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CLASSIFICATION OF RETINAL FUNDUS IMAGES USING DEEP LEARNING FOR EARLY DETECTION OF DIABETIC RETINOPATHY

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Abstract: Diabetic Retinopathy is an issue of diabetes mellitus, which leads to progressive damage and even blindness of the retina. Its early detection and medication are important in order to prevent the retina's degradation and damage. With the advances in deep learning, techniques have been applied rapidly and widely in the field of medical. Image analysis is becoming a better way to advance ophthalmology. This approach utilizes accurate visual analysis to identify the abnormality of blood vessels with improved performance over manual procedures. Employing computational approaches for the respective purpose would help in accurate retinal analysis. The proposed system includes classification of retinal fundus images into its Diabetic Retinopathy grades for early detection of Diabetic Retinopathy.

IndexTerms **- Classification, Convolutional Neural Network, Deep Learning, Diabetic Retinopathy, Retinal Blood Vessels.**

I. INTRODUCTION

The retina in the eye is the innermost layer of the eye which is sensitive towards light. The optics of the eye creates a focused 2-D image of the visual world on retina which acts as a camera. The light induces chemical and electrical reactions that initiates the nerve impulses. These are then forwarded to visual centers to the optic nerve of the brain. The retina acts as a film or image sensor in a camera. The human eye is a unique and most sensitive region of the human body where the vascular condition can be directly observed. The blood vessels are one of the main features of a retinal image and most of its properties are affected by major diseases such as diabetes etc. Blood vessels plays an important role in eye retina in comparison with other parts like fovea, optic cup, optic disc etc. Diabetes is the disease which affects every body part such as kidneys, eyes etc. Eye being an important part needs special observation. The patients suffering from diabetes can suffer from Glaucoma, Diabetic Retinopathy, Cataract etc. All these eye diseases result in blindness if not treated properly. People suffering from diabetes for more than 25 years has more chance of causing diabetic retinopathy. Diabetic Retinopathy (DR) is a prolonged disease and is a state of an eye in which destruction arises due to diabetes. It is one of the most eminent reasons behind the blindness. The increase in blood sugar due to diabetes causes injury to the small blood vessels in the retina causing diabetic retinopathy. It affects the retina of both eyes, which leads to vision loss if not treated. Poorly controlled blood sugar level, high blood pressure, and high cholesterol increases the risk of Diabetic retinopathy. Diagnosing diabetic retinopathy based on the features is a complex procedure. Due to evolution of Computer vision in recent times and availability of large dataset, it is now possible to use a deep learning for the detection and classification of Diabetic retinopathy. The method proposed in this paper focuses on detecting and classifying the various stages of Diabetic Retinopathy grades by using Convolutional Neural Network (CNN). Diabetic Retinopathy caused by the uncured diabetes beholds the symptoms which begins from microaneurysms, hemorrhages appear. When the severity increases, hard exudates appear in the retina. These exudates come into existence due to proteins leakage from the blood which are yellow in color. After more increase in severity, there is destruction in blood vessels which leads to formation of soft exudates which are white in color. Various stages of Diabetic Retinopathy are No DR, Mild DR, Moderate DR, Severe DR and Proliferative DR. The manual classification of blood vessels is very difficult as it requires expertise since the fundus images are very compound. Additionally, it is very time consuming when the dataset is very humongous. So, there is a need automatic classification of blood vessels so that the early diagnosis of Diabetic Retinopathy disease can be performed. In this paper, Literature survey of various papers on the chosen topic are discussed. Next section gives us the brief about proposed methodology. Further Results and discussions are mentioned which provides us with the idea of final output produced. And lastly overall arguments and several findings are properly summarized in the conclusion section.

II. LITERATURE SURVEY

KULWINDER S MANN et al. [1], presents an algorithm that will segment the retinal blood vessels. The algorithm which used Convolutional Neural Network was applied firstly on training images which have results of manually segmented images already. Then the algorithm was implemented and evaluated on training images and it successfully detected the normal as well as abnormal images from the images provided by various datasets such as CLAHE and DRIVE. Then the optimized features are used for training of the system and final classifying the images using Naïve Bayes classifier for the classification of images into healthy as well as pathological retina. In future with the advances in the technology, the image processing techniques, various algorithms and methods can become much more efficient and precise. M. VIVEK KUMAR et al. [2], in their work focuses on analysis that whether the retinal images are normal or abnormal and find the metrics of Diabetic Retinopathy. To detect the Diabetic Retinopathy from given retinal fundus images from dataset using k-means clustering algorithm. The accurate image segmentation is possible only if the image is preprocessed as per image size and quality. Preprocessing includes feature extraction and boundary detection methods are applied for segmentation of the disease affected blood vessel. K-means clustering algorithm is used in segmentation of blood vessels. TOUFIQUE AHMED et al. [3] has proposed all-inclusive review of the principle and application of deep learning in analysis of retinal fundus image. Study is been done on different proposed models using deep learning of retinal fundus images by observing their performance as well as the limitation, and then proposing the suitable methodology to overcome such limitations in order to improve performance and accuracy. For measuring the performance of a method in segmenting retinal vessels, three metrics are calculated: accuracy, sensitivity and specificity. AZHAR IMRAN et al. [4] proposed a comprehensive review of the state of the art supervised and unsupervised blood vessel segmentation methodologies. The objective of this study was to establish a professional structure to familiarize an individual with up-to-date vessel segmentation techniques. In, future the segmentation results can be improved by combining the anatomical knowledge of the vascular structure and the optic disc and applying post-processing steps to remove noise. NASSER TAMIM et al. [5] proposed a method for segmentation of retinal blood vessels is the first step for several computer aided-diagnosis systems (CAD), not only for ocular disease diagnosis such as Diabetic Retinopathy but also of non-ocular disease, such as hypertension, stroke and cardiovascular diseases. A supervised learning-based method, using a multi-layer perceptron neural network and carefully selected vector of features. A transfer learning model, VGG16, as a pre-trained model with multilevel/multi-scale deep supervision layers was incorporated to segment the retinal blood vessel. In future concentrating on the handling of the outlier values may help in decreasing the reliability of using feature selection techniques or hierarchical classification as a way to increase system performance. DOLLY DAS et al. [8], gives a brief but precise description on Diabetic Retinopathy, its causes, symptoms, features and the various grades of Diabetic Retinopathy. It describes the causes of Diabetic Retinopathy blindness based on the features such as shape, size and their location and structural deformities with respect to the retinal blood vessels. In future, Diabetic Retinopathy detection using any of prevalent Deep Learning techniques can be approached and analyzed to obtain better feature extraction and image classification, for early detection of Diabetic Retinopathy through easy and affordable means. MOHAMED M. ABDELSALAM et al. [7] focuses on early detection and classification of Diabetic Retinopathy using OCTA images using deep learning and Artificial neural network. The usage of the features such as selecting strategy feature as inputs in Artificial Neural Network is helpful in early diagnosis of Diabetic Retinopathy to avoid a long and difficult course of treatment and also to avoid blindness in early stage. A K-means technique for color compression was used for clustering the retinal fundus images for differentiating and segmenting regions of interest where the Diabetic Retinopathy is present, and then diabetic parts were segmented out and then finally, Diabetic Retinopathy was recognized. Future work is to design a new Graphical User Interface (GUI) application that can extract the selected image features for early detection and diagnosis. EMAN ABDELMAKSOUD et al. [10] focuses on Deep Learning and conventional methods to classify healthy and Diabetic Retinopathy grades. Different methodologies such as pre-processing method to enhance the quality of the image's, post-processing method is used to prepare the images for segmentation phase. Segmentations with high accuracy allow a better look at the vessels of the retinal images therefore even a faster diagnosis for eye diseases such as Diabetic Retinopathy, which is now the leading cause for blindness at mid ages. The proposed system's main contribution is to detect and analyze various pathological changes accompanying Diabetic Retinopathy development in the retina without injecting the patient with dye or making expensive scans using deep learning and Convolutional Neural Network. MOHAMMAD Z. ATWANY et. al. [11] proposed Diabetic Retinopathy classification methods with a general focus on deep learning techniques and a high focus on classical methods. Diabetic Retinopathy classification can be categorized to either binary classification which aims to detect the presence or absence of Diabetic Retinopathy and multi-class classification, which determines the exact stage of Diabetic Retinopathy. Accordingly, further methods were developed to focus on lesion-based classification pre-trained Convolutional Neural Network architectures.

III. PROPOSED METHODOLOGY

Figure 3.1 shows the detailed methodology process carried out in the proposed system. Each block in the architecture diagram is explained below.

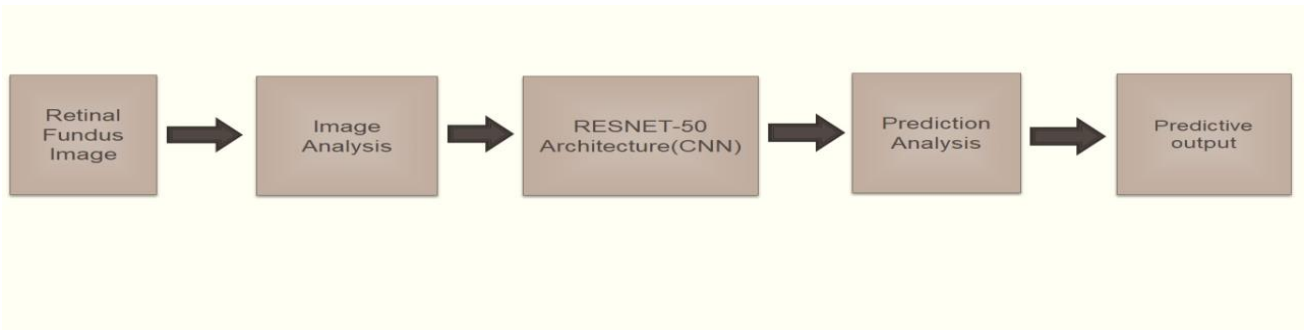

Fig.3.1. Architecture Diagram

The basic idea behind this research is to apply and analyze different Diabetic Retinopathy grades. After this classification on the retinal fundus images is performed to produce the output for No, Mild, Moderate, Severe and Proliferative Diabetic Retinopathy grades respectively.

1. RETINAL FUNDUS IMAGE: The input for the project is retinal fundus image from APTOS Blindness Detection dataset from Kaggle which contains 5590 images. The fundus is the interior, back surface of the eye which is made up of retina, macula, optic disc etc.

2. IMAGE ANALYSIS: The dataset contains 5590 images which are divided into 3662 training images and 1928 testing images. Training images are a bunch of images for which the required outcome is known i.e. The training dataset is labelled and contains 5 grades of Diabetic Retinopathy. Image analysis is done for image information extraction and cross-verifying the input labels. It is used to detect various important components and features of the input image.

3. RESNET- 50 ARCHITECTURE (CONVOLUTIONAL NEURAL NETWORKS): In the proposed system 3662 training images undergoes training which helps the model to learn the images and their grades according to the labels given. The input is given to a program that analyzes their features and passes the features through a classification routine that determines the appropriate weights to use on the features in order to best achieve the required result. The model is trained using the RESNET-50 architecture which uses supervised learning for classification. Keras is prominent due to its simplicity of building models. RESNET-50(Residual Neural Network) is a model that can work with 50 neural network layers that stacks residual blocks on top of each other to form a network which consists of 5 stages each of convolution and identity block. Each convolution block and identity block have 3 convolution layers.

4. PREDICTION ANALYSIS: Prediction for detecting Diabetic Retinopathy grades is basically done using trained model. According to training data future outcome is predicted. It improves decision making and reduces risk by identifying Diabetic Retinopathy at early stage.

5. PREDICTIVE OUTPUT: Finally, the classification of retinal fundus image is done into its grade using the above mentioned pre-trained CNN model. Classification is done into 5 grades of Diabetic Retinopathy which are" GRADE 0 - NO DR"," GRADE 1 – MILD DR"," GRADE 2- MODERATE DR"," GRADE 3 - SEVERE DR"," GRADE 4 - POLIFERATIVE DR".

IV. RESULTS AND DISCUSSIONS

This experimentation is performed on the Retinal Fundus Images Dataset downloaded from APTOS Blindness Detection dataset from Kaggle which contains 5590 images which was divided into 3662 training and 1928 testing datasets. A laptop with Windows 10 Operating System powered by GPU Processor of NVIDIA, Radeon, etc. and minimum RAM of 4 GB with an i5 Processor is required.

1.DATASET DESCRIPTION: The size of dataset is 10 GB which includes a total of 5590 image data which is taken from APTOS Blindness Detection dataset from Kaggle which was divided in 3662 training and 1928 testing datasets. 3662 images were used for training and 1928 images were used for testing. The dataset is labelled and contains 5 classes. Below is the input retinal fundus from the dataset. Figure.4.1. shows the input retinal fundus image:

Fig.4.1. Retinal Fundus Image

2.DETECTION AND CLASSIFICATION: In this stage detection of diabetic retinopathy were determined by training the dataset using CNN. Datasets where selected and labelled as No DR, Mild DR, Moderate DR, Severe DR and Proliferative DR. The purpose of using all datasets together in training is to diversify training and to automatically detect Diabetic Retinopathy. The Diabetic Retinopathy images were classified by adding the mechanism of pretrained CNN models.

3.PERFORMANCE EVALUATION BASED ON ACCURACY: In this stage accuracy of the model is determined. Figure 4.2 shows the training and validation accuracy. It can be seen in the following graph the accuracy gradually increases with respect to time with increase in number of epochs.

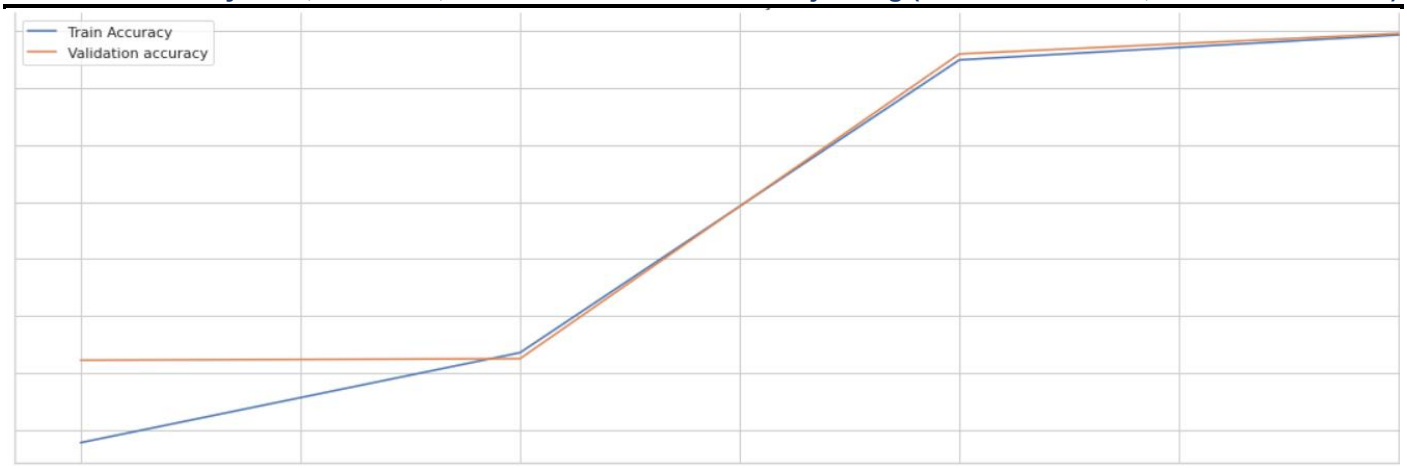

Fig.4.2. Training and Validation Accuracy

4.PERFORMANCE EVALUATION BASED ON LOSS: In this stage loss of the model is determined. Figure.4.3. shows the training and validation loss. It can be seen in the following graph the loss gradually decreases with respect to time with increase in number of epochs.

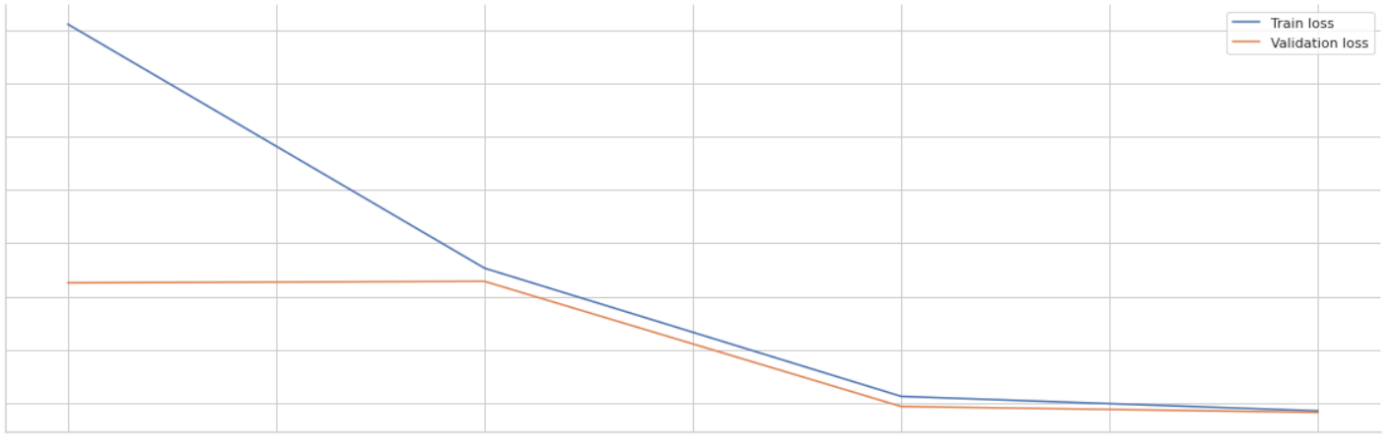

Fig.4.3. Training and Validation Loss

5.RESULT: Eventually, the final result of classification is displayed using GUI (graphical user interface). The GUI helps us to predict or classify the retinal fundus images into its Diabetic Retinopathy grades. If the eye is not infected from Diabetic Retinopathy it will show “GRADE 0 - NO DR” and if it is lightly infected it will show “GRADE 1 – MILD DR” and so on which will be helpful in the process of treatment to the patient. Classification is done to know the severity of disease. Figure 4.4. shows the classification for “NO DR” Diabetic Retinopathy grade and Figure.4.5. shows the classification for “SEVERE DR” Diabetic Retinopathy grade.

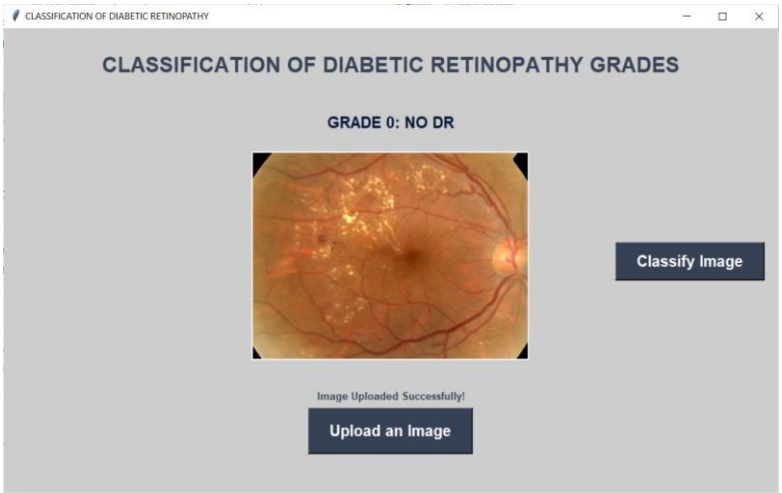

Fig.4.4. Classification for Diabetic Retinopathy grade “NO-DR” using GUI.

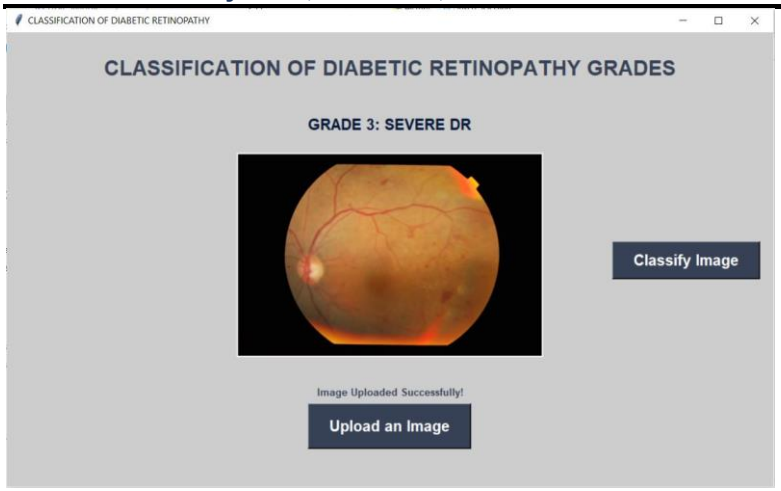

Fig.4.5. Classification for Diabetic Retinopathy grade "SEVERE-DR" using GUI.

V. CONCLUSION

Diabetic Retinopathy is a diabetes issue that affects retina. It is caused by the damage to the blood vessels of the light-sensitive tissue at the back of the eye that is retina. It is the most common and leading cause of vision loss among people with diabetes. The idea of applying deep learning in detecting Diabetic Retinopathy is highly preferable. Employing computational approaches such as image recognition techniques for this purpose would help in efficient retinal analysis. The fundus image classification approach is achieved through pretrained RESNET-50 model which is based on Convolutional Neural Network (CNN) architecture. Hence classification is done by displaying the Diabetic Retinopathy grades in the designed GUI (graphical user interface) screen.

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