Detection and Classification of Diabetic Retinopathy Using CNN

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Abstract – Nowadays Diabetic retinopathy is common eye disease in most of the countries. Due to Diabetic Retinopathy new small, fragile, week blood vessels are produced. If it is not treated accurately at early stage then it will lead to serious problems such as blindness or vision loss also. So there is need for regular eye checkup. Manual examination of fundus images to check retina changes in microaneurysms, exudates, blood vessels, hemorrhages, and macula is a very time-consuming and it requires very expert doctors and its subjective process. A computer-aided diagnosis system can help to reduce all these problems.
We propose an automatic system that includes image transform procedure for DR detection using Degenerated area detection and Ridgelet Transform, then extract the features and image classification with convolution neural network.

Keywords: Diabetic Retinopathy (DR), Fundus retinal image, Image Transformation, Automatic Detection, Feature, Extraction, CNN,

I. INTRODUCTION

Diabetic retinopathy (DR) is very serious problem of diabetes mellitus (DM), which is a leading cause of visual loss in working-age populations.[1][4][7]. If a person is having Diabetes from last 8-10 years, he can get its side effect such as Diabetic Retinopathy. if anyone get affected by Diabetic Retinopathy, then his retinal vessels start to weaken and swell ultimately getting punctured in various locations. Due to diabetes levels of blood sugars get increase and that can damage blood vessels in the body including on the back of the eye.
Diabetes damage blood vessels in the retina, it is called diabetic retinopathy. New abnormal blood vessels are generated on the optic nerve. This procedure is called "neovascularization". This new blood vessels are very small, thick, fragile and weak. So it easily break and blood is leak from the blood vessels called a vitreous hemorrhage.
Lots of proteins come out from the blood vessels and start dropping on the retina which will block the light coming into eyes and resulting in blurred vision. It is the first stage which is called NPDR (Non-Proliferative Diabetic Retinopathy). Next stage is the PDR (Proliferative Diabetic Retinopathy) in which what happens is that vessels gets blocked. This problem commonly called as ischemia.
To overcome this problem which starts blocking the light coming into our eyes and ultimately causes blindness. PDR is very severe in comparison to NPDR. Timely detection of it required to prevent the disease as it has no cure. DR usually affects both eyes. It is required to ensure that the risk of vision loss is reduced. The only way people with diabetes can avoid DR is to be present at all the eye examination scheduled by their doctor.
The current eye care practice for DR involves examination of multiple field fundus images for finding abnormalities by a trained expert. Depend on the observed abnormality in the retina at the time of the examination, diabetic patients are referred to an ophthalmologist for further diagnostic evaluation and possibly treatment. This procedure is time consuming and requires many diabetic eye care resources. So there is a need to develop an automatic computer-aided diagnose system for detection of Diabetic Retinopathy to identify between normal and abnormal blood vessels present in the digital retinal image [3].

There are two types of DR:

A. Non-Proliferative diabetic retinopathy (NPDR) [11][12]:
This is the milder type of diabetic retinopathy and is generally doesn't show any symptoms.

B. Proliferative diabetic retinopathy (PDR) [11][12]:
PDR is the most difficult level of diabetic retinopathy and refers to the formation of new, abnormal blood vessels in the retina.

To detect Diabetic Retinopathy, we take original retinal fundus image. Preprocessing is done using ROI segmentation. Then perform detection of degenerated pixels and measurement of degenerated pixels using histogram area calculation. For classification of Diabetic retinopathy CNN algorithm is used.
In this paper section I represents introduction, section II represents review literature, section III represents implementation analysis, section IV represents mathematical model and section V represents result analysis.

II. LITERATURE REVIEW

Kedir M. Adal [1] proposed a Automated System for the Detection and Classification of Retinal Changes in Longitudinal Fundus Images. At early stages, DR is microaneurysms, so in this case blood vessels are damaged, and blood is leaked from them. These lesions normally appear as small, round dark-red spots, called roundish blobs. So author proposed Laplacian of Gaussian (LoG) operator to detect such roundish blobs from fundus images.

Lama Seoud [2] proposed automatic telemedicine system for computer-aided screening and grading of diabetic retinopathy. A MAs and HEs has wide variety of shapes and sizes. So, no singe template can match all sizes and shapes. Author find out new set of shape features such as Relative Area, Elongation, Eccentricity, Circularity, Rectangularity, Solidity etc. To find out the performance of the method on different images, author tested it on six independent databases.

Sohini Roychowdhury [3] proposed a computer-aided screening system (DREAM) for analysis of diabetic Retinopathy using machine learning. To classifying retinopathy lesions from non-lesions different classifiers are used such as Gaussian Mixture Model (GMM), k-nearest neighbor (kNN), support vector machine (SVM), and AdaBoost. Main contribution of author is reduction in the number of features used for lesion classification by using Adaboost feature ranking classifier.

Shuang Yu [4] proposed a method for automatic neovascularization detection on optic disc region. For optic disc detection, local phase symmetry algorithm is used. non-local means filter is used to get the only major vessels in the image and remove the fine vessels. For neovascularization detection, multi-level Gabor filter is applied. Then features are extracted from preprocessed image such as Vessel Morphological Features and Texture Features. To select most important features recursive feature elimination (RFE) algorithm is used. And lastly to classify NVD images and non-NVD images, support vector machine algorithm is used.

Vaishali Suryawanshi [5] provides a texture-based approach using Gray Level Co-occurrence Matrix (GLCM). Then the texture features such as contrast, correlation, energy, homogeneity, and entropy are extracted from the GLCM matrix. Further training is done with Pattern-recognition classification problem using a two-layer feed-forward network with sigmoid output neuron neural network to achieve maximum accuracy.

Sandra Morales [6] find insight capabilities in the texture of fundus to differentiate between non healthy and healthy images. In particular, the major focus lies in discovering the performance of Local Binary Patterns (LBP) as a texture descriptor for retinal images. It depends on looking at the local variations around every pixel and passing labels to different local patterns. Thereafter, the distribution of the labels is evaluated and used in the classification stage. The main aim of this paper is to differentiate between DR, AMD and normal fundus images at the same time and avoiding any previous segmentation stage of retinal lesions.

Arisha Roy [7] uses a filter based retinal vessel extraction, exudates detection using Fuzzy C means, detection and removal of the optical disk using Convex Hull. Support Vector Machines (SVM) is used to classify the fundus images into Normal and Non-proliferative Diabetic Retinopathy (NPDR) or Proliferative Diabetic Retinopathy (PDR).

Rishab Gargeya [8] proposed a robust diagnostic technology to automate DR screening. Referral of eyes with DR to an ophthalmologist for more assessment and treatment would help in reducing the rate of vision loss, enabling timely and accurate diagnoses.

Shailesh Kumar [9] build an improved diabetic retinopathy detection scheme by extracting accurate area and ate the number of microaneurysm from color fundus images. Here two features namely; number and area of MA have been determined. Initially, pre-processing techniques like green channel extraction, histogram equalization, and morphological process have been used. For detection of microaneurysms, principal component analysis (PCA), contrast limited adaptive histogram equalization (CLAHE), morphological process, averaging filtering have been used. Classification of DR has been done by linear Support vector machine (SVM). The sensitivity and specificity of DR detection system are observed as 96% and 92% respectively.

Dr. V. Ramesh [10] proposed a system to determine the correlation among the various risk factors of diabetic retinopathy and design a model to predict the risk level of diabetic retinopathy. Collected data are preprocessed for classification of risk level. Here MLP classification algorithms are used to predict the risk factor. A model is designed using the .NET platform to predict the risk level of the diabetic retinopathy.

III. IMPLEMENTATION DETAILS

The main objective this system is to develop diagnostic tool for automated DR detection. The algorithm processed color fundus images and classified them as healthy or DR. We proposed a method for detection and classification of Diabetic retinopathy using Convolution Neural Netwo. So, there are total five phases in the architecture.

A. System Architecture:

The proposed system can help to detect Diabetic Retinopathy (DR) using fundus camera images to avoid vision loss and blindness as part of early disease diagnosis for elderly patients. Figure 1 shows the structural design of the proposed system.

1.Image Input:
Input to the system is different colour retinal fundus images.

2. Image Pre-Processing:
The illumination of the retina is often nonuniform, due to luminosity and contrast variation. Lesions may be hardly visible in areas of poor contrast or low brightness. Therefore, preprocessing steps are required to address these issues.

a. Region of Interest segmentation:
Thresholding is used for image Segmentation from where blood vessels are to be extracted. It typically used to locate objects and boundaries in image. Image Segmentation is the technique of partitioning a image into multiple parts. The goal of segmentation is to simply to represent image for meaningful and easier to analyse.

b. Image Enhancement:
To enhance quality of image, Gaussian Blur Transform is used. It blur the image by using Gaussian function. It is a widely used in graphics software to reduce image noise and reduce detail. A Gaussian kernel is array of pixels in square format where the pixel values are corresponding values of a Gaussian curve in 2 Dimensional format. Each pixel in the image gets multiplied by the Gaussian kernel. This is done by placing the center pixel of the

kernel on the image pixel and multiplying the values in the original image with the pixels in the kernel that overlap. The values resulting from these multiplications are added up and that result is used for the value at the destination pixel.

c. Green Plane Extraction:

The green plane is extracted, and a series of morphological opening operations are applied. Erosion and dilation with a specific structuring element. The erosion operator takes to pieces of data as inputs. The initial is the image which is to be eroding. The second is (usually small) a set of coordinate points known as a structuring element (also known as a kernel).

3. Image Transform:

Image transform contains two steps such as Degenerated Area Detection and Ridgelet Transform.

A. Detection of degenerated pixels:

To detect the degenerated region (dark pixels) particle analysis is performed. A particle is a contiguous region of non-zero pixels. These particles are extracted from a grayscale image by thresholding the image into background and foreground states. Zero- valued pixels are placed in the background state, and all non-zero valued pixels are placed in the foreground. Particle analysis dealing with a sequence of processing operations. e. Geometric features of the degenerated area are calculated such as area, volume.

B. Measurement of degenerated pixels area (Histogram area calculation):

To calculate the total degenerated area, the histogram is calculated, which gives the number of non-zero pixels and zero-pixels. The number of non-zero pixels represents the degenerated area.

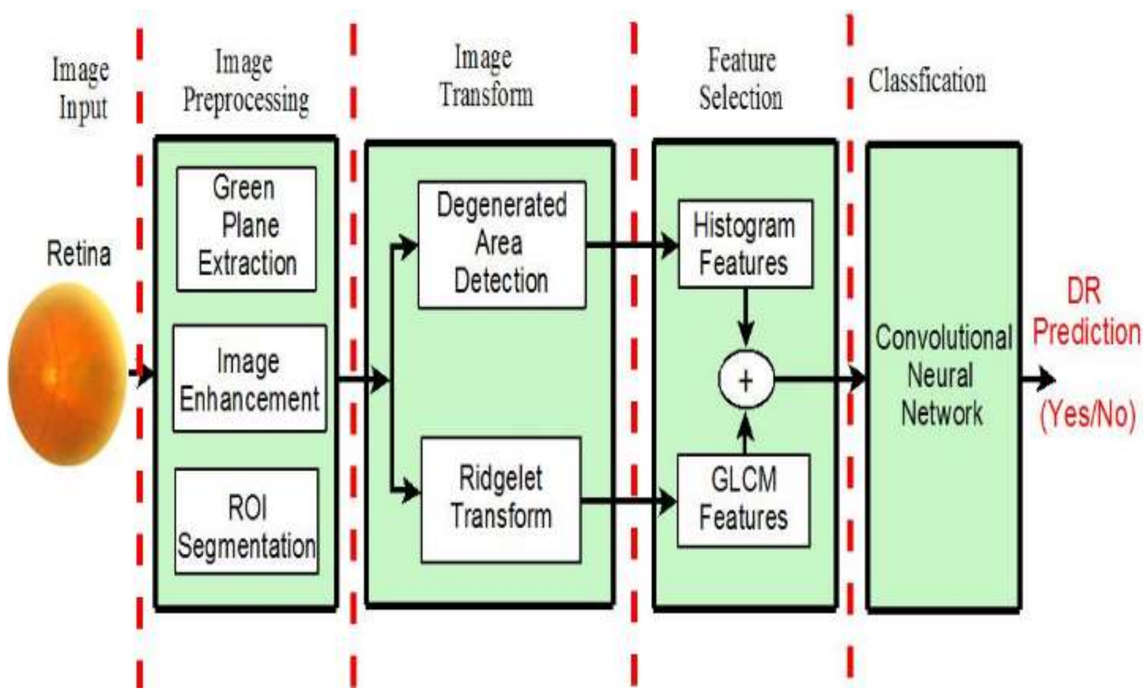

Figure 1 : System Architecture

4.Feature Extraction:

Once blood vessels extracted, we have to extract features. So, histogram features and GLCM features are calculated such as Inverse difference moment, Homogeneity, Maximum Probability, Cluster shade, Cluster prominence etc.

5. Classification:

Convolution Neural Network is used for classification of Diabetic Retinopathy images and non-Diabetic Retinopathy images. CNN image classifications takes input as a image, process it and classify it under certain different categories. CNN uses neurons which is similar structure like humans brains.
Input for CNN is taken from Kaggle website https://www.kaggle.com/c/diabetic-retinopathydetection/data.

The output is - A clinician has rated the presence of diabetic retinopathy in each image on a scale of 0 to 4, according to the following scale:

0 - No DR
1 – Mild
2 – Moderate
3 – Severe
4 - Proliferative DR

A CNN consists of an input and an output layer, with multiple hidden layers. The hidden layers of a CNN normally consist of Convolutional layers, pooling layers, fully connected layers, and normalization layers. CNN will be used to train the images analytics engine for recognizing important data from images.

IV. RESULT ANALYSIS

A. Dataset Used:

1. Large data set of Fundus Images.
2. The data- set consists of retinal images forming image pairs. These image pairs are divided into 3 different categories based on their characteristics. The images were acquired with a Nidek AFC-210 fundus camera, which acquires images with a resolution of pixels and both in the x and dimensions.
3. Kaggle diabetic retinopathy database.
4. Publicly available by California Healthcare Foundation on Kaggle website.

B. Results:

In our proposed system we used a large dataset of the fundus image. Where accuracy and precision are calculated based on false positives images, i.e. which are items incorrectly labeled as belonging to the class and false negatives, which are items which were not labeled as belonging to the positive class but should have been. We are considering 5 classes in which we have classified the stages i.e.

0 - No DR
1 – Mild
2 – Moderate
3 – Severe
4 - Proliferative DR

For the mentioned classes the accuracy and precision is calculated by using the formula. The precision is the percentage of documents that are correctly classified as positive out of all the documents that are classified as positive. Where, TP, FP, and FN are truly positive, False positive and false negative images. Here, we tested the data set of 2000 images for the class 0 ,2 and 3, 1200 image for class 1. For class 0 the true positive images are 1971. The true positive, False positive and false negative images from each class in given in below table.

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

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

Fig 2: Accuracy and Precision

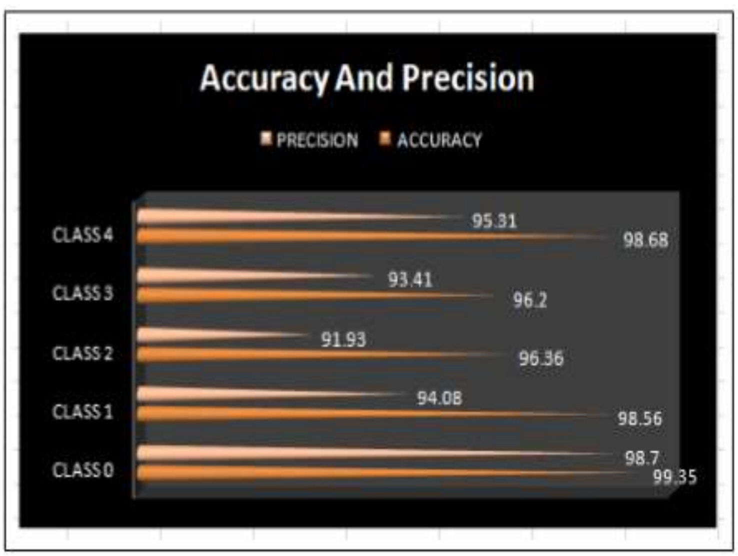

Fig 3. Accuracy and Precision

The below figure gives the class wise distribution of images.
Here we detect DR based on CNN classification. The algorithm can help to detect total damaged area in the macula from the color retinal images. The accuracy in the detection. of DR for mentioned 2 classes i.e.no DR, mild, moderate, severe and Proliferative DR stage. The table shows the same.

Classes	TP	TN	FP	FN
Class 0	1971	6331	26	28
Class 1	1129	7173	71	50
Class 2	1891	6411	166	148
Class 3	1789	6516	126	202
Class 4	1525	6777	75	36

Fig. 4. Class wise Distribution of Images

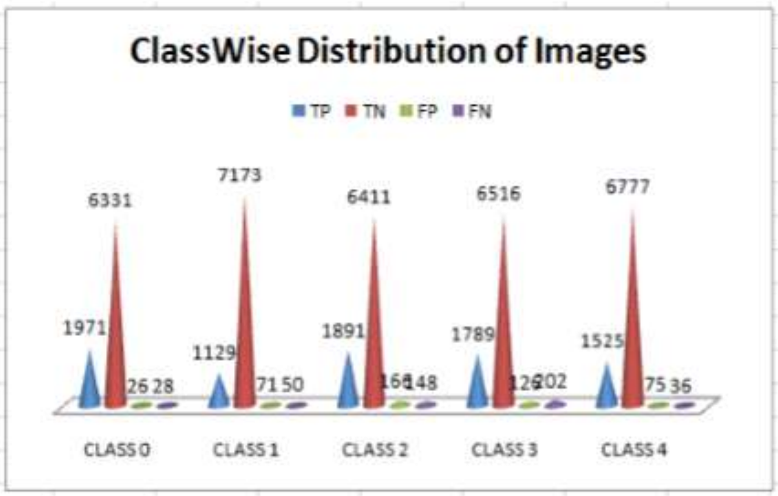

Fig. 5. Plot of Class wise Distribution of Images

Class Label	Accuracy
0	98.55
1	94.08
2	94.55
3	89.3
4	95.31

Fig. 6. Class wise Accuracy Detection In DR

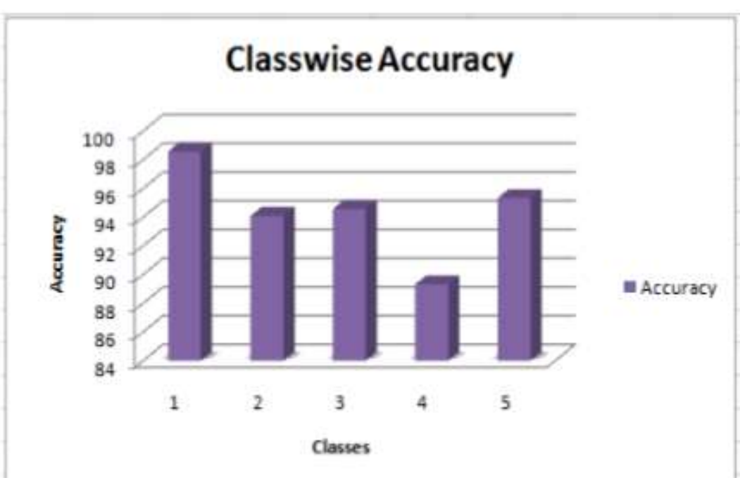

Fig. 7. Plot of Class wise Accuracy Detection In DR

V. CONCLUSION

Diabetic retinopathy is a serious issue which affects the eyes and results in blindness. Analyzing the DR images manually is quite time-consuming and expensive. The proposed system provides a robust solution for DR detection within a fundus photograph obtained from diabetic patients. The system has high efficiency in providing efficient, low-cost DR diagnostics by using CNN. The implementation of such an algorithm on a global basis could reduce drastically the rate of vision loss attributed to DR.

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