

# Detection of Diabetic Retinopathy using Convolutional Neural Network

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**Abstract** - Diabetic Retinopathy is a complication of diabetes that is caused due to the changes in the blood vessels of the retina and is one of the leading causes of blindness in the developed world. Upto the present, Diabetic Retinopathy is still screened manually by ophthalmologist which is a time consuming process and hence this paper aims at automatic diagnosis of the disease into its different stages using deep learning. In our approach, we trained a Deep Convolutional Neural Network model on a large dataset consisting of around 35,000 images to automatically diagnose and thereby classify high resolution fundus images of the retina into five stages based on their severity. Within this paper, an application system is built which takes the input parameters as the patient's details along with the fundus image of the eye. A trained deep convolutional neural network model will further extract the features of the fundus images and later with the help of the activation functions like relu and softmax along with optimizer like adam an output is obtained. The output obtained from the Convolutional Neural Network (CNN) model and the patient details will collectively make a standardized report.

Patients suffering from diabetes, who have controlled blood sugar levels will have a slower onset and progression of diabetic retinopathy. The early stages of diabetic retinopathy have no visual symptoms. Hence it is recommended that everyone with diabetes must have a comprehensive dilated eye examination once a year. Detecting and treating the ailment at an earlier stage can limit the potential for significant vision loss from diabetic retinopathy[4].

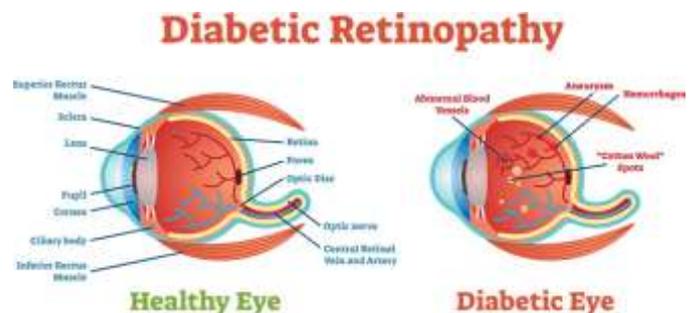


Fig -1: Comparison of Healthy eye and Diabetic eye

**Key Words:** Automate, diabetic retinopathy, fundus, convolutional neural network, retina

## 1. INTRODUCTION

Diabetic retinopathy is an ailment that occurs in people suffering from diabetes causing progressive damage to the retina, the light-sensitive lining at the back of the eye. Diabetic retinopathy is a serious sight-menacing complication of diabetes. The ability of the body to store and use sugar is intervened by diabetes. The disease is characterized by excess of sugar levels in the blood, which can cause damage throughout the body as well as the eyes[1].

Over a period of time, diabetes can cause damage to the blood vessels in the retina. Diabetic retinopathy is a condition that occurs when blood and other fluids start leaking from these tiny blood vessels causing the retinal tissue to swell. This results in cloudy or blurred vision. This condition usually affects both eyes. The longer a person has diabetes, the more is the probability that they will develop diabetic retinopathy. If left untreated, diabetic retinopathy can lead to blindness. Diabetic people who experience long periods of high blood sugar, have a tendency of fluid accumulation in the lens which in turn changes the curvature of the lens, leading to blurred vision. However, once blood sugar levels are under control, blurred vision will improve.

Figure 1 shows the difference between healthy eye and diabetic eye and represents which are is getting affected and where it is getting affected.

The medication of diabetic retinopathy varies depending on the severity of the disease. In order to seal the leaking blood vessels or to discourage other blood vessels from leaking laser surgeries can play an important role. In order to stop the formation of new blood vessels your optometrist might need to inject medications into the eye. People with severe diabetic retinopathy might need a surgical procedure to remove and replace the gel-like fluid in the back of the eye, called the vitreous. Surgical procedures may also be needed to repair a retinal detachment. Retinal detachment is a separation of the light-receiving lining in the back of the eye. The diabetic people can help prevent or slow the growth of diabetic retinopathy by taking prescribed medication, sticking to controlled diet, exercising on a regular basis, controlling high blood pressure, avoiding alcohol and smoking[2][4].

Diabetic Retinopathy comprises of certain stages which help us to distinguish the severity of the disease and accordingly come up with the prevention methods. The stages of diabetic retinopathy include:

1. No DR: In this stage the eye is not affected with the disease. i.e eye is healthy

2. Mild DR: In the first stage, mild nonproliferative, there will be balloon-like swelling in small areas of the blood vessels in the retina.
3. Moderate DR: In the second stage, known as moderate nonproliferative retinopathy, some of the blood vessels in the retina will become blocked.
4. Severe DR: The third stage, severe nonproliferative retinopathy brings with it more blocked blood vessels, which leads to areas of the retina no longer receiving adequate blood flow. Without proper blood flow, the retina can't grow new blood vessels to replace the damaged ones.
5. Proliferative DR: The fourth and final stage is known as proliferative retinopathy. This is the advanced stage of the disease. Additional new blood vessels will begin to grow in the retina, but they will be fragile and abnormal. Because of this, they can leak blood which will lead to vision loss and possibly blindness.

Convolution neural network is a subset of deep learning neural network. It is mainly used for image classification and image analysis. The goal behind CNN is to mimic how human brain analyzes the image. Convolution neural network is comprised of one or more convolutional layers and then followed by one or more fully connected layers. The CNN consist of input, hidden and output layer. The input layer basically consist of arrays of pixels. The hidden layer is the most important layer as it plays the main role in image computation. Hidden layer comprises of activation functions and biases. The output layer helps us to determine the class score. The benefit of CNN's is that they are easier to train with providing high accuracies.

## 2. BACKGROUND

The main difficulty faced by DR affected patients is that they are unaware of the disease until the changes in the retina have progressed to a level that treatment will in turn tend to be less effective. Automated screening techniques for the detection purpose have great significance in saving cost, time and labour. The screening of diabetic patients for the development of diabetic retinopathy can reduce the risk of blindness by 50%. With the increase in the rate of the patients affected by the disease there is all the more need for automated systems to take the charge since the number of ophthalmologists is also not sufficient to cope with all patients, especially in rural areas or if the workload of local ophthalmologists is substantial. Therefore, automated early detection could limit the severity of the disease and assist ophthalmologists in investigating and treating the disease more efficiently. There may exist different kind of abnormal lesions caused by diabetic retinopathy the most frequent being exudates, hemorrhage, microaneurysm.

A handful of researches have been presented in the literature for Diabetic Retinopathy using various methods. Recently,

the use of automation method using fundus images for DR have received a great deal of attention among researchers. A brief review of some recent researches is presented here.

Previous studies [5] indicated that the importance of developing several automated methods for detecting abnormalities in fundus images. The purpose of those studies was to improve their automated hemorrhage detection method to help diagnose diabetic retinopathy. They found a new method for preprocessing and false positive elimination in the present study. The brightness of the fundus image was changed by the nonlinear curve with brightness values of the hue saturation value (HSV) space. In order to emphasize brown regions, gamma correction was performed on each red, green, and blue-bit image. Subsequently, the histograms of each red, blue, and blue-bit image were extended. After that, the hemorrhage candidates were detected. The brown regions indicated hemorrhages and blood vessels and their candidates were detected using density analysis. They removed the large candidates such as blood vessels. Finally, false positives were removed by using a 45-feature analysis. To evaluate the new method for the detection of hemorrhages, they examined 125 fundus images, including 35 images with hemorrhages and 90 normal images. The sensitivity and specificity for the detection of abnormal cases was were 80% and 88%, respectively. Those results indicate that the new method may effectively improve the performance of their computer-aided diagnosis system for hemorrhages.

Researchers have described [6] that Diabetic retinopathy, an eye disorder caused by diabetes, was the primary cause of blindness in America and over 99% of cases in India. India and China currently account for over 90 million diabetic patients and are on the verge of an explosion of diabetic populations. That may result in an unprecedented number of persons becoming blind unless diabetic retinopathy can be detected early. The automated diabetic retinopathy problem was hard computer vision problem whose goal was to detect features of retinopathy, such as hemorrhages and exudates, in retinal color fundus images. They described their initial efforts towards building such a system using a range of computer vision techniques and discuss the potential impact on early detection of diabetic retinopathy.

Another study [7] subscribed that Diabetic retinopathy (DR) was an important cause of visual impairment in industrialized countries. Automatic detection of DR early markers can contribute to the diagnosis and screening of the disease. The aim of that study was to automatically detect one of such early signs: red lesions (RLs), like haemorrhages and micro aneurysms. To achieve that goal, they extracted a set of colour and shape features from image regions and performed feature selection using logistic regression. Four neural network (NN) based classifiers were subsequently used to obtain the final segmentation of RLs: multilayer perceptron (MLP), radial basis function (RBF), support vector machine (SVM) and a combination of those three NNs

using a majority voting (MV) schema. Their database was composed of 115 images. It was divided into a training set of 50 images (with RLs) and a test set of 65 images (40 with RLs and 25 without RLs). Attending to performance and complexity criteria, the best results were obtained for RBF. Using a lesion-based criterion, a mean sensitivity of 86.01% and a mean positive predictive value of 51.99% were obtained. With an image based criterion, a mean sensitivity of 100%, mean specificity of 56.00% and mean accuracy of 83.08% were achieved.

There are various explorations [8] stating that the automated analysis of human eye fundus image was an important task. Diabetes was a disease which occurs when the pancreas does not secrete enough insulin or the body was unable to process it properly. That disease affects slowly the circulatory system including that of the retina. As diabetes progresses, the vision of a patient may start to deteriorate and lead to diabetic retinopathy. The main stages of diabetic retinopathy were non-proliferative retinopathy (NPDR) and Pro-liferative retinopathy(PDR).In that paper, they have approached a computer based approach for the detection of DR stages using color fundus images. The features were extracted from the raw image, using the image processing techniques and fed to the Support Vector Machine (SVM) for classification. The results showed a sensitivity of 99.45 % for the classifier and Specificity of 100%.

### 3. METHODOLOGY

This section is divided in two major parts that is image processing of data and training that neural network with the processed image. The images are taken from Kaggle, where all the images are in one zip file. The images have been further classified in different levels of Diabetic retinopathy for the neural network.

#### A) Image classification:

A python program has been written that takes labelled class name image input from a excel sheet and copies that image to the folder that have same class name to which that image belongs.

image	level
10_left	0
10_right	0

**Fig 1: Snippet of train file.**

In the above figure there is an image table containing image name and level. The table indicates that the image belongs to which level of diabetic retinopathy the python program classifies image.

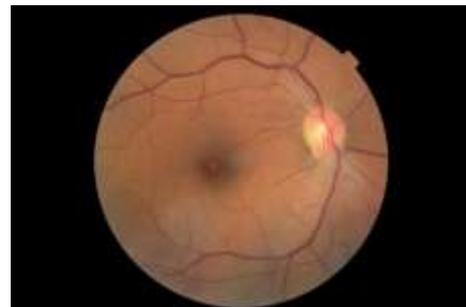
#### B) Image resize:

All the fundus images taken for training have 4928x3264 resolution but will be resized down to 1024x720 resolution. Python’s opencv2 library has been used to resize the image, setting quality parameter as 95%

#### Fundus image:

Fundus photography involves capturing a photograph of the back of the eye i.e. fundus. Specialized fundus cameras that consist of an intricate microscope attached to a flash enabled camera are used in fundus photography. The main structures that can be visualized on a fundus photo are the central and peripheral retina, optic disc and macula. Fundus photography can be performed with colored filters, or with specialized dyes including fluorescein and indocyanine green

Following figure shows the fundus image of the eye. This image is further processed to check whether it is a fundus image or not. The proposed system operates as a web app where the user can upload any kind of image and can fool the neural network. Hence to avoid this dilemma a filter has to be applied that will only allow fundus image to be passed to neural network.



**Fig-2: Fundus Image of eye.**

The filter basically uses opencv2 python library which uses Scale-Invariant Feature Transform (SIFT) algorithm to compute the key points and the key point description of the image. Key point descriptor is a 16x16 matrix that describes the neighbourhood around the keypoint



**Fig -3: Key points of the image**

Figure 3 explains how the key points found by the filter are used for detecting whether it is a fundus image or not.

On acquisition of key points and the key point descriptor of user entered image as well as the predefined fundus image, the next step is the comparison of those key points and key point descriptor using FLANN based matcher. Fast Library for Approximate Nearest Neighbours (FLANN) uses the key point neighborhood to find the match between images. The key point descriptor has been passed to this algorithm, as it stores key point neighborhood in 16x16 matrix.

The FLANN's knnmatcher method is used to find matches between two images which will take good ratio test to find best matches. If the number of matches are 0 then image is not a fundus image whereas if the number of matches are greater than 0 the image is a fundus image.

On confirmation, that the image is a fundus image it is then passed to the neural network. The architecture of the neural network is represented as follows:

Layer Name	Layer Specification	Layer Activation Function
Input Layer	64x64x3	Null
Convolution2D-1	32x(3x3)	ReLU
MaxPooling2D-1	2x2	Null
Convolution2D-2	32x(3x3)	ReLU
MaxPooling2D-1	2x2	Null
Flatten	Null	Null
Dense-1	128 units	ReLU
Dropout-1	20%	Null
Dense-2	128 units	ReLU
Dropout-2	20%	Null
Output	5 units	Softmax

### 1. Convolutional Layer

The first layer is convolutional layer, this layer performs heavy computation which make further job easy. This layer works as an input layer taking 128x128x3 (i.e. 128 pixels width and height, and 3 because images have depth 3, the color channels) as the input size of the image. Filters of 3x3 matrix will slide over all the spatial locations. The convolutional layer comprises a set of independent filters. Each filter is independently convolved with the image resulting in 32 feature maps.

### 2. Max-pooling Layer

In Max-pooling layer highest weighted feature is extracted, this is achieved by converting above 3x3 matrix in more compressed matrix. The above 3x3 matrix is the converted

into 2x2 matrix which involves only the highest weighted feature that is present in 3x3 matrix.

### 3. Flatten Layer

Flatten layer converts the matrix of image into one single dimension array which acts as an input to the dense layer.

### 4. Dropout Layer

The dropout layer performs inexpensive and powerful operation that highly improve generalization abilities of the neural network. This method involves randomly removing and restoring neurons during the training with a probability determined by the hyperparameter called dropout rate.

### 5. Dense Layer

The fully connected layer has its neurons connected to all neurons in the previous layer. These layers are used as last elements of deep neural classifier, which are feed by the features extracted by the successive convolutional layers.

### 6. Output layer

The last layer that produces the output of the network is a softmax layer or sigmoid neuron, depending on the solving task - binary or multiclass classification.

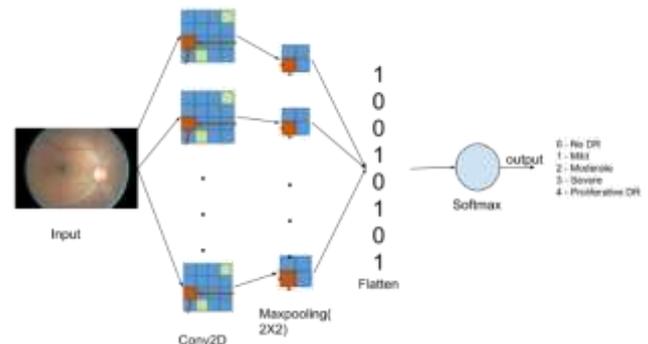


Fig-4: Neural Network Architecture.

### Activation Functions

#### 1. ReLU:

Rectified Linear Unit (ReLU) is the most used activation function in the world right now. Since, it is used in almost all the convolutional neural networks or deep learning.

$$f(x) = x^+ = \max(0, x), \tag{1}$$

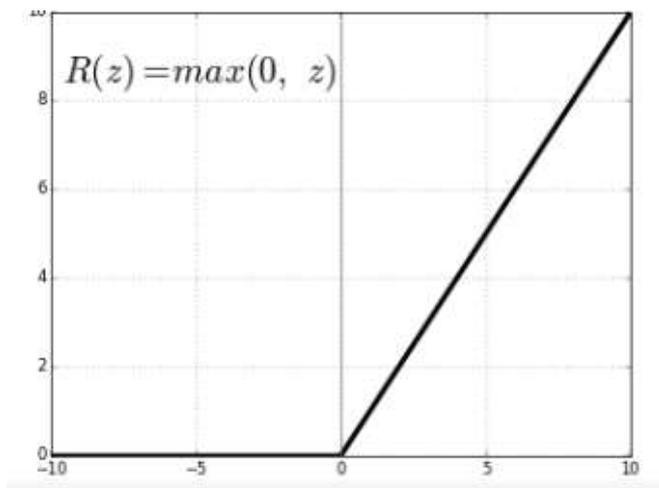


Fig-5: Graphical representation of ReLU.

As you can see in the above figure, the ReLU is half rectified (from bottom).  $f(z)$  is zero when  $z$  is less than zero and  $f(z)$  is equal to  $z$  when  $z$  is above or equal to zero.

2. Softmax:

The softmax function is a more generalized logistic activation function which is used for multiclass classification.

$$\sigma(\mathbf{z})_j = \frac{e^{z_j}}{\sum_{k=1}^K e^{z_k}} \text{ for } j = 1, \dots, K \text{ and } \mathbf{z} = (z_1, \dots, z_K) \in \mathbb{R}^K \quad (2)$$

4. IMPLEMENTATION DETAILS

A. Technologies used:

*Python 3.5.4:* Python is an interpreted high-level programming language for general-purpose programming. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales. In July 2018, Van Rossum stepped down as the leader in the language community after 30 years [17].

*Keras library:* Keras is a high-level neural networks API, written in Python and capable of running on top of TensorFlow, CNTK, or Theano. It was developed with a focus on enabling fast experimentation [18].

*Flask library:* Flask is a micro web framework written in Python. It is classified as a micro framework because it does not require particular tools or libraries. It has no database abstraction layer, form validation, or any other components where pre-existing third-party libraries provide common functions. However, Flask supports extensions that can add application features as if they were implemented in Flask itself. Extensions exist for object-relational mappers, form validation, upload handling, various open authentication technologies and several common framework related tools.

Extensions are updated far more regularly than the core Flask program. Flask is commonly used with MongoDB, which gives it more control over databases and history[19].

*HTML, CSS and JavaScript:* Hypertext Markup Language (HTML) is the standard markup language for creating web pages and web applications. With Cascading Style Sheets (CSS) and JavaScript, it forms a triad of cornerstone technologies for the World Wide Web.

Web browsers receive HTML documents from a web server or from local storage and render the documents into multimedia web pages. HTML describes the structure of a web page semantically and originally included cues for the appearance of the document[20].

*SQL database:* Structured Query Language (SQL) is a domain-specific language used in programming and designed for managing data held in a relational database management system (RDBMS), or for stream processing in a relational data stream management system (RDSMS). It is particularly useful in handling structured data where there are relations between different entities/variables of the data. SQL offers two main advantages over older read/write APIs like ISAM or VSAM. First, it introduced the concept of accessing many records with one single command; and second, it eliminates the need to specify how to reach a record, e.g. with or without an index[21].

B. Results:

We have created a webapp for the client where the client can use its username and password credentials to login in our system and use dashboard to interact with our system.

Test case:

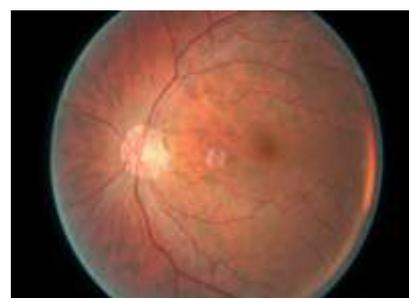


Fig- 6: Fundus image of eye.

Figure 6 is test case used for prediction of diabetic retinopathy.

Dashboard:

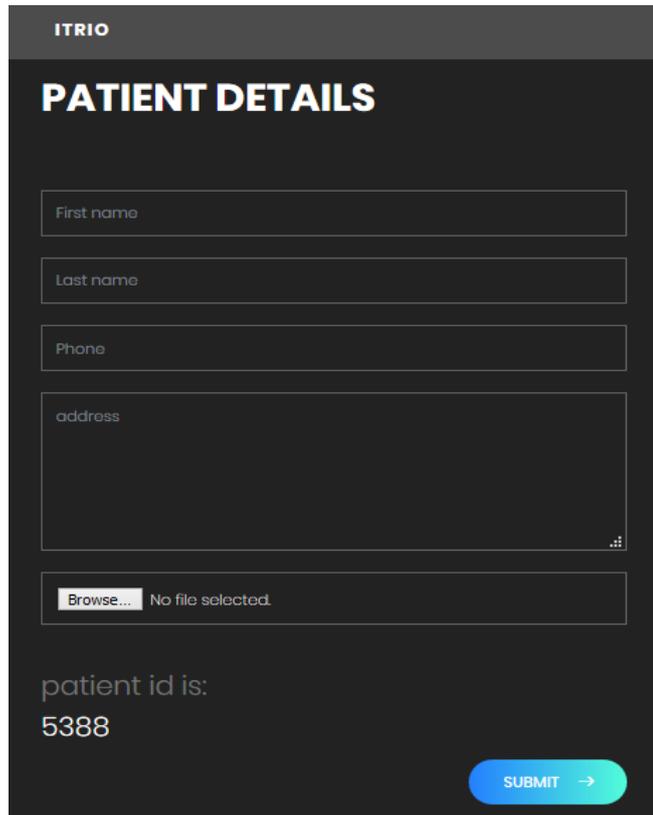


Fig-7: Dashboard Form.

Figure 7 depicts the form where client will fill the patients detail along with its fundus image which can be chosen using browse option. Once all the details are filed this will sent to the server where over neural network will pick the image using patient id.

Prediction:

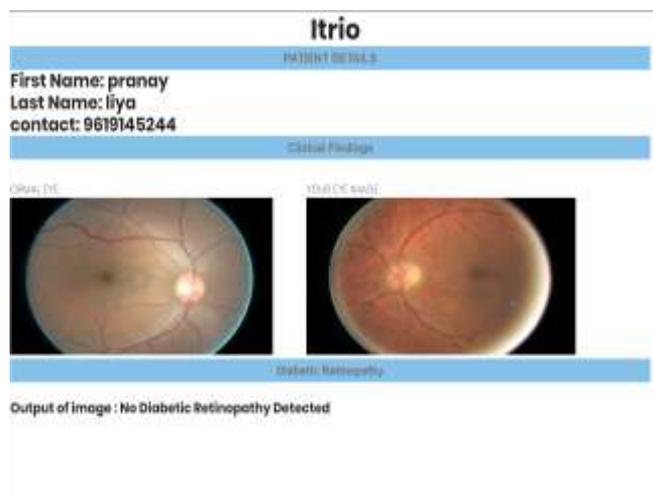


Fig- 8 : Neural Net predicting result

Figure 8 depicts the result that is predicted by neural network. The right side image, is the image that is uploaded by client and the result of the neural network is displayed in Output of image. In the above figure we can see that patient's eye is not effected and result is displayed as No Diabetic Retinopathy Detected by our neural network.

5. CONCLUSION

On success of our project we can quickly detect Diabetic Retinopathy with high accuracy from our trained neural network and our system will help to reduce the damage cause by diabetic retinopathy at early stage. Our report generation system will give analysis of patient's eye and will help doctors to take quick action .Our system can be further enhanced by training our neural network model on different eye disease so one can get one stop solution for all eye diseases.

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