of the human body is created via a technological process called medical imaging, which is then used for diagnostic purposes. "It is often believed to choose the group of procedures that create photographs of the body's interior parts in a non-invasive manner. Computer-assisted diagnosis (CADx) and computer-aided detection (CADe) are both names for the same thing: tools that help doctors make sense of the pictures they see in their practice." Today's CAD technologies are mostly used for recognizing a specific lesion type [2].

It's true that computer analysis can't replace a doctor's expertise. "Different, potentially substantial problems may be detected by combining the clinician's diagnosis with the computer's analysis."diagnosis done by retinal specialists who utilizes the output from a computerized analysis of medical pictures as a second opinion in identifying lesions, estimating the amount of illness, and making diagnostic judgments" is a common definition of a computer-aided diagnosis (CAD). Final CAD diagnosis is established by retina specialists [3]."

There are two primary considerations in medical imaging that contribute most to a correct diagnosis. "While computers have had a major influence on the image-gathering process, the interpretation of such images is still the exclusive purview of humans. Pictures are analyzed by a computer; if any anomalies are found, the images are sent to retinal specialists; otherwise, they are archived without human review [4]."

This thesis explains how computer-aided design techniques were created with the goal of automating retinal screening. "Those who are at risk of developing an illness with obvious symptoms are the ones who benefit from screening. It allows for earlier illness detection, which in turn improves the effectiveness of therapy." By giving the computer a more autonomous role than just offering a second opinion, automated screening expands upon the concept of CAD [5].

After 10 years, DR is almost certain for anybody with diabetes, regardless of how well their diabetes is managed. "DR almost seldom has any impact on the retina. Retinal blood vessels may get damaged due to diabetes over time. Retinal vascular damage (DR) refers to this kind of injury. Non-proliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR) are the two broad categories into which DR may be placed (PDR). Normal-progression retinopathy (NPDR) is the first stage of DR. It is also known as background retinopathy or pre-proliferative retinopathy. Patients with NPDR will exhibit normal visual functioning (20/20 vision) and show no signs of the condition." Retinal exudates, or edema, are the result of fluid leaking into the retina [6].

Microaneurysyms, Hemorrhages, and Hard Exudates are the three components of NPDR (EX). Red lesions include both MA and HM, although the latter is more common. "MA is easily recognizable as discrete, tiny, red circles, often between 10 and 100 m in diameter. Fundus photos show MA as red, but red-free images show it as a black spot. Dot HM, edema, and exudates may be caused by leaking MAs. In appearance, dot HMs are almost identical to MAs. Typically, a dot HMs is less than 200 m in diameter. Since we can't separate them clinically, the term dot hemorrhage/ micro aneurysms (H/Ma) is used commonly. HMs occurs when blood leaks into the retina from newly formed, fragile blood vessels." Unless the bleeding is near the macula, it will not affect your eyesight. [7]

Affected organs include the kidneys and the eyes due to the damage diabetes causes to the body's blood vessels. "Diabetic retinopathy is an irreversible eye condition that may develop in people who have diabetes for a long time. Microaneurysyms, hemorrhages, exudates, and new blood vessels are all abnormalities caused by diabetic retinopathy, a common eye condition. The result of this is impaired eyesight or total blindness. Diabetic retinopathy may be either non-proliferative (NPDR) or proliferative (PDR), depending on how far along the disease progression the affected eye is (PDR). There are three stages of non-proliferative diabetic retinopathy: mild, moderate, and severe." Mild NPDR is defined by the presence of one microaneurysyms [8].

Hemorrhages, an increase in microaneurysyms, soft exudates, and venous beading are all signs of moderate NPDR. "Microaneurysyms, micro hemorrhages, and other vascular anomalies are more common in patients with severe NPDR. Post-Disaster Recovery (PDR) is a terminal phase. In PDR, new blood vessels form in response to signals for nutrition supplied by the retina. Because of this, the optic disc may develop new blood vessels. The existing capacity for screening for diabetic retinopathy is constrained by the large gap between the number of patients with diabetes and the number of ophthalmologists. Analysis of all retinal FUNDUS pictures is a tedious and time-consuming operation. We can't be sure if there are anomalies in all of these pictures." As a result, it is necessary to automate the grading process so that more people can be checked, and if necessary, sent to an ophthalmologist [9].

Screening for diabetic retinopathy is facilitated by a number of mechanized methods. "In this work, we take a look at the state of the art in automated diabetic retinopathy diagnosis, namely the identification of microaneurysyms. Diabetic retinopathy's first stage is the existence of microaneurysyms. Diabetic retinopathy grading relies heavily on the detection of microaneurysyms since they serve as a benchmark for determining whether or not an eye picture is indicative of a healthy retina [10]." The paper is divided into a Literature review of the SRM in Section 2, the Comparative study on recent methods in Sections 3, a research gap described in Section 4, conclusion described in Section 5

LITERATURE REVIEW

Author has published a database of Diabetic Retinopathy that may be automatically detected by screening system utilizing Kirsch's edge detection technique [11]. "The Kirsch template approach is used to extract the retinal blood vessels from pictures. It successfully discovers the new blood vessels creation in retinal pictures by preprocessing, vessel extraction, feature extraction and categorization of retinal images."

In [12] author have proposed an excellent approach to search out the exudates and hemorrhages in fundus pictures. "k- Means color compression technique is used to minimize the color dimension in distinct areas of fundus photographs. Diabetic Retinopathy identification is based on fuzzy inference technique. Sensitivity and accuracy, among other performance metrics, are computed." The accuracy of the fuzzy logic classifier applied to the fundus pictures is 96.67%.

Diabetic retinopathy is the subject of the author's in-depth investigation, which may be found in [13]. "The fundamental difficulty with Diabetic Retinopathy is that it causes blindness. Due to diabetic retinopathy, almost 25,000 individuals lose eyesight in every year. The initial symptom of Diabetic Retinopathy is retinal damage, resulting to frequent leakage from blood vessels. Diabetic retinopathy is the damage to the retina caused by long-term high blood sugar levels." Both of a person's eyes will be impacted. Preventing blindness calls for early detection and screening.

In [14], the author introduces a low-dimensional color auto-correlogram feature that is spectrally adjusted to DR pictures. "Classification utilizing the suggested feature is carried out inside a multi-class, multi-instance learning system. Extensive trials, including comparisons with a few state-of-the-art picture classification algorithms, have been undertaken, and the findings indicate that the suggested methodology is promising since it beats other methods by a considerable margin."

In [15] author have presented a novel technique to classify the exudates.vvK-means clustering is used to detect the optic disc and kirsch's template edge detection algorithm is used for blood vessels segmentation. The intensity computation and features extraction are carried out. Here SVM classifier is used to classify the true or false exudates for high gray level variation in exudates. The detection and classification of exudates with an accuracy of 94.17% is obtained with the proposed method.

Diabetic retinopathy in fundus pictures may be detected automatically using a technique described by the author in [16]. "Preprocessing, feature extraction, and classification steps make up the proposed system. K-nearest neighbor, Gaussian mixed model, and support vector machine are the classification methods used. Both KNN and GMM classifiers have a modest computing footprint. We now know that SVM has a significant computational complexity." There is an increase in performance of the suggested method, as well as a quantifiable increase in sensitivity and specificity.

The author of [17] suggests a new SVM classification strategy for detecting exudates in retinal pictures. "Median filter and Adaptive histogram equalization technique are used to preprocess the retinal picture. Next, the processed picture is segmented. In order to divide up a picture into its constituent parts, the k-means clustering technique is used." Fundus pictures are analyzed for exudates, and then classified using SVM classification.

The author of [18] describes a method for identifying and categorizing DR's many forms. "The veins and other areas are separated using a shrinking edge-mark segmentation technique. The four characteristics of length, breadth, size of cotton wool area, and shape of picture are utilized to identify the phases of retinopathy." With the suggested method, retinal pictures are classified using a recursive Support Vector Machine and it is shown that the detection is precise.

Diabetic retinopathy may be detected automatically in retinal pictures using machine learning approaches, as demonstrated by the author in [19]. "Bag of visual words is used to extract features from images in this pre-processing technique. Using a multi class classifier, such as Local Binary Pattern (LBP), Speeded up Robust Features (SURF), or Histogram of Oriented Gradients (HOG), it sorts diabetic retinopathy retinal pictures into distinct phases (HOG). Include them in a satchel of visual metaphors for added impact." Multi class classifiers like support vector machines and random forests are utilized on retinal pictures.

An approach combining image processing and machine learning is suggested for analyzing diabetic retinopathy retinal fundus pictures [20]. "The retinal fundus pictures are categorized using a bag of visual words approach. To categories fundus pictures such as lesions, exudates, and micro aneurysms, the suggested classifier is utilized, and it achieves an accuracy of 94.4%, which is greater than any of the current approaches in the literature."

Microaneurysyms and non-microaneurysyms are discussed in [21]. "The suggested work consists of four stages: preprocessing, candidate extraction, texture feature extraction from the candidate area using a Gabor filter, and lastly classification utilizing the recovered features. Microaneurysyms have been classified using support vector machines (SVM) (MAs)." Images of diabetic retinopathy in India were used to evaluate the suggested method (IDRiD).

The author of [22] suggests utilizing color fundus pictures to do an algorithmic screening for diabetic retinopathy. "Edge-guided candidate micro aneurysm identification, mixed-features candidate classification, and image- and lesion-level feature fusion for diabetic retinopathy prediction make up the core of our method."

According to [23], the author has explained the methods for early DR diagnosis discussed in this article fall into three major categories: "traditional image processing, traditional ML methods, and DL-based approaches. The development of completely automated, user-friendly early DR diagnosis and grading systems has a great deal of room to grow, despite the fact that much progress has been made in these three categories of early DR diagnosis."

The microaneurysyms reported by the author in [24] are the first warning signals of diabetic retinopathy (DR), which may eventually cause blindness (MAs). "These MAs are practically circular in form, but their dark color and small size make them difficult for human ophthalmologists to detect. Curing DR before irreversible blindness sets in requires prompt and precise diagnosis of microaneurysyms."

Author [25] explained it in detail. "To aid in the early identification of DR, a machine learning approach is presented for detecting microaneurysyms utilizing directional local contrast (DLC). First, an increased enhancement function based on Hessian matrix eigenvalues analysis was used to better highlight and segment blood vessels. Next, potential locations for microaneurysyms were generated using form features and connected components analysis; this time, blood vessels were disregarded."

Micro aneurysm detection in retinal fundus pictures is shown in [26]. "Images with low illumination and a shifting depth of focus must be preprocessed so that lesion and non-lesion features may be seen clearly. Then, we apply the negative pixel intensity rank transform (PIRT) to identify the retinal pictures with the smoothest areas and sharpest edges. The next stage involves taking the rank transformed picture and removing the optic disc and the blood vessels."

True micro aneurysm candidates are finally chosen by histogram thresholding.

Authors [27] suggest using a 10-layer convolutional neural network to automatically, concurrently segment and differentiate exudates, hemorrhages, and micro-aneurysms. “Before segmentation, the input picture is normalized. This work demonstrates that a single convolutional neural network can be trained to accurately segregate these abnormal characteristics across a variety of fundus pictures.”

To illustrate, the author of [28] provided a description Diabetic retinopathy screening relies heavily on the detection of microaneurysyms, the disease's initial sign. “Automatic identification of microaneurysyms in fundus pictures is difficult due to the complex backdrop. First, a unique deep convolutional encoder-decoder network for microaneurysyms identification is created to find the MAs by the differences between the skip connections in the network, which are in turn prompted by the properties of microaneurysyms.” Then, to highlight misclassified microaneurysyms, a weighted dice loss, the smooth dice loss, is introduced.

As the author explains in [29], when diseases are diagnosed and treated early enough, they seldom cause permanent vision loss. “The most common cause of blindness is diabetes, and microaneurysyms (MAs) are an early sign of diabetic retinopathy. Diabetic retinopathy may be detected early with the use of a fundus examination. However, it is challenging for doctors to spot MAs on retinal scans since MAs generally look as little black spots.” This is why there are so many MA detection investigations.

The author of [30] explains that diabetic retinopathy may be treated at every stage of the illness, from early detection to complete prevention of visual loss. “There is substantial evidence that the number of microaneurysyms in a patient's retina is directly related to the severity of diabetic retinopathy. Therefore, it is crucial to diagnose Microaneurysyms in order to prevent future difficulties.” Fundus photos are a painless method of diagnosing retinal disease.

COMPARATIVE STUDY

S.No.	Title	Year	Methodology
31	“Automated Microaneurysyms Detection in Retinal Images Using Radon Transform and Supervised Learning: Application to Mass Screening of Diabetic Retinopathy”	2021	“Develop unsupervised and supervised MAs detection algorithms. First, retinal pictures are pre-processed to reduce background fluctuation for accurate detection.”
32	“Deep learning algorithms for detection of diabetic retinopathy in retinal fundus photographs: A systematic review and meta-analysis”	2020	“Background One of the primary causes of blindness throughout the world is diabetic retinopathy (DR). To slow or stop the course of visual loss, early diagnosis and treatment of DR is preferable.”
33	“Machine Learning Techniques for Ophthalmic Data Processing: A Review”	2020	“This review considers colour fundus imaging and OCT. The study includes machine learning algorithms that identify glaucoma using eye measurements and visual field data.”
34	“Technical and imaging factors influencing performance of deep learning systems for diabetic retinopathy”	2020	“Deep learning (DL) is useful in constructing diabetic retinopathy (DR) algorithms, perhaps overcoming budgetary and personnel obstacles.”
35	“Artificial intelligence for diabetic retinopathy screening, prediction and management”	2020	“In terms of particular complications, diabetic retinopathy affects the eyes more often than any other kind of diabetes-related condition. Patients with diabetes and diabetic retinopathy often only get treatment in tertiary care facilities, which are more costly and have fewer resources available.”
36	“Computerized retinal image analysis - a survey”	2020	“In this research, we take a look at how automated computer-aided approaches are being utilized to identify retinal disorders.”
37	“A survey on medical image analysis in diabetic retinopathy”	2020	“Damage to the blood vessels in the retina, known as diabetic retinopathy (DR), is a common but serious consequence of diabetes.”
38	“Diabetic retinopathy detection through artificial intelligent techniques: a review and open issues”	2020	“This research summarises DR detection methods from five angles: datasets; picture pre-processing methods; machine learning-based approaches; deep learning-based methods; and performance metrics.”

RESEARCH GAP

“Based on our extensive literature assessment, we've identified a number of open research questions that might help advance the state of the art in CAD-based early DR detection. In general, DL architectures have outperformed more conventional methods for DR stage classification. However, when tested on larger patient cohorts, particularly when fundus pictures are acquired using a variety of cameras, the obtained accuracy drops below 0.5. It's possible that new features or layout variations in captured photographs might be introduced by using a camera with a different design. More refined DL approaches can effectively handle complicated healthcare data.” With proper consideration of minor MA, attention-based CNN architectures may increase classification precision [41-52].

Image size, contrast, lighting, light incidence angle, etc., might vary across retinal pictures because of the various camera settings. “Most current approaches only allowed for the use of a single dataset during training and testing. Models that can handle data from a variety of distributions and can be independently verified are urgently needed in the field of data science. Most current approaches pre-process the colour fundus pictures before using any data modelling, but a thorough performance study is required to fully grasp why this is necessary. Massive amounts of labelled fundus data at the pixel and picture level are required for supervised DL using CNN models and deeper architectures. Obtaining such pictures is labour-intensive, time-consuming, and costly since it requires the participation of highly trained medical professionals. Higher accuracy doesn't always indicate proper segmentation; hence it may not be a good metric for assessment. Since the MA mask typically contains millions of black pixels and hundreds of white pixels, it is possible to achieve 99% accuracy even if all white pixels are omitted.” For a more precise comparison with current methods, a system that assesses at the pixel, lesion, and picture levels might be developed.

“Ophthalmologists would benefit greatly from a completely automated, real-time instrument with high usability that may aid in the diagnosis of DR; hence, further study in this area is needed. In most cases, colour fundus pictures obtained from expensive fundoscopy equipment have been used. Smartphone fundus photos are inexpensive and easy to transport, but they have not been investigated for use in early diagnosis."

Most current segmentation methods rely heavily on morphological features for MA detection. "Problem-causing features of an MA are not investigated, but predictive score-based approaches are not investigated either. Patients' follow-up appointment data might be used for this purpose. Early clinical decision-making may be helped by the recognition of certain features, such as the likelihood that an MA will leak in the future, that it will rupture, that it will get plugged, or that it will resolve itself. For early DR diagnosis, the majority of current studies rely only on imaging data. Metadata about patients are not investigated in conjunction with one another, including demographic information and vital signs." Potential exists for the creation of early diagnostic systems that integrate data from several modalities.

CONCLUSION

One of the most common causes of irreversible eye damage and blindness is diabetic retinopathy, a kind of diabetes-related eye disease. "Early identification of DR, which may be done by looking for microaneurysyms, can prevent future difficulties and vision loss. This article presents a thorough writing examination of huge deals with PC supported finding based calculations for acknowledgment and division of Mama, including everything from customary picture handling strategies to ongoing investigations that have used DL based approaches. To begin with, we talked on how finding Mama is critical for DR early determination." Then, at that point, we gave scientific categorization of Mama Location and division strategies, characterizing them as either picture handling based, AI based, or early conclusion using profound learning techniques.

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