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Diagnosis of Diabetic Retinopathy using Fundus Images and Image Processing Methods

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Abstract: Diabetes is a metabolic condition that causes organ failure, including retinal damage. Diabetic Retinopathy causes blindness by leaking blood vessel fluid into the retina also called as exudates. Thus, there has been a surge of interest in automated methods for detecting diabetic retinopathy using image processing techniques. Using real-time image dataset and image processing techniques, the proposed system is able to detect major retinal abnormalities such as enlarged retinal veins, blood spots, and white-yellow patches that indicate fluid leakage. The system analyses colour retinal images to determine the extent of damage and locate clusters of injured pixels within the region. The technique has a greater detection accuracy of 88%, and it has been demonstrated to be successful in detecting exudates and abnormalities from fundus images. In addition, the system is extremely helpful. To make suggestions for possible treatments based on an examination of the fundus images.

Keywords: Diabetic Retinopathy, Image processing, Fundus images, Image Processing techniques, Exudates, Green channel extraction, Excessive growth of retinal veins, Red blood spots, Fluid leakage, Microaneurisms.

I. INTRODUCTION

Among the top preventable causes of blindness worldwide [1], diabetic retinopathy (DR) is a blood vessel disease that affects the small blood vessels in the eye. According to a study conducted by Suresh K. Pandey [2], about 18% of diabetic patients can be found in India, and there is a possibility that number may rise to between 40 and 45% in the near future. Furthermore, half of DR sufferers are unaware of their disease. Thus, early detection and treatment of DR are crucial to preventing avoidable vision loss worldwide [3].

Diabetes, which has an unfavourable influence on blood sugar levels in the body, can lead to diabetic retinopathy (DR), which affects the retina. It develops when the retina's blood capillaries and arteries become damaged due to diabetes. DR is the most common microvascular consequence of diabetes and the leading cause of blindness and vision loss worldwide. DR causes changes to the vascular anatomy of the retina, which ultimately results in damage to the retina over time, nevertheless, there are no early symptoms of DR. Retinal blood vessels are damaged by the excessive development of glucose and/or fructose. Microaneurisms (MAs) [1][3][9], minute swellings on the side of blood vessels, are the most common first lesions that develop as a result of DR. In the first stages, no noticeable visual impairment is seen. It is the first symptom of diabetic retinopathy that most people notice. (See Figure1(b)).

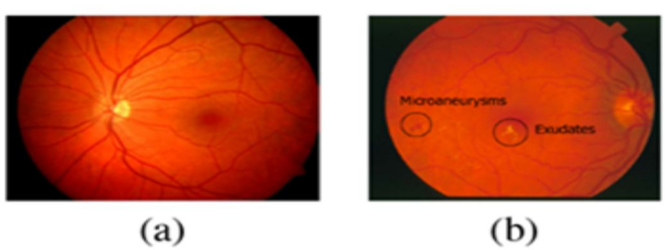

Figure 1: A fundus image with diabetic retinopathy, (a) Healthy Retina b) Diabetic Retina [11]

In addition, some people develop exudate [3][9] when fluid and lipids escape from damaged blood vessels onto the macula (Refer to figure1(b) of the retina). The macula swells as fluid enters it, resulting in impaired vision. As the disease progresses, oxygen deficiency in the retina causes delicate, new blood vessels to grow beside the retina and in the clear, gel-like humour called vitreous inside the eye. The exudates can be either white or yellow, and they come in different shapes and sizes. The retina could be damaged if these new blood vessels if left untreated.

A. Symptoms

In its early stages, diabetic retinopathy rarely causes any noticeable symptoms. Diabetic retinopathy symptoms may include: hazy vision, the inability to perceive colour normally., the patient reports seeing "floaters," sometimes known as "transparent, colourless spots and dark strings." Perceptual angle. Vision-obscuring patches or streaks. Or in some cases Complete blindness that occurs unexpectedly.

There are major 2 types of DR, refer figure 2.

1) *Non-proliferative Diabetic Retinopathy (NPDR) [3] [4]:* This form of diabetic retinopathy is far less severe and often has no symptoms at all.
2) *Proliferative Diabetic Retinopathy (PDR) [3] [4]:* On the other hand, PDR, or proliferative diabetic retinopathy, occurs when new aberrant blood vessels grow in the retina and is the most severe form of diabetic retinopathy.

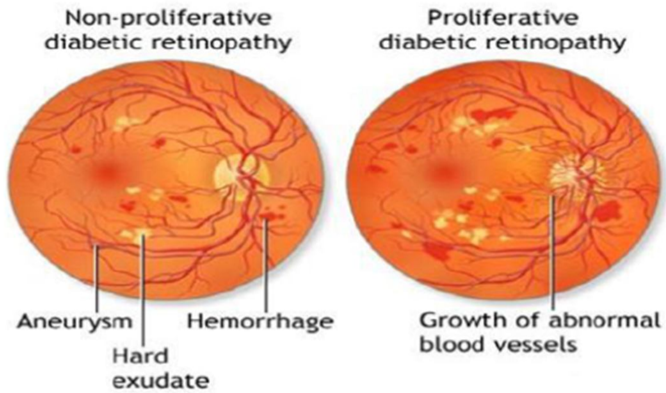

Figure 2: - Types of Diabetic Retinopathy (a) Proliferative DR. (b) Non-proliferative DR.

Thus considering the complications of untreated DR on person's vision, the proposed system assists healthcare professionals in analysing the Digital Retinal Fundus image and classifying the DR into three main visible retinal abnormalities, including abnormally excessive growth of retinal veins, red blood spots, and white-yellow spots indicative of fluid leakage, using an image dataset of 50 images (where some of them obtained from the doctor) from various sources and image processing techniques [2][7][8] [10]. It has also been demonstrated that the system is accurate in detecting abnormalities in retinal fundus images.

II. LITERATURE SURVEY

Table I: Literature Survey

	Author, Year	Description
1	Revathy R, et al.[3], 2020	The study by Revathy R. et al.[3] proposes a hybrid classifier comprised of support vector machine, k nearest neighbour, random forest, logistic regression, and multilayer perceptron network for the extraction of three features including exudates, haemorrhages, and micro aneurysms. The best experimental results we have are for an accuracy of 82%.
2	Ling Dai, et al.[4],2021	DeepDR, a deep learning system developed by Ling Dai et al., can detect early-to-late diabetic retinopathy. DeepDR uses 466,247 fundus images from 121,342 diabetic patients to train for real-time visual quality evaluation, lesion detection, and grading. Three external datasets and a local dataset with 200,136 fundus photos from 52,004 patients are evaluated. Microaneurysm detection is 0.901 accurate.
3	Aurongo Mohammod Nasir et al.[5] ,2022	Researchers Aurongo Mohammod Nasir et al. used a smartphone-based fundus image recording technique to automatically diagnose DR from fundus photos using a Random Forest-based classifier. Their research was published in the journal Ophthalmology. [5] . The research makes use of the EyePACS dataset that is hosted on Kaggle and is accessible to the public. The model achieves greater levels of weighted precision (76.27), recall (72.11), and F1 score (76.22) than earlier models that were trained on the same dataset.

4	Minal Hardas et al.[6], 2022	Classification approach utilising Support Vector Machine (SVM) developed by Minal Hardas et al.[6] with 16 classes that forecast abnormalities singly or in combination depending on the chosen class. Gaussian mixture model (GMM), K-means, Maximum a Posteriori (MAP) algorithm, Principal Component Analysis (PCA), Grey level co-occurrence matrix (GLCM), and Support Vector Machine (SVM) are all part of the suggested study for illness diagnosis utilising DR. On the DIARETDB1 dataset, the proposed method achieves an accuracy of 77.3%.
5	Kashif Moin et al.[7], 2022	Diabetic retinopathy was diagnosed and reliably graded into five groups or stages using convolutional neural network (CNN) methods by Kashif Moin et al. [7] on the publicly available Kaggle dataset. and achieved a remarkable precision of 88%.
6	Nikhil Sathya Kumar et al.[8],2021	Attention based networks (Transformers), Convolutional neural networks (CNN), and multi-layered perceptrons (MPLs) are all employed by Nikhil Sathya Kumar et al. [8] in the detection of DR. More than 3,600 tagged photos form the basis of the Kaggle dataset used to train these models. With an accuracy of 86.4%, Swin-Transformer ranks as the most reliable.
7	Aswin Shriram Thiagarajan et al.[10].2020	When compared to more conventional Machine learning techniques, the maximum accuracy of the automatic detection method developed by Aswin Shriram Thiagarajan et al. [10] for diabetic retinopathy is an impressive 80%. The scientists drew on the IRDiR Disease Grading Dataset, which includes digitised fundus images of varying degrees of Diabetic Retinopathy organised in discrete frequency distributions.

The aforementioned results suggest that utilising multiple machine learning models greatly improves the accuracy of diabetic retinopathy identification.

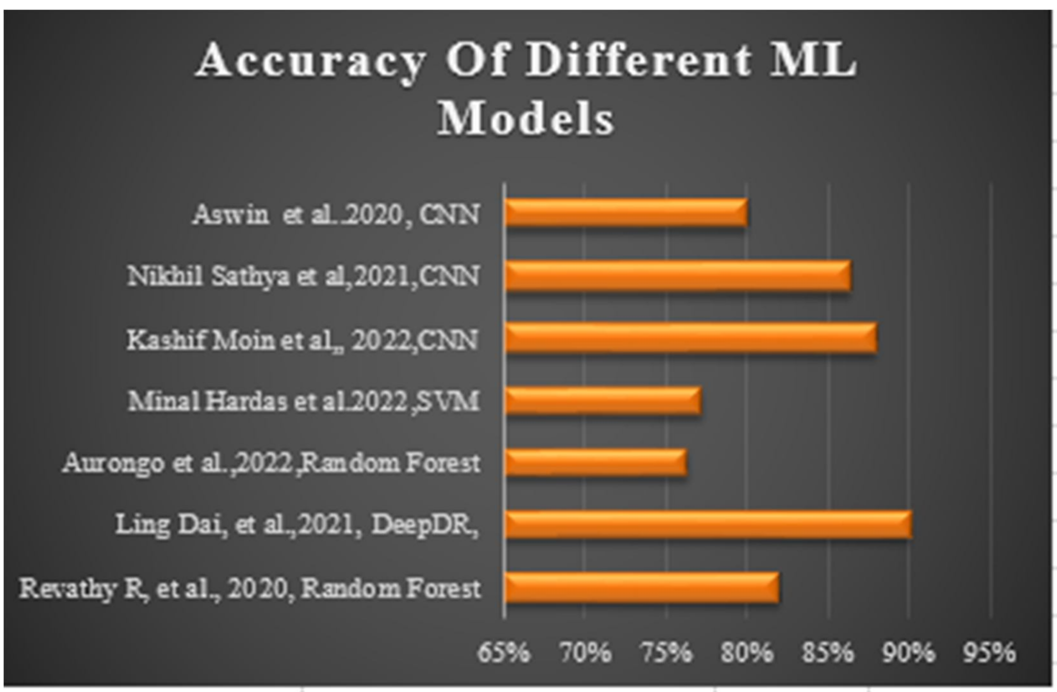

Figure 3: - Accuracy of Different ML Models

However, the accuracy must be improved so that medical professionals can reap more clinical benefits, such as the detection of tentative severity and the detection of approximately % of exudates, microaneurysms. Therefore, the system aids in getting around these restrictions and provides more precise DR detection having three main categories like normal eye, proliferative diabetic retinopathy(PDR), and non-proliferative diabetic retinopathy (NPDR).

III. IMPLEMENTED SYSTEM

As part of early illness diagnosis, the proposed method can aid in the detection of Diabetic Retinopathy (DR) using fundus camera images to assist prevent vision loss and blindness in the elderly. There are three types of DR: normal eye, PDR, and NPDR. However, because the system's primary goal is to detect normal eye and DR, we have classified it as normal eye or diabetic retinopathy as a binary classification. The collected fundus images are analysed for signs of micro aneurysms, exudates, and other optic nerve anomalies.

The figure 3 shows the architecture of the proposed system for the detection of:

1) Exudates Detection
2) Nerve Anomalies Detection
3) Micro aneurysms Detection

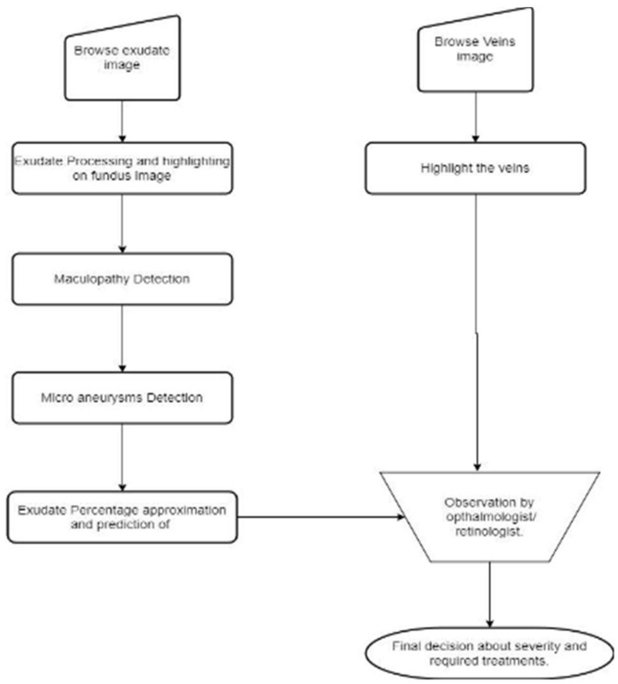

Figure 4: - Architecture of the Proposed system

Systems GUI

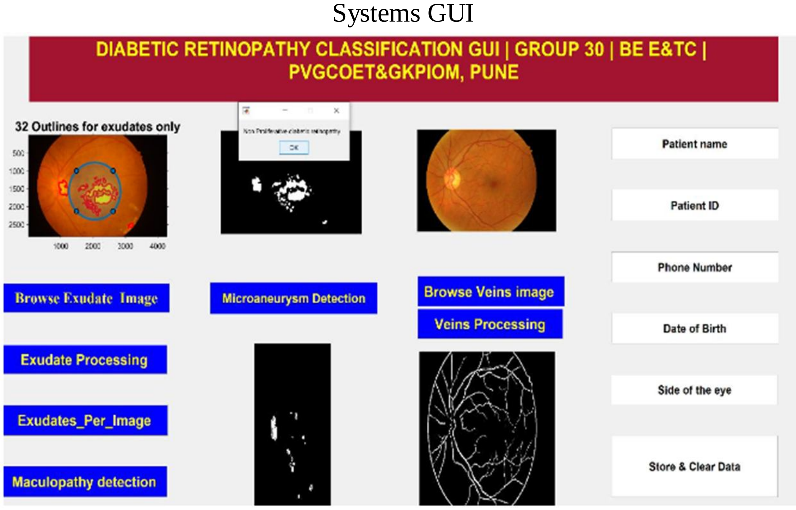

Figure 5: - System GUI

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MATLAB is used to build a GUI. Our method stores patient names, IDs, and timestamps that match the timestamp of the photo. MATLAB can save original and processed images. Moreover, to save all patient entries and map them to corresponding images, the doctor's assistant needs a storage solution, so the text fields with patient name, ID, and timestamp are used to save the patient name. Browsing the exudate image brings up a binary image on the right and maps the exudates on the fundus image in red color borders and creates a scale around the fundus image to perform maculopathy detection. Next, we press the microaneurysm detection button, which leads to the image on the lower axis that highlights the tiny spots known as microaneurysms. After that, we perform the vein highlighting process using the two remaining buttons.

A. Part 1: Exudates Detection

1) *Data Collection:* Images of the retinal fundus are obtained from the healthcare institution. In order to evaluate the effectiveness of the system, about a thousand images are examined. The system saves patients' data in a text file using the system GUI (see to Figure 5 for all the information required while registering the patient's data), which is subsequently saved in the location where the images are stored.
2) *Input Image:* Histogram is plotted when an input fundus image in RGB format has been provided. To get the most information on the soft/hard exudates, the green channel of this image is extracted.
3) *Histogram Localization:* To increase contrast in a fundus image and measuring the brightness of image by representing the frequency of each pixel Histogram Localization is used. Moreover, this localization is used to get an important indication for detection of retinal components like veins or macula.
4) *Median Filtering:* The median filter plays a vital role in the field of image processing. This has led to its application in noise reduction, where it is utilised to keep edges sharp. The filter's ability to remove background noise from the fundus image improves in proportion to the length of the distribution tail.
5) *Banalization of The Subtracted Image Between Filtered and Inverse Filtered Image:* Banalization of images facilitates image segmentation into primary text and background. Thus, following binarization, the image appears as shown below
6) *Erosion and Dilation:* Morphological erosion reduces floating pixels and narrow lines , moreover, dilation help to enhances visibility and fills small holes by thicken the lines and shaping grow. Thus, binarization has been done before erosion and dilation because binary raised images work better than grayscale images.

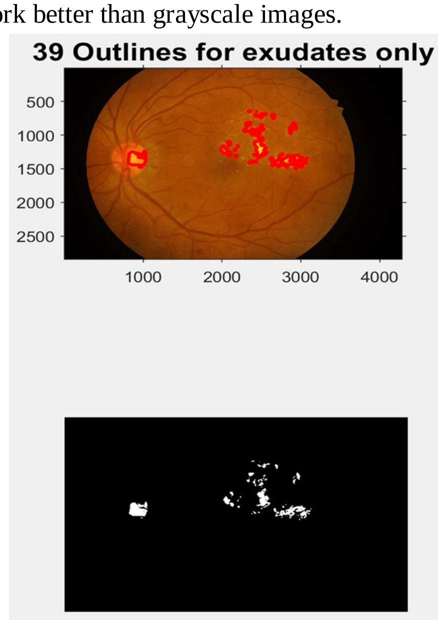

Figure 6: - Exudates Detection

7) *Exudates Detection:* Finally, in order to detect exudate from the fundus image, the dimensions of extracted images are extracted. Then, utilising image processing methods, the number of boundaries of the exudates are depicted in the plot's title. Below figure represents the flow chart of Exudates detection.

Flowchart

Figure 7: - Flowchart of Exudates Detection

B. *Part 2: Veins Segmentation*

1) *Standardization:* The input image was resized to the desired dimensions, and then converted to double format. Another fill matrix is made to preserve only the "a" component by converting the image to LAB colour space.
2) *Preprocessing:* On the reformed LAB image, PCA is carried out. The output is scaled back to the original dimensions of the image, and only the selected portion is retained. improved the image's contrast and applied an average filter to make it more appealing to the eye. The improved image is then subtracted from the smoothed image.

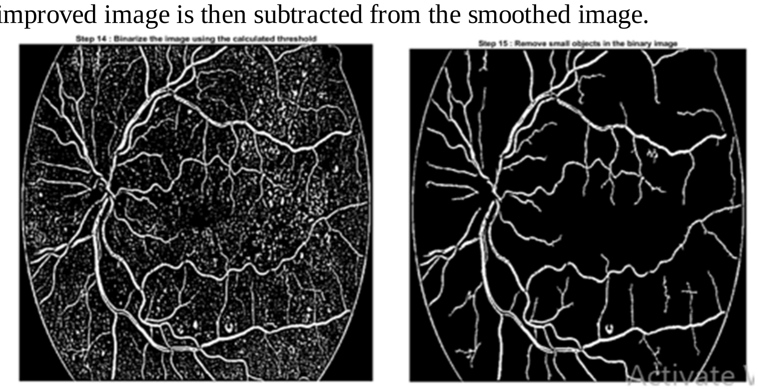

Figure 8: - Segmentation

3) *Segmentation:* Segmentation uses Otsu's approach to determine the cutoff value. once more. Image is binaries with the threshold so that clutter in the binary picture are avoided by erasing little items with

Flowchart

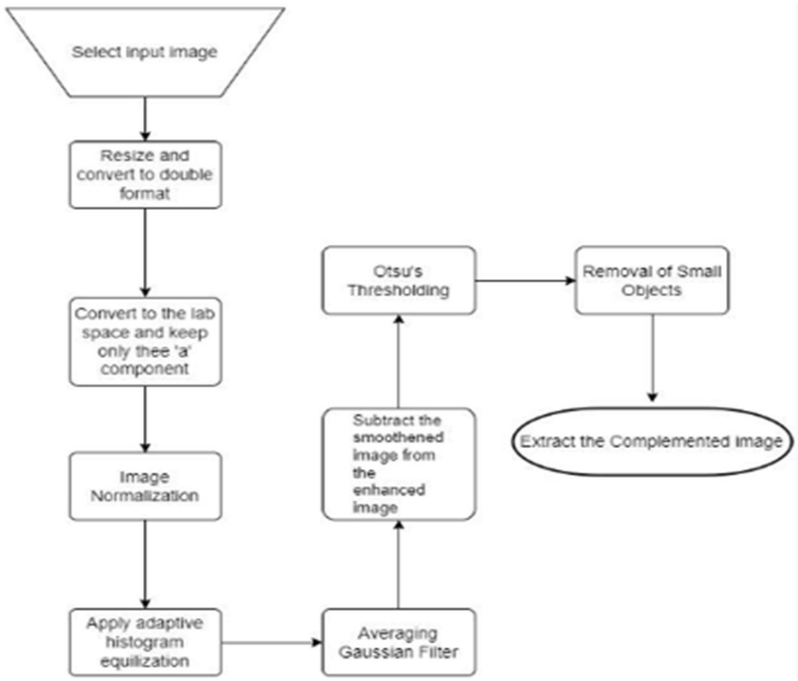

Figure 9: - Flowchart of Veins Segmentation

C. Part 3: Microaneurysms Detection

1) *Pre-processing:* To begin with, we downsize the image to 576 X 300, so that only the important MA's remain, and noise doesn't creep in. The next step is to perform 2D discrete Cosine transform and the inverse of it, so as to extract the important components from the image. It is followed by median filtering for noise removal.

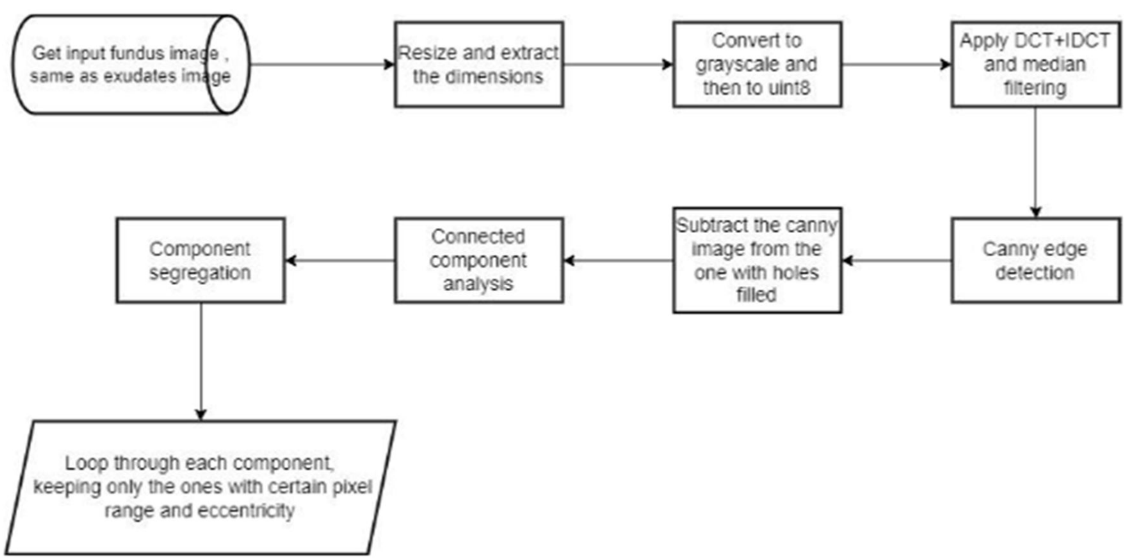

Figure 10: - Microaneurysms Detection

2) *Component Extraction:* In order to reduce the quantity of data required for processing and display the final image with black or white holes, the Canny Filtering is applied to fundus preprocessed image objects._After applying the canny filter, the blank spots in the image are filled in black and white. In the final step, the image that has had the canny filter applied, is subtracted from the image that has had its holes filled. Due to the fact that the microaneurysms are brought it can easily be identified.

D. Part 4: Maculopathy Detection

Maculopathy, also known as macular degeneration, is a condition that affects the central section of the retina, known as the macula, and causes vision loss in those over the age of 50. In Maculopathy, inflammation or abnormal blood vessel growth releases fluid into the retina, impairing vision. The proposed image processing method aids in the detection of Maculopathy utilising fundus images. As a result, these methods can aid in the early detection of maculopathy and the prevention of visual loss. The first axis in the GUI displays an input fundus image using the browse exudate image option. Following that, by pressing the exuded processing button, which displays a binary picture to the right and maps the exudates onto the fundus image in red color boundaries, as well as creating a scale around the fundus image, in order to complete the maculopathy detection operation.

IV. RESULT AND DISCUSSION

A. Dataset Used

Data set of 50 Fundus Images (.jpeg/ .jpg/ .png format) procured from medical professionals as well as online datasets are used for experimentation. Moreover, as the fundus images contains lot of noise that affects the system performance, hence images mostly used that are obtained from the doctors.

B. Experimental Evaluation

The accuracy and precision of the proposed approach are calculated based on false positives (FP), false negative (FN), True positive (TP) and true Negative (TN) images given in table 2.

Table II: Class wise Distribution of Images

	TP	TN	FP	FN
CLASS 0	18	26	4	2
CLASS 1	26	18	2	4

Thus the accuracy and precision are calculated by using the below formula.

$$Precision = \frac{TP}{TP \times FP}$$

$$Recall = \frac{TP}{TP \times FN}$$

We tested the data set for the class 0, 1 such as normal image and image with abnormality such as (DR).

Table III: System Accuracy

	ACCURACY	PRECISION	SENSITIVITY	SPECIFICITY
CLASS 0	88.00%	81.82%	90.00%	86.67%
CLASS 1	88.00%	92.86%	86.67%	90.00%

The graphical representation of the above table is represented in following graph.

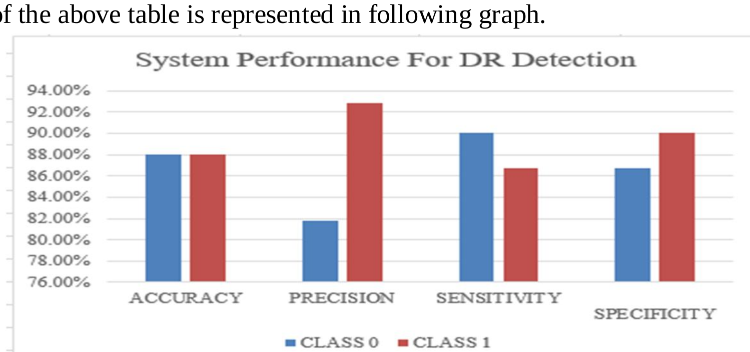

Figure 11: Class Wise Accuracy and Precision Comparative graph

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The proposed system gives an overall 88% accuracy for detection of DR using Image processing algorithm.

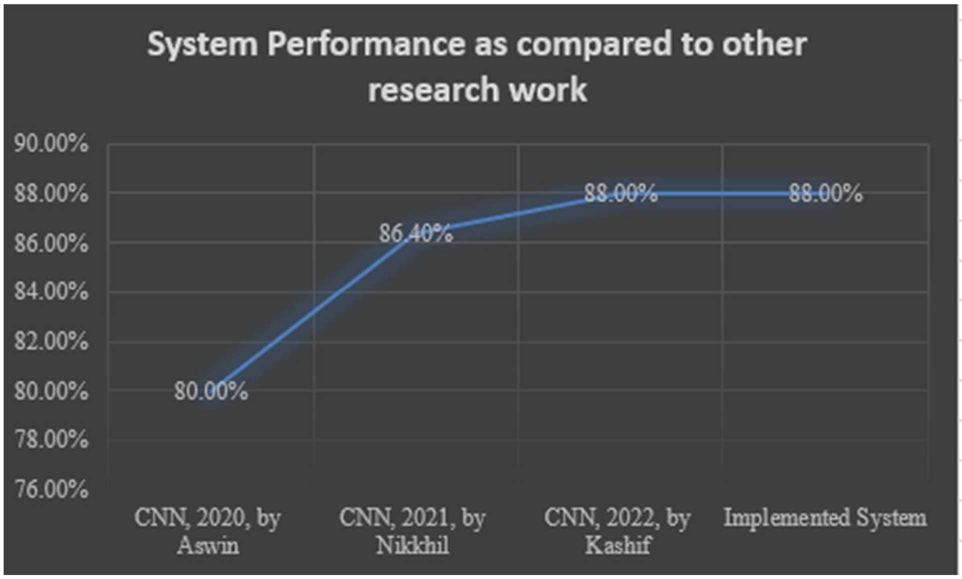

Figure 12: System Performance as compared to other research work

The system also outperforms (88%) as compared to other CNN model that has been proposed earlier.

V. CONCLUSION

One of the biggest causes of avoidable blindness around the world is diabetic retinopathy (DR). There is currently no cure for AMD, although early detection and treatment can help avoid or delay serious visual loss. Finding lesions requires ophthalmologists to manually inspect fundus images, which is a time-consuming and tiring task in and of itself. Thus, the implemented system supports medical professionals in analysing fundus images for abnormalities. This technique has also been shown to detect the development of retinal veins, blood spots, and white-yellow spots with an increased accuracy of 88% using image processing methods. In addition to this, it was also observed that the implemented system performed far better than the earlier work that had been done by the researchers (refer table 1). Although the system has improved detection accuracy, its performance is hampered by the large size of the dataset. This allows for a larger dataset to be collected in the future. Our retinopathy detector has to be made more accurate and sensitive.

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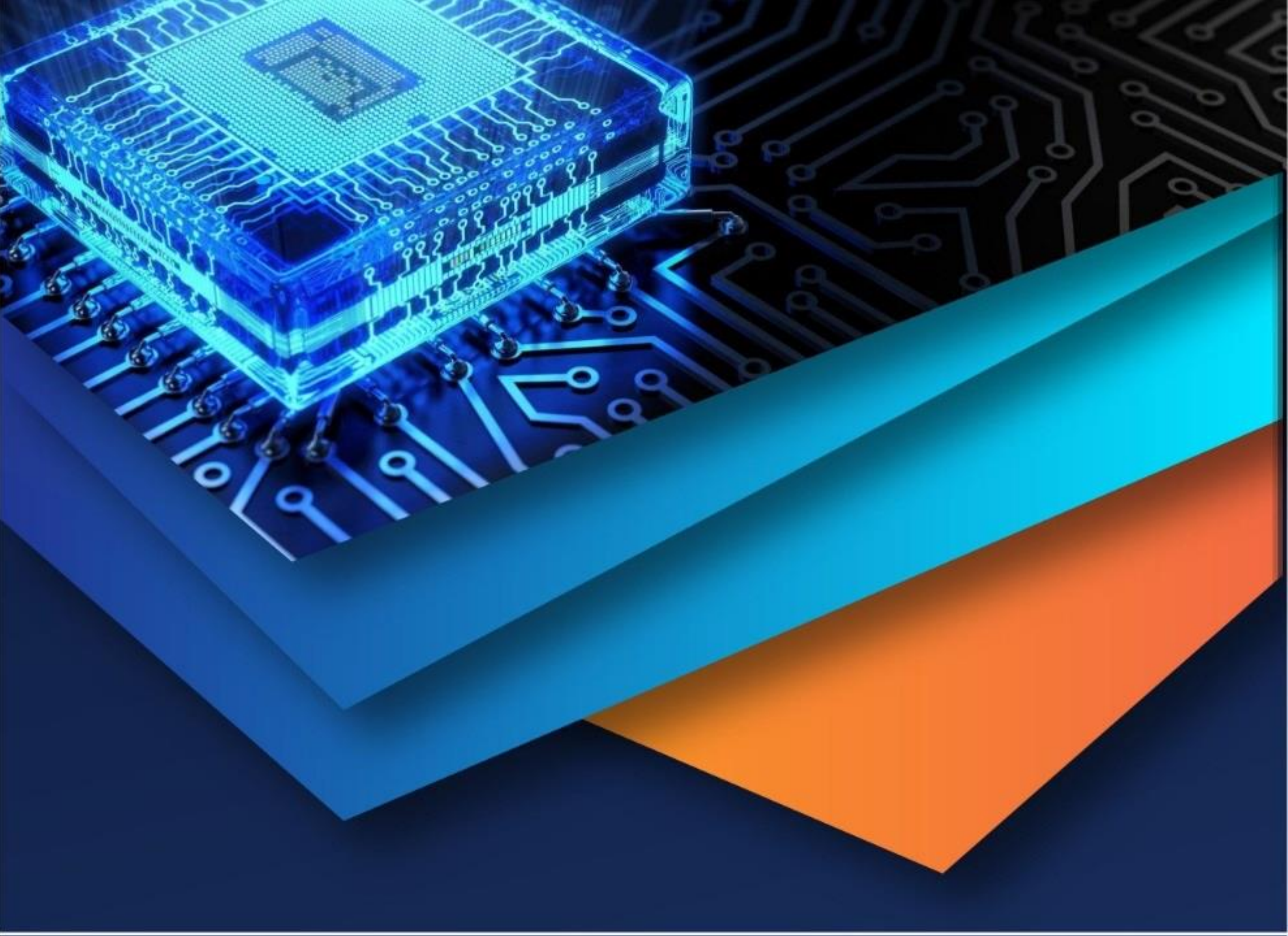

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