The Identification and Detection of Diabetic Retinopathy Using Image Processing Techniques based on Medical Imaging : A Survey

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Abstract: *Diabetic Retinopathy is a primary reason for blindness in persons with diabetes mellitus (DM). It is a retinal illness. It causes the blood vessels to enlarge in the retina. If the diabetes level is high, this will result in blindness since it affects the retina. Early identification through routine tests is the key to effective therapy. The ophthalmologists would be able to identify more accurately and easily diagnose the patient's condition with the use of automatic screening of retinal photographs. The survey on the identification of retinal pictures through the use of suitable data mining techniques and also image processing methods has been emphasized. Different methods are adopted to distinguish between normal and aberrant retinal pictures, which will save the physicians' evaluations.*

Keywords: **Diabetic Retinopathy, Diabetes mellitus, pre-processing, microaneurysm, Optic disc, Exudate.**

1. INTRODUCTION

Being a human, the eye is a very important organ through which we see the outside world. There exist many purposes as eyes react to light. Rods, Cones present in the retina allow vision and also light perception, thereby helping in colour differentiation. Diabetic Retinopathy is one of the disastrous complications of diabetes, and in diabetic patients, it is the leading reason for vision problems. The epidemiological study ranks diabetic retinopathy among some of the leading types of blindness. Diabetic retinopathy is a microangiopathy, the specific features of which include: a. Rupture of small retinal blood vessels; b. Visual loss. Diabetic retinopathy affects 99% of type I diabetics after twenty years and 60% of type II diabetics. The patient requires a high degree of monitoring in order to prevent visual loss since the condition is asymptomatic and if diagnosed at a later stage is very severe. There are few ophthalmologists to allow easy and regular screening of diabetic retinopathy in quality-assured settings across the international community.

The symptoms of DR could be explained by the presence of exudates (EXs), haemorrhages (HMs), and microaneurysms (MAs). DR is an asymptomatic disease, Identification of this disease and treatment is rigorous in the research area. various research organisations in different universities are under the process of building a full-fledged automated DR detector to cut down the process cost and burden on ophthalmologists. Diabetic retinopathy as a disease may cause partial or sometimes complete loss of visibility.

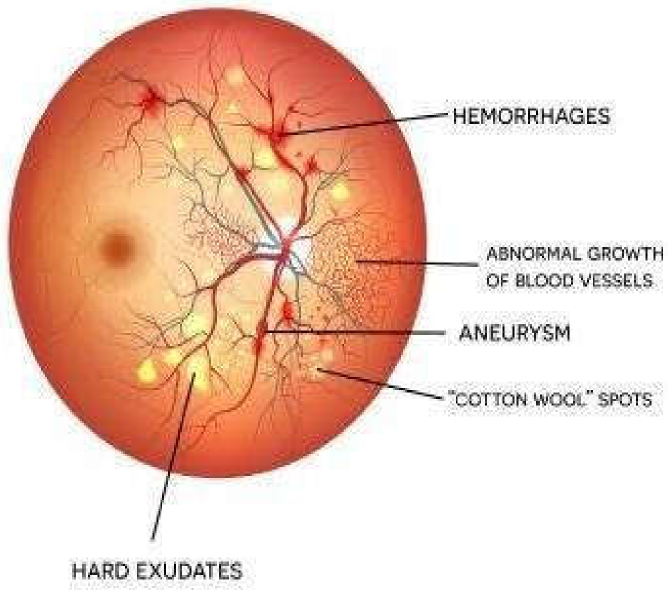

Fig 1: Diabetic retinopathy

2. LITERATURE REVIEW

Dasari in [1] describes the systematic review examining the most recent developments to detect diabetic retinopathy by deep learning on fundus images. The review explores AI methods, neural networks, performance assessments, and future research directions. Methods like deep learning-based technologies for retinopathy disease detection and neural network designs like CNNs, RNNs, and GANs are utilized in the research. In this methodology, results are incorporated with advanced deep learning and AI techniques. The approach is challenging as it incorporates heterogeneous data sources in the research. In [1], Dasari recommends the scope of exploration in developing DL models incorporating heterogeneous data sources and also discussing challenges and future directions in DR detection and classification.

Jain in his paper [2] "Diabetic Retinopathy Detection Using Quantum Transfer Learning" presents several valuable insights into the detection of diabetic retinopathy (DR) using advanced technologies. Jain also explains the demerits of old Traditional diagnostic methods for DR, which rely on ophthalmologists analyzing retina fundus images, are often time-consuming and costly. This creates a barrier to effective screening, especially in resource-limited settings.

In [2], the importance of proposing a novel approach using quantum transfer learning, which combines classical neural networks with quantum computing techniques, is discussed. This hybrid model is designed to enhance the efficiency and accuracy of DR detection, addressing the limitations of classical methods.

Rubi Dahiya in [3]describes that diabetic retinopathy is a complication of diabetes that affects the eyes, primarily due to damage to the blood capillaries in the retina. This condition can lead to severe vision problems if not detected early. In [3] An experimental model was developed to predict diabetic retinopathy at an early stage. This model serves as a foundation for evaluating the effectiveness of different algorithms. Provides insights into algorithm effectiveness and scalability. Contributes to understanding algorithm impact on model performance.

Shanmuga [4] describes an automated system that classifies diabetic retinopathy severity using deep learning models. the research also achieves 80% sensitivity, 82% accuracy, and 0.904 AUC for classification. the methodology use CNN, VGG-16, VGG-19 to incorporate an automated classification system for diabetic retinopathy severity grading. In [4] they achieve Achieved 80% sensitivity, 82% accuracy, 82% specificity, 0.904 AUC which it classifies images into 5 categories ranging from 0 to 4 to specify the severity. However, the method uses manual DR detection, which is time-consuming, and also lack of early symptoms makes early detection difficult.

Jesse Vislisel in [13] describes diabetic retinopathy (DR) as a vascular disease of the retina that affects patients with diabetes mellitus. The chance of developing diabetic retinopathy (DR) is closely linked to how long a person has had diabetes. Type 2 diabetes often develops gradually and can remain undetected for many years, meaning that patients might already have DR by the time they receive a diagnosis. In contrast, individuals with Type 1 diabetes are usually diagnosed earlier in their condition, and they generally do not experience retinopathy until several years after their diagnosis. The risk of developing retinopathy tends to rise after puberty. Additionally, maintaining good glucose control not only helps reduce the risk of DR but also lowers the chances of other serious complications related to diabetes. Therefore, it's crucial for diabetic patients to receive proper education on this matter. The most important risk factors for DR include the duration of diabetes and the level of hyperglycemia, but other contributing factors can include hypertension, dyslipidemia, smoking, nephropathy, and pregnancy (AAO 2008). Furthermore, the anatomy and classification of diabetic retinopathy in fundus images are described in a more detailed manner.

S P Meshram in [14] suggests Retinal image vessel segmentation and their branching pattern can provide us with information about abnormality or disease by examining its pathological variance. Retinal vascular patterns play a vital role in the automated screening and diagnosis of diabetic retinopathy, aiding ophthalmologists in their efforts. Early detection of this prevalent diabetes-related complication, which harms the retina, is essential for preserving the vision of those living with diabetes.

Diabetic retinopathy impacts the eyes due to damage to the blood vessels in the retina, the light-sensitive tissue at the back of the eye. Initially, individuals may experience no symptoms or only minor vision issues, but if left unchecked, this condition can lead to blindness. Anyone with type 1 or type 2 diabetes is at risk, as diabetic retinopathy is a common ocular manifestation of this systemic disease, affecting nearly 80% of patients who have had diabetes for a decade or longer. Despite these concerning figures, studies suggest that proper treatment and regular eye monitoring could prevent at least 90% of new cases. The risk of developing diabetic retinopathy increases with the duration of diabetes.

Detecting blood vessels manually can be quite a challenge because their appearance in retinal images is pretty complex and lacks contrast. Typically, segmentation relies on the contrast differences between the blood vessels and their surrounding areas in a digital image, where all the vessels are interconnected. There's been a lot of research on this topic, with various methods like region-growing techniques, morphological and thresholding techniques, neural network approaches, statistical classification methods, and hierarchical techniques being explored.

In this paper, we introduce a new algorithm for detecting blood vessels in digital retinal images using Contrast Limited Adaptive Histogram Equalization (CLAHE). This method boosts the local contrast of the pixels that make up the blood vessels and those from the background, enhancing the candidate pixels from the background. We apply CLAHE to digital retinal images, which is a specific type of Adaptive Histogram Equalization. It works by breaking the image into several small, non-overlapping regions for processing. Our method has been tested on the publicly available GOLD STANDARD database of manually labeled images, achieving a sensitivity of 65% and a specificity of 98.97%. The algorithm is accurate and robust as well as fast.

Lowering the threshold value improves the sensitivity of the algorithm but decreases the predictivity. The proposed method can be improved and the specificity of implementation can be increased by using some additional steps.

Changira Sinthanayothin in[15] describes Worldwide ophthalmologists are confronted by the dramatic growth in the incidence of diabetes. Diabetic retinopathy (DR) is the most prevalent complication in diabetes, and its effects vary from minor vision impairment to blindness. Repetitive screening for DR is cost-effective, but it is also an expensive and hard business. Several research have studied the use of automated image analysis to overcome this challenge. Large populations are required to evaluate the effectiveness of such programs, and a consistent and rigorous approach is necessary to offer an indication of system performance in real clinical situations. Methods: In a systematic review, we intended to find studies with technique and design that are comparable or duplicate real screening circumstances. A total of 1,231 papers were discovered using PubMed, Cochrane Library, and searches. Three manual search tactics were carried out to find articles missing in the original search. Four steps of screening yielded 7 studies suitable for inclusion. The computerized screening method has been created to identify the normal and an abnormality of retinal pictures with the sensitivity-80.21% and specificity 70.66% correspondingly. Seven studies were included. The detection of DR has good sensitivities (80–95.2%).

The causes for false negative (misclassify abnormal to the normal pictures) for 56 photographs are as follows: 38 retinal pictures have just Microaneurysms and Haemorrages, which has not yet count to the validation procedure. pictures contain very little exudates or weak exudates. Another 7 photos are too dim to distinguish.

The causes for false positive (misclassify the normal to diabetic retinopathy pictures) for 142 photographs are as follows: most improperly categorized photos were due of the artifacts surrounding the vessels, the artifacts that comparable to exudates, misclassified of the optic-disc in preceding technique and the artifact from the laser pointer.

Thomas Walter in[16]suggests, In the scope of computer aided diagnosis of diabetic retinopathy, a novel method for identification of exudates is introduced and explored. The presence of exudates inside the macular area is a primary feature of diabetic macular edema and permits its detection with a high sensitivity. Hence, identification of exudates is a crucial diagnostic job, in which computer help may play a vital role. Exudates are discovered us in their high grey level variation, and their outlines are identified by means of morphological reconstruction procedures. The identification of the optic disc is important for this strategy. Detect the optic disc by way of morphological filtering methods and the watershed transformation. The system has been tested on a small picture library and compared with the performance of a human grader. As a result,a mean sensitivity of 92.8% and a mean predictive value of 92.4%. Robustness with regard to modifications of the parameters of the method has been assessed.

There are three primary ways in which it may contribute: image enhancement, mass screening (including identification of diseases and retinal characteristics), and monitoring (including feature detection and registration of retinal pictures). The differentiation between hard exudates and soft exudates (cotton wool spots), is not achievable with the suggested algorithm.

Kheng Guan GOH in [17] explains that diabetic-related eye illness is the most prevalent cause of blindness globally. The most effective therapy is early discovery via routine testing. This creates a significant number of retinal pictures for medical specialists to evaluate. A mix of novel image processing and data mining approaches to automate the preliminary analysis and diagnosis of diabetic- associated eye illness using digitized retinal pictures. Our findings reveal that we are able to properly identify aberrant symptoms such as: improper optic disc to cup ratio, presence of exudates and tortuous blood vessels. With this, the system can categorize the retinal photos into normal and pathological ones, thereby reducing down on the amount of retinal photographs doctor has to evaluate More over half(57.6%) of all newly recorded blindness in Singapore is caused by retinal disorders, as stated by Lim (1999). ADRIS may identify symptoms such as the size of optic disc and cup, and its ratio; exudates or unspecific on in the inter vascular area; and the existence of tortuous main vessel. The performance of the optic disc and cup identification algorithm as well as its ratio computation is determined to be up to expectation, as validated by the numerous clinicians working with the system. The detection of the exudate and the identification of blood vessel is within expectation.

Jerusha in [18] describes, Diabetes is the most frequent genetic illness which is widespread in the globe. Diabetes elevates the likelihood of acquiring various health issues one of them is diabetic retinopathy which is an eye disorder induced owing to the obstruction of blood vessels in the retina. Symptoms of diabetic retinopathy is not particularly obvious. Hence, early identification is the only viable option of lowering the risk linked with the condition. This research is primarily about how computers may be made to gain high level cognizance from the ophthalmic pictures for the detecting procedure. The purpose is to employ convolution neural networks and deep learning approach to construct a robust algorithm for the automated detection system.Neural Network is generally a computer which is given a human neural system. As in a biological brain system it accepts an input and creates a reply depending on the input. Basically in Image processing utilizing neural networks , the computer is taught depending on particular inputs . These inputs are processed and learned to a minute level by the computer. Hence, the trained computer functions as a neural network which identifies and sends the information according to the purpose it has been created for.

Many of the old approaches like Digital image processing, SVM were time-consuming and needed high quality digital fundus, 3D pictures for effective detection. Overcomes the disadvantages of past research by adopting a simple and efficient technique combining deep learning and Back Propagation methods. An novel assessment on five phases of diabetic retinopathy and attained accuracy of 97%.

Carson Lam in [19] indicates Diabetic retinopathy is a primary cause of blindness among working-age individuals. Early identification of this illness is crucial for excellent prognosis. Color fundus images contain features that are characterized for the use of convolutional neural networks that diagnose stages of diabetic retinopathy. This study's network models demonstrated results close to the standard benchmarks in the tests, with a validation sensitivity of 95%. In the multinomial classification models, we identified that most errors stemmed from the CNN misclassifying mild COVID cases as normals since the CNN failed to identify faint disease symptoms. We found that mean enhancing preprocessing techniques such as contrast limiting adaptive histogram equalization and also labeling help in improving the quality of these datasets by verifying them with experts made these subtle features easier to detect. Through transfer learning using GoogLeNet and AlexNet models from ImageNet our peak test accuracies reached 74,5%, 68.8% and 57.2% for 2-ary, 3-ary and 4-ary classifying model respectively. This led to the development of an automated diabetic retinopathy grading system that can sort out images into categories that are mild, moderate, severe or very severe. CNN applies input image through a particular weight matrix to extract feature while retaining the 2D spatial relationship. To that end, we compared different architectures to select the best compact CNN for the binary classification and goal of achieving previously reported performance levels. We also adapted on training a multi-class version to increase sensitivity for mild or early diagnosis and different data preparation and image augmentation techniques were employed to improve test ac Hansen et al. Thanks to this support we was able to incorporate more new data augmentation techniques and conduct more experiments to make a better work. To ensure validity and reliability of the data, we collected a series of images confirmed by professional ophthalmologists. Last changed the problem of limited sample size using deep layered CNN with transfer learning in discriminant color space for recognition tasks, as well as training and evaluation of two networks AlexNet and GoogLeNet for 2-ary, 3-ary and 4-ary classification models appropriate in accordance with the optimal set for the training data set.

Muhammad Hamdi Mahmood in [20] argues, Digital image processing is one of the most extensively utilized computer vision technologies in biomedical engineering. In the contemporary day ophthalmological practice, biomarkers analysis by digital fundus image processing analysis considerably helps to vision research. This further promotes improvements in medical imaging, allowing this sturdy technology to acquire vast scopes in biomedical engineering platform. A variety of diagnostic techniques are used to analyze images of the retinal microvasculature, allowing for the measurement of geometric characteristics such as vessel tortuosity, branching angles, branching coefficients, vessel diameter, and fractal dimensions. The markers extracted from these characterized digital fundus images offer valuable insights, linking quantitative abnormalities in retinal vascular topography to several conditions, including diabetic retinopathy, macular degeneration, hypertensive retinopathy, transient ischemic attacks, neovascular glaucoma, and cardiovascular diseases. Additionally, this non-invasive research tool is automated, making it suitable for large-scale screening initiatives. This review will also delve into recent studies focused on image processing techniques for extracting quantitative features of the retinal microvasculature, particularly emphasizing factors associated with early signs of transient acute chemical attacks or strokes. The analysis of fundus retinal images has emerged as a crucial area within biomedical engineering, serving as a key method for identifying various disorders related to retinal vasculature.

Bhavin in [21] describes the identification of microaneurysms(MAs) from colour fundus pictures using image processing. In this study, we provide a web application to identify MAs from fundus picture more effectively and on real- time purpose. This research contains a new approach to identify and mask the optic disc (OD) and blob detection to detect MAs. To assess the accuracy of the system, we processed 63 colour fundus pictures and obtained an accuracy for 95% accuracy for optic disc removal and 56% accuracy for microaneurysms identification.

TABLE 1. Comparison of different methods

Author	Method	Accuracy	Sensitivity	Specificity
Meshram[2]	Blood vessels detection	70%	Not reported	Not reported
Changira[3]	Optic disc,blood vessel	Not reported	80.21%	70.66%
Jerusha [8]	Evaluation of 5 stages of DR	97%	Not reported	Not reported
Carson [9]	Classification of 5 stages of DR	74.5%	95%	Not reported
Bhavin [11]	Optic disc	95%	Not reported	Not reported
	Microaneurysms	56%		

3. METHODOLOGY

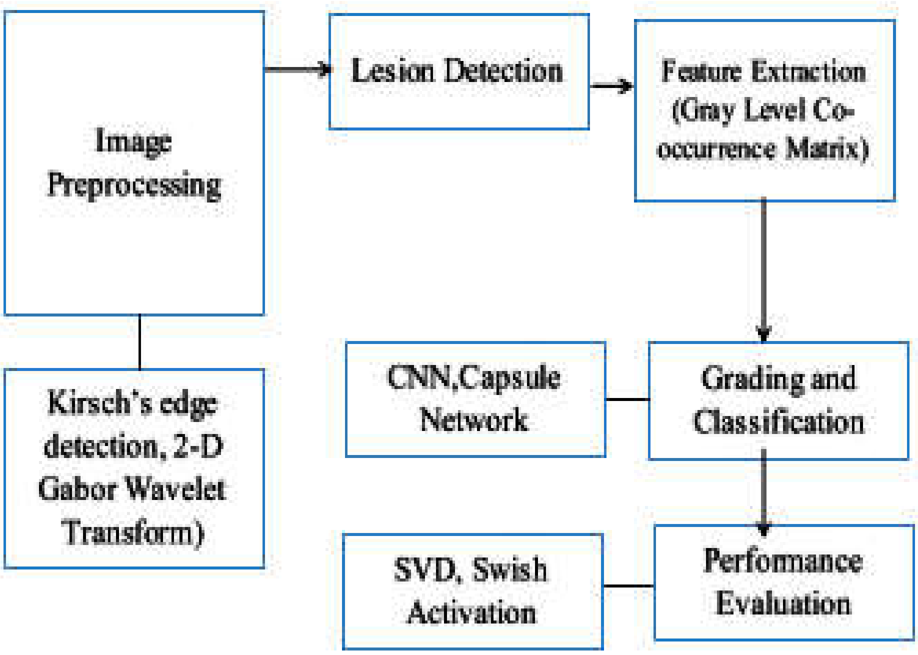

Figure 2: Proposed Methodology

A. Image Acquisition

The process of acquiring information for the identification and Detection of DR largely entails gathering high-quality fundus pictures. These images will be helpful for training and verifying with models which follows machine learning techniques.

1. Images may be collected from any open source dataset which are publicly available datasets like, Messidor, e-ophta, DiaretDB, Indian Diabetic Retinopathy Image Dataset [5] [6].

2. Clinical real-time data is collected from the hospitals

and clinics where DR patients are screened [7].

B. Image Preprocessing

Cleaning and Preprocessing of the images are as follows.

1. Resize the retinal image within ROI. Converting them to gray images and resizing or compressing without losing the quality. So that processing time and overloading time could be reduced.
2. The green channel in an RGB picture is predominant since it offers enhanced visibility of the retinal characteristics, namely microaneurysms, and exudates. This process decreases the intricacy of the picture while preserving crucial information vital to DR detection [6].
3. The color image is converted to gray scale image.
4. Filtering method like Median Filters are applied on the image to minimize the noise or distortions without reducing blurring the bold edges.

C. Feature Extraction

Feature extraction is conducted using the Gray Level Co-occurrence Matrix (GLCM). This method analyzes the spatial relationship between pixels to derive texture features. GLCM captures the frequency of pixel pairs with specific gray-level values occurring at a given distance and orientation.

Key features extracted include:

- Contrast
- Dissimilarity
- Homogeneity
- Energy
- Entropy

These features provide a comprehensive representation of the texture characteristics of the lesions, are vital in classification tasks. The GLCM coefficients are generated comparing the conditional joint probabilities of gray levels in the spatial window of interest, allowing for detailed texture analysis [8][9].

Optic disc:

The dissimilarity in the optic disc does boundary localization a tough task. The optic structure is obtained at the middle of the disc, much evident on the temporal side. The optic cup looks more brighter than the Disc, It covers below 40% in disc, however, Its attributes like size, position, shape is variable.

Sobel Edge Extraction:

Edge detector helps to identify the reign around the viens built on the intensity of the gray levels of the image. The above variations work well with the use of Sobel edge detection method, where sensing the gradient change is easy and cost effective[10].

Related to various edge operators, This edge detection holds various benefits. First, Sobel provides a smoothen the random noise present in the image. Second, the edge will be bright and bold as it contains, two rows, columns in the pixels,

Curve Fitting Approach:

The structure of disc may vary from round to oval. So it requires a range of ellipses, to capture inside the extracted edges. Identifying the best-fitting model along the very few features are truly difficult task.

Exudates identification:

Exudates are liquid structure, will be present in the eye and form lesions. The existence of exudates shows the retinal problems along with forms of vascular damage. A KNN classifier will be adopted to detect the presence of exudate.

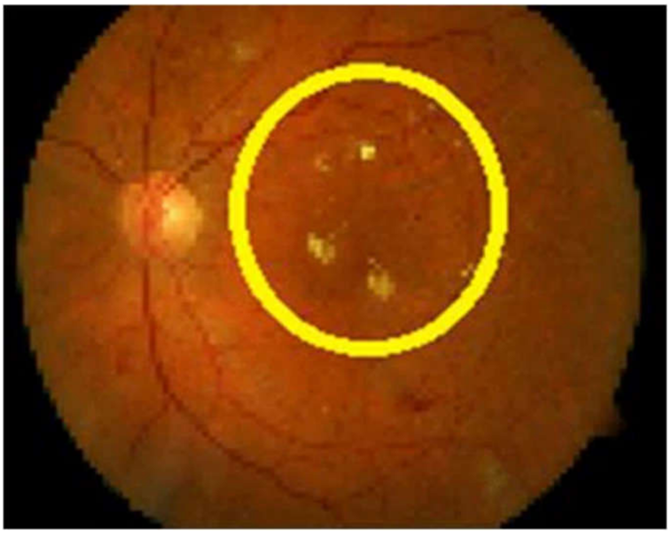

Figure 3: Identification of Exudates

KNN Classification: (K-Nearest Neighbour):

After histogram thresholding, smoothing, and edge detection, the image is divided. For classifying each pixel into a vessel or not, the KNN is applied with the values of pixels.

Vessel Detection:

The appearance of Vessels are an vital factor to identify numerous diseases. The structure of vessels must appear in huge, straight and gentle curves. During dilation , they take a wavy structure. The average diameter of veins is 125µm.

Histogram Thresholding:

When an optic cup has been identified, the optic disc region's histogram distribution, reveals an important pattern. Thresholding is the primary operation of segmentation of the images, and also it converts gray-scale images into binary images [9].

An important metric in the method of thresholding is the choice of threshold value. The threshold value could be specified as

$$g(x,y) = \begin{cases} G0 \text{ if } f(x,y) > T \\ Gb \text{ if } f(x,y) \leq T \end{cases}$$

where, f(x,y), the original image, g(x,y) is the threshold image.

Smoothing:

Smoothing is often used to reduce noise in an image or to produce an image having less pixel values. The individual points are reduced than the adjacent signals to produce the smoother signals. General methodology of the smoothing is that the slow changing of data values could be given more attention to provide the accurate matching solutions of the data values. The curve fitting also helps to provide accurate match of the pixels.

Grading and Classification:

For grading and classification, two advanced neural network architectures are employed: Convolutional Neural Networks (CNNs) and Capsule Networks. Convolutional Neural Networks (CNNs): Capsule Networks enhance the classification process by preserving the metric properties among features which is beneficial for recognizing complex patterns in the images. This architecture addresses some limitations of traditional CNNs by maintaining the pose information of features. This activation property is considered to know the output of each neuron in the network layers to enhance model performance by allowing for non-linear transformations [12].

Capsule Networks: Capsule Networks enhance the classification process by preserving the spatial relationships between features, which is beneficial for recognizing complex patterns in the images. This architecture addresses some limitations of traditional CNNs by maintaining the pose information of features.

Performance Evaluation

The final phase involves performance evaluation, which employs Singular Value Decomposition (SVD) and Swish Activation functions.

1. Singular Value Decomposition (SVD): SVD is applied to reduce the dimensionality of the feature set, improving the computational efficiency and performance of the classification model.
2. Swish Activation: The Swish activation function is used in the neural network architectures to enhance the learning capabilities of the model. This function has been shown to outperform traditional activation functions like ReLU in various deep learning tasks.

Algorithm for Singular Value Decomposition (SVD) with Swish Activation Function:

Input Matrix Preparation:

Prepare the feature matrix A from the extracted features using the Gray Level Co-occurrence Matrix (GLCM).

Singular Value Decomposition (SVD):

Decompose the matrix A into three matrices. $A=U\Sigma V^T$

Here, U contains the left singular vectors, Σ is a diagonal matrix containing singular values, and VT contains the right singular vectors.

Dimensionality Reduction:

1. Select the top k singular values from Σ to form a reduced matrix Σk.
2. Construct the reduced feature matrix Ak:

$$A_k=U_k\Sigma_k V_k^T$$

This step helps in retaining the most significant features while reducing computational complexity and overfitting[11].

Neural Network Model Setup:

Neural Network model Initialization (either CNN or Capsule Network) to be trained on the reduced feature set A_k.

Activation Function Implementation.

Swish Activation Function:

The Swish activation function is applied in the neural network architectures to enhance the learning capabilities of the model. This function proves the outperform traditional activation. Functions like ReLU will be used in various deep-learning tasks.

Algorithms for SVD with Swish Activation Function:

Input Matrix Preparation: Prepare the feature matrix A from the extracted features using the Gray Level Co-occurrence Matrix(GLCM).

Implement the Swish activation function defined as:

Swish(x)=$x\cdot\sigma(x)$,

Where $\sigma(x)$ is the sigmoid function

$$\sigma(x) = \frac{1}{1+e^{-x}}$$

This activation function is applied to the output of each neuron in the network layers to enhance model performance by allowing for non-linear transformations [12].

4. EXPERIMENTAL RESULTS

The experiment was conducted to train the neural network using the reduced feature matrix A_k with the Swish activation function applied to the hidden layers. The test model has shown better results in the detection of the DR. The experiments shows the results were better with an Accuracy of 93.64%, Sensitivity of 96.7% and Specificity of 92%.

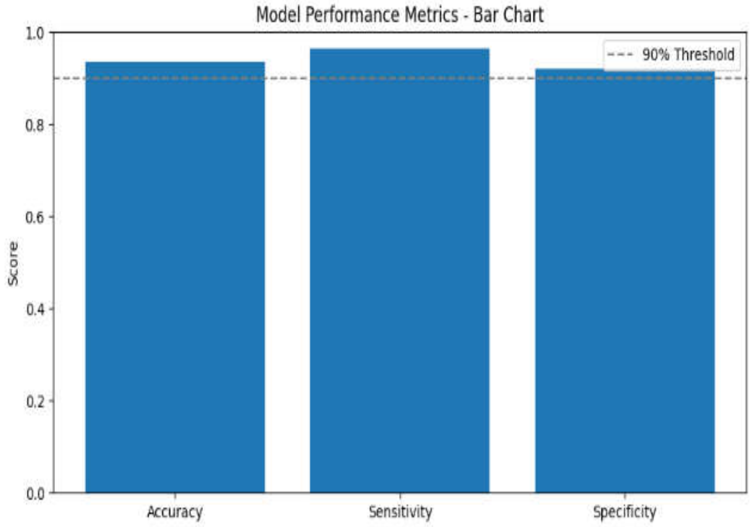

Figure 4: Performance metrics of the experiment

5. CONCLUSION

The results acquired from the proposed screening method shows better results in terms of Diabetic Retinopathy. The classifiers and edge detectors lays attention to the feature classification techniques to properly identify the illness linked with the retina using image processing techniques. Despite the results, The performance could have been improvised by tuning the model. Due to adequate usage of available data, the performance was compromised in this analysis. Yet the scope of improvement is vast to make completely automated DR detectors in real-time usage.

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