DESIGN THINKING APPROACH FOR EFFICIENT AND ROBUST PREDICTION ON DIABETIC RETINOPATHYUSING DIANET MODEL

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Abstract—Vision-impairing lesions on the retina are a common consequence of diabetes mellitus known as Diabetic Retinopathy (DR). Failure to catch it early can result in blindness. Regrettably, DR is irreversible, and treatment can only preserve vision. If DR is diagnosed and treated early on, the risk of permanent vision loss can be drastically reduced. Unlike computer-aided diagnosis systems, the time, effort, and expense involved in manually diagnosing DR retina fundus images by ophthalmologists is significant. Medical image analysis and classification are two domains where deep learning has recently become widespread because of its improved performance. When it comes to analyzing medical images, convolutional neural networks are the deep learning approach of choice. In this study, we present a method for detecting diabetic retinopathy uses DiaNet Model (DNM). The Gabor filter is employed in the Picture Pre-processing phase for the purpose of improving the visibility of blood vessels as well as for texture analysis, object recognition, feature extraction, and image compression. OurDNM Model can benefit from a reduction in the number of attributes under certain conditions. We observe a mean classification efficiency of 89.76% on testing data, which is significantly higher than state-of-the-art methods.

***Keywords*—Design Thinking, Neural Network, Diabetic Retinopathy, Machine Learning, DNM, CNN**

I. INTRODUCTION

Earlier illness diagnosis increases the likelihood of successful therapy. Lack of insulin leads to high blood glucose levels, the hallmark of diabetes. The number of adults affected by this disease is estimated at 425 million. The kidneys, heart, blood vessels, and retina are all compromised by diabetes [1]. Diabetic retinopathy (DR) is a condition where the retina's blood vessels enlarge and leak fluids and blood as a result of the effects of diabetes [2, 3]. If DR progresses to its worst form, it might cause total blindness. Around 2.6% of all cases of blindness are due to DR. Long-term diabetics are at a higher risk of developing DR. Diabetic individuals who don't have regular retinal exams are at increased risk of going blind, thus it's crucial that they be screened for the disease.

The advancement of imaging techniques relies on the creation of devices sensitive enough to detect a variety of physical signals not readily detectable to the human senses yet generated by the body or organ under study. In order to create a picture from the signals that have been identified, our system must first convert them into information. In light of this, a substantial amount of research into improving current technologies and creating new medical imaging methods has been conducted during the past 20 years. There is a wide range of development in the field of medical imaging techniques, from regions where research is at a purely conceptual stage to sectors where well-developed prototypes are employed in medical research but aren't yet apart of the clinical routine for varied purposes [4].

Diabetic retinopathy is an eye condition that commonly affects diabetics. DR is a potentially fatal eye disease that affects persons with diabetes and causes them to lose their eyesight. Retinal blood vessels are severely damaged by the extremely high blood sugar levels. When leaky blood vessels in the eye cause the macula to expand or thicken, they block blood

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flow to the retina. New blood vessels might form abnormally on the retina at times. Any of the aforementioned can led to irreversible eye damage. Unfortunately, diabetic retinopathy often goes undiagnosed until it has progressed to the point that it threatens a person's eyesight. The ability to save one's sight depends on an early diagnosis. In the first stages of diabetic retinopathy, symptoms may not present themselves. It might impair your ability to read or notice distant objects. Signs of a worsening infection include floaters, or spots floating in the line of sight, an increase in the number of floaters, clouded vision, and diminished ability to see in the dark. Changes in one's eyesight, Inability to differentiate between different shades of colour, Vision distortions like black or empty spots caused by floating particles and Complete and total blindness

Compared to a human diagnosis, automated approaches for DR detection are more efficient and save both money and time. Misdiagnosis is more common with a manual diagnosis, and it takes more time and effort to complete. The deep learning (DL) subfield of machine learning uses non-linear processing steps arranged in a hierarchical structure to learn features with no human oversight and to categories data. Among the several forms of computer-assisted medical diagnosis, DL stands out [5]. Classification, segmentation, detection, retrieval, and registration are just some of the many ways that deep learning is used in medical image analysis. In recent years, DL has seen widespread adoption for application in the identification and categorization of DR. Even with the integration of numerous disparate sources, it is still able to correctly understand the properties of the input data. Many other ML approaches exist, such as limited Boltzmann machines, convolutional neural networks (CNNs), auto encoding, and sparse coding. In contrast to machine learning approaches, their performance improves with a rise in the volume of training data owing to an increase in the number of taught features. Additionally, DL techniques did not call for any sort of manual feature extraction.

A. Diabetic Retinopathy

The blood vessels of the retina, the part of the eye that identify light, are what produce diabetes. Diabetic retinopathy may initially present with no symptoms or with just modest visual impairment. However, this can cause blindness if not treated.

This disorder can occur in both type 1 and type 2 diabetics. This issue of the eye becomes more frequent the longer a person has diabetes and the less well their blood sugar is managed.

B. Symptoms of Black fungus

Vision loss from diabetes can be avoided with proper care. Signs of diabetic retinopathy are often present in both eyes. In the first phases of diabetic retinopathy, we may not experience any symptoms. Progression of the disorder may result in the following:

- Increasing numbers of floaters have been spotted.
- Having trouble seeing clearly.
- Sporadically experiencing clear and fuzzy eyesight.
- Spots or voids in your visual field.
- Having trouble seeing in the dark.
- Observing that colors look washed out or faded.
- This includes visual loss.

C. Risk factors

Diabetic retinopathy can affect everyone who has diabetes. The likelihood of contracting this eye disease might rise due to:

- Long-term diabetes management challenges
- Not being able to keep your blood sugar under control
- Issues with hypertension
- Elevated blood lipids
- Pregnancy
- Use of tobacco products

The following image, Figure 1, gives a general idea of what diabetic retinopathy looks like in its early stages. Inadequate blood sugar levels can eventually cause the small blood vessels that supply the retina. Nevertheless, these newly formed blood vessels often don't mature correctly, leading to complications like bleeding. This is illustrated in Figure 1(a), which depicts the perception of a Normal Eye Image and the DR image is shown in Figure 1(b).

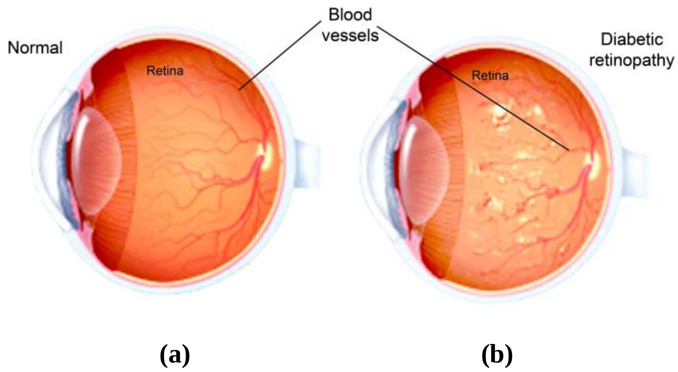

Figure 1.Eye Images of (a) Normal and (b) DR

D. Dataset

To further refine our models, we utilized pre-existing retinal pictures from the EyePACS dataset [12]. Over 80,000 retinal pictures were included in the EyePACS dataset, each labelled as belonging to one of five severity levels of DR. Figure 2 displays a few excerpts from the dataset as well as the total number of photos in each group. A deep learning method known as DNMis used to achieve this. Using this line of thinking on the dataset and doing proper sample training, a simple and effective conventional learning model for predicting diabetic retinopathy may be developed in a short amount of time. Typical and abnormal examples of diabetic retinopathy are depicted graphically in Figure 2.

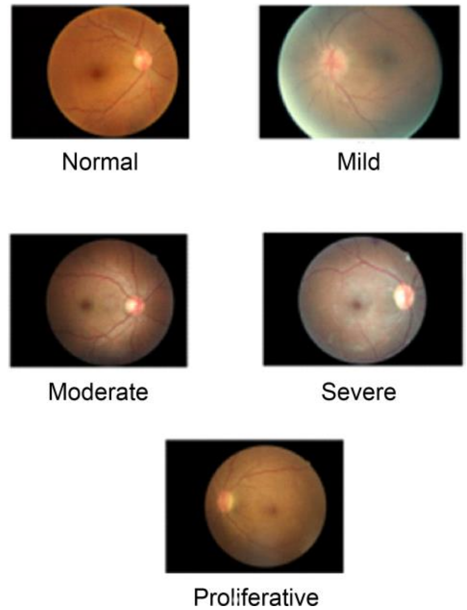

Figure 2.Image samples from Dataset

E. Major Objectives

The major purposes of the proposed strategy for diabetic retinopathy prediction are as follows.

1) In order to determine if a patient has diabetes based on images of their retina, we presented a new technique and established a deep learning model, DNM.

2) We presented the EyePACS dataset for diabetes diagnosis, which includes both healthy and diseased retinal pictures from individuals with diabetic retinopathy.

3) To aid medical professionals in assessing the pandemic's severity early on with the use of deep learning so that they can respond more quickly to patients.

4) To provide a reliable forecasting rationale that will significantly reduce the time spent sustaining persons during this critical period.

II. Related Study

Today, diabetes affects a large percentage of the global population. The dramatic increase in the number of people diagnosed with diabetes in India has led to an increase in a variety of other ailments that are causing social unrest. Whether it's Type 1 or Type 2 diabetes, diabetic retinopathy (DR) is one of those illnesses that doesn't make any noise until it's too late. This condition can cause irreversible vision loss if not caught early. This is why an algorithm is developed in software for early detection of diabetic retinopathy in [6]. Potentially useful for early DR identification that doesn't require a medical professional, this method is cost-effective and time-efficient. In order to recognize the white lesions, cotton-wool patches, and hard exudates that are characteristic of DR, this study used MATLAB-based image processing, which draws on principles from Computer Science and Biomedical Engineering. The examination image of the patient's eye is categorized based on the pixel count value.

Damage to the retina brought on by diabetes can cause blindness. Vision loss might occur if diabetic retinopathy is not treated in its early stages. Five subtypes of diabetic retinopathy have been identified. They're quite OK; typical; mild; moderate; safe; PDR. The deadly illness typically requires the processing of a colored fundus picture by specialists. Diabetic retinopathy is difficult to analyses and identify manually due to the high potential for human error. Manual diagnosis of DR is laborious and time consuming. A variety of computer-based methods have been used to identify DR; these methods display the retinal blood vessels but are unable to discern between the early and late stages of the disease and to analyses the laborious characteristics involved in doing so. Computer vision based results are not very reliable. Diabetic retinopathy is categorized into its several phases using an ANN in this article [7]. Accuracy and efficiency improved as a result of that.

One kind of eye illness brought on by diabetes is called diabetic retinopathy (DR). Vision's significance in people's lives has grown alongside the rise of modern science and technology. Therefore, it is of great importance to learn how to automatically categories photos of diabetic retinopathy. A unified and objective medical diagnosis is challenging to achieve using the standard manual categorization approach, which necessitates expert knowledge and takes considerable time. Using transfer learning, the author of paper [8] suggests a strategy for detecting diabetic retinopathy. First, get the information from Kaggle's website, and then improve it by amplifying it, inverting it, folding it, and adjusting the contrast. Then, employ a pre-trained model, such as VGG19, InceptionV3, Resnet50, etc. The ImageNet dataset was used to train each neural network. To use these models, we must first move the DR images. The photos are then categorized into five groups, each representing a different stage of diabetic retinopathy. The experimental findings demonstrate that the approach can achieve a generalization ability of 0.60, which is higher than that of the conventional direct training method and more resilient and generalizable.

In modern medicine, image estimate has emerged as a crucial tool for the accurate diagnosis of illness. A computer model based on retinal images and a neural network was developed by the author [9] to make diagnoses of Diabetic Retinopathy (DR). There are two main parts to our computational model: feature extraction and classification. Blood vessel and micro aneurysm identification were used to pull the most relevant characteristics for feature extraction from digital fundus pictures. The Diabetic Retinopathy dataset from the Kaggle Community was utilized for this analysis. We have successfully employed CNN to foretell the onset of diabetic retinopathy (DR).

To put it simply, diabetes can induce visual abnormalities such as diabetic retinopathy (DR). If the high blood glucose levels that cause this condition are not managed, the retina will suffer permanent damage. A powerful automated method is proposed in article [10] that can identify and categories the various stages of DR. Features are being retrieved from the segmented optic disc and retinal nerves using the Gray Level Co-occurrence Matrix (GLCM) technique. For DR stage detection, we employ a Fuzzy classifier and a Convolutional Neural Network for classification. STARE, DIARETDB0, and DIARETDB1 are the databases of choice here.

Diabetes, commonly called the silent killer, has skyrocketed in prevalence over the past few years, making it a huge public health issue. Instead of spending a lot of time manually determining whether or not a patient has diabetes, ophthalmologists are seeking for faster and more efficient ways to make that determination. Achieving early diagnosis of this condition is crucial for effectively managing it. Since the eye is one of the essential organs that becomes damaged at the earliest stage of diabetes, it might be a critical organ for detection. Therefore, ocular analysis can serve as a portal for the immediate diagnosis of diabetic retinopathy (DR). Consequently, the author [11] sought to provide a method by which we can easily and efficiently determine whether a person is affected by diabetes or not, allowing the patient to immediately begin the subsequent treatments without the need to undergo the lengthy and laborious processes of various manual tests for detection of DR. Determining the exact location of three key areas of the eye is crucial for DR detection. In this work, we set out to pinpoint the exact locations of three key areas of the retina: the macula, the optic disc, and the outside boundary of the retina.

III. System Methodologies

Pre-training a CNN model on the dataset is the first step in developing DNM. We then put a couple extra layers onto the network before the last one to help it better grasp the data and identify more nuanced patterns. First, we train our enhanced network on a database for the Diabetic Retinopathy identification, toidentify whether a patient has Diabetic Retinopathyor Normal. We have a model that can tell the difference amongNormal and Diabetic Retinopathy retinal images when this phase of tweaking is complete. Our objective, however, is broader: it is to identify retinal pictures that have been affected by diabetes. We do this by applying the DNMmodel to the diabetes dataset, which includes images of the retina from both categories of patients, and fine-tuning it there. This technique utilizes image capture, image pre-processing, classification techniques, categorization, and accuracy estimations to make a DR diagnosis.

Data Collection

There are a total of 88,702 colour fundus photos in the Kaggle Diabetic Retinopathy (DR) dataset, 35,126 of which are used for training and 53,576 for testing. EyePACS contributed the photos, which were taken using a wide range of equipment in a variety of settings at several primary care clinics in California and abroad. Each patient had two identically-resolution photos taken of their left and right eyes. Clinicians used the Early Treatment Diabetic Retinopathy Study (ETDRS) scale to evaluate the seriousness of DR in each picture.

Data Preprocessing

We used the EyePACS dataset for DR staging and used the pre-processing procedures described by the winning solution in the Kaggle Diabetic Retinopathy Detection challenge. In the preliminary processing phase, we did the following. We started by isolating the circles in each image, and then we shrunk them down to fit within a 300-pixel circle, representing the retina. After eliminating the border-noise by cropping the outside 10%, subtracting the local mean from a 4x4 pixel neighborhood, and lastly placing the reduced retina on a dark background inside a square-shaped picture with tight boundaries, we had our final product. To ensure that all of the processed photos are aligned with one another and feature a consistent backdrop, we ran each image through a series of pre-processing procedures that reduced them from their original sizes and contrasts to a uniform 570 by 570 pixel image with a black background.

Data Augmentation

With the goal of making our method more bulletproof, we used many data augmentation methods to our dataset. As a means of enriching the data, we flipped it horizontally at random and messed with the brightness and contrast. All retinal pictures in the EyePACS dataset were subjected to the identical pre-processing and enhancement methods.

Classification

Image processing's strengths lie in its ability to enhance visuals for human interpretation. Images may be analyzed to have data retrieved for computer analysis. The difficulty of categorizing images has emerged as a major article in the field of image processing. In terms of the limitations of existing image classification models, this research proposes a novel technique to classification using DNM. Accurate results are produced by the DNMmodel given here thanks to the combination of a deep learning algorithm like DenseNet to automatically extract features from input and a top-level identification system like XGBoost to process those characteristics.

Convolutional Neural Network

Automatic illness diagnosis, categorization, and staging are all made easier by CNN, an artificial neural network architecture designed to learn low and high-level aspects of medical images. Convolutional, pooling, and fully linked layers are the standard building blocks of a CNN. Each layer's output, known as an activation or a feature map, can be fed into the training of a higher-level layer. To extract various low and high-level characteristics, the convolutional layer applies a collection of linear filters to the input picture or activation map. By subsampling the activation maps, the pooling layer can minimize the number of network architectures and increase the stability of the derived features. A series of linear filters may be used to implement the pooling layer by averaging the pixel values contained within a mask, or a set of non-linear filters can be used to implement the pooling layer by sorting the pixel values included within some area of the picture and obtaining the maximum value.

DenseNet Model

Dense nets are convolutional networks with many connections between nodes. There are several basic changes, although it is nearly identical to a ResNet. DenseNet uses all past output as an input for a forthcoming layer, while ResNet uses an additive technique in which a preceding layer's output is used as an input for a later layer. Since the great distance among the input and output layers in high-level neural networks causes the gradient to dissipate before it reaches the final layer, DenseNet was designed to address this issue and increase the reliability. Architecture of DenseNet Model is shown in figure 3.

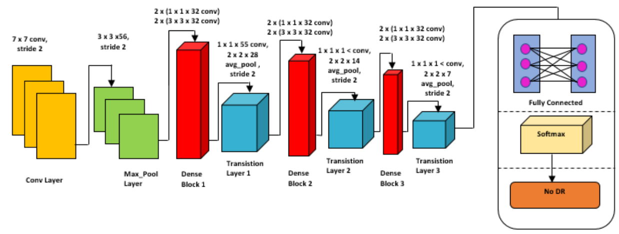

Figure 3. Architecture of DenseNet Model

DiaNet Model

The detailed architecture of the DiaNet model for classification tasks is depicted in Figure 3 of this research. Multiple more models were constructed to help us gauge the efficacy of our strategy and to serve as benchmarks moving forward. DiaNet and its version DenseNet-121 were created by swapping out the original model's backbone for a ResNet50 instance that had already been trained on ImageNet. Before sending the data to the DenseNet's input layer, the geographical information is normalized. After training DenseNet using the BP method for a few epochs to produce the proper structure for image classification. As the GBM version, we opted for XGBoost.By combining two high-quality classifiers, our DiaNet model is able to automatically extract features from input, leading to more precise classification performance.The Architecture of the DiaNet Model for Image Classification is shown in figure 4.

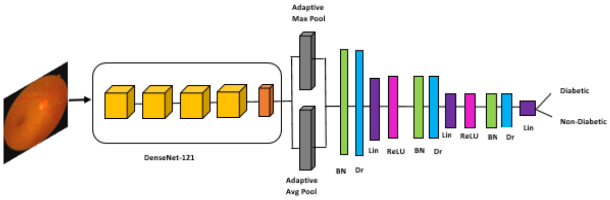

Figure 4.The Architecture of the DNMfor Image Classification

The suggested DiaNet model's categorized results are then shown in ThinkSpeak's website using NodeMCU. The model's block diagram is shown in Figure 5.

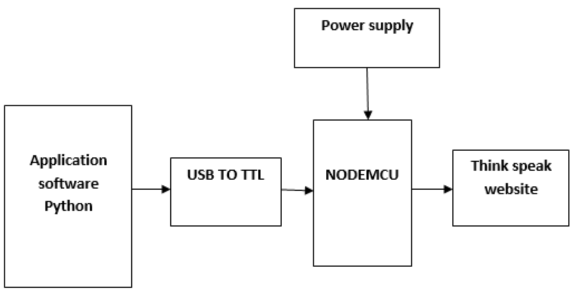

Figure 5. Model Block Diagram

IV. Results and Discussions

Experiments are done on the aforementioned database to identify the efficacy and validity of the model, and it is compared to conventional methods. We also look at the classification results of other methods using the same information to evaluate the efficacy of the DNM model. Foreseeing DR identification with 89.76 percent accuracy is the goal of a revolutionary DNMtechnique. The recommended method employs the open-source programming language Python and the Jupyter Notebook as a tool for generating scripts to predict the detection of diabetic retinopathy. Figure 6 depicts the input image that was utilized to make the forecast.

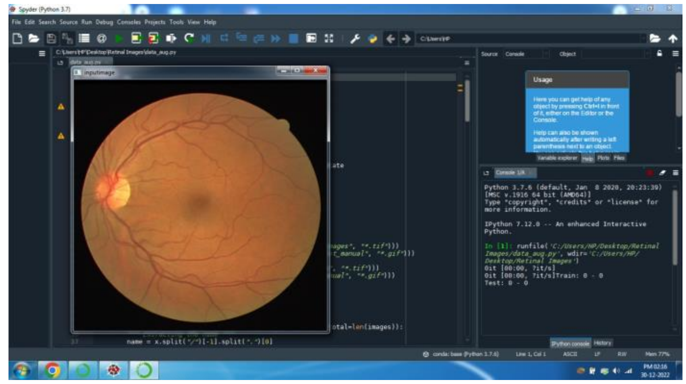

Figure 6. Input Image

Figure 7 depicts an example of the recommended method's preprocessed image's visual impression. Gabor filters, tailored to character pictures based on statistical data, are used to extract features directly from grayscale character images. To improve Gabor filters' functionality with low-resolution pictures, an adaptive sigmoid function is used to modify their outputs.

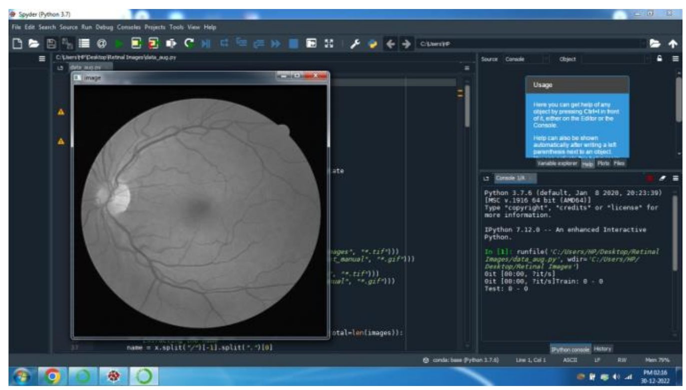

Figure 7. Preprocessed Images

Figure 8 depicts the result of the recommended model for the input picture. Input images may be checked for signs of diabetic retinopathy using the suggested model. In Table 1, we provide the results of a comparison between our suggested model and the DenseNet Model. Based on the data in the table, we can say that the accuracy of our suggested models is higher than that of DenseNet. While the already-existing model was only 84% accurate, ours was 89%.

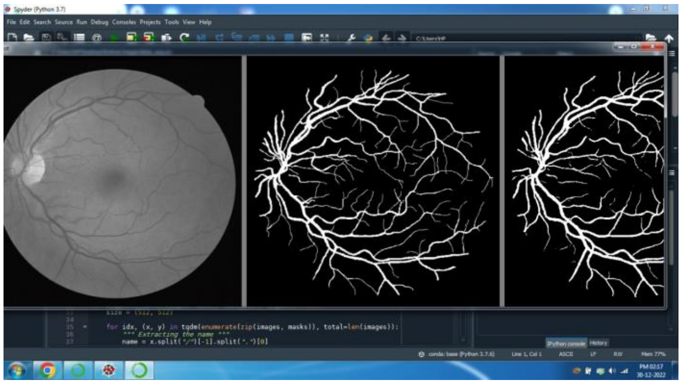

Figure 8. Results of a DNM model's image processing

Model	Accuracy	Specificity	Sensitivity	F1
DenseNet	84	83	85	84
DNM	89	79	83	81

Table 1: Performance Metrics of Various Models

The results of the suggested model are shown on ThinkSpeak Website by means of the Internet of Things. Information compiled from the model on website is displayed in Figure 9.

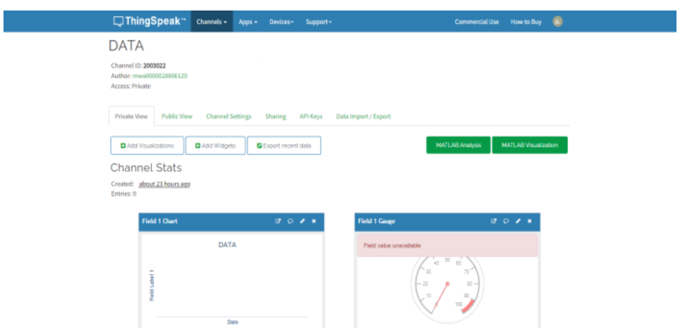

Figure 9.Website data presentation.

Comparison of the proposed DNMwith the baseline model DiaNet in terms of performance measures is depicted in Figure 10.

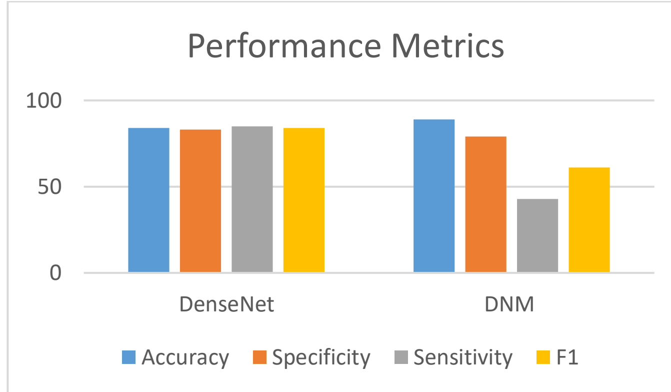

Figure 10.Comparison between DNM and Existing Model.

V. CONCLUSION AND FUTURE WORK

It is estimated that 425 million persons throughout the world have diabetes, a disorder characterized by elevated blood glucose levels due to an insufficient production of the hormone insulin. Retinopathy is more common among diabetics. Damage to the retinal blood vessels has been linked to hyperglycemia (high blood sugar). As a diabetic eye consequence, diabetic retinopathy (DR) causes the retinal blood vessels to enlarge and leak fluids and blood. When untreated, it can cause blindness in one or both eyes. In the event that the problem is addressed quickly, its severity may be reduced. Using DNM, this research offers a fresh perspective on classifying Diabetic Retinopathy. The number of parameters needed for DNMhas been reduced, and back propagation is no longer necessary after the fully connected layer is established. Also, feature learning was automated. Since the best accuracy ratio attained using the proposed technique was almost 89%, the generated model may be relied upon. In the future, it is possible to enhance the work by utilizing several ensembled algorithms to boost efficiency and aid in DR detection with more accuracy.

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