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Fractal Analysis and Convolutional Neural Network Based Diabetic Retinopathy Grade Classification

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Abstract

Diabetic retinopathy is a disease caused in eyes of the diabetic patients. The images of retina of the eyes are taken from the MESSIDOR dataset. Features are extracted by considering the fields using fractal dimension. The extracted features are then given as input to the Convolutional Neural Network for training the classifier. The classifier classifies the normal person and the person with diabetes. Then few more features are extracted to grade the diabetic patients in addition to finding normal and abnormal patients. The feature extraction has supported the classifier in yielding better results when compared to the other existing methods for grading the diabetic patients.

Keywords: *diabetic retinopathy, convolutional neural network, fractal dimension, feature, grading*

1. Introduction

Diabetic Retinopathy is a disease that affects the nervous system in the eyes and leads to poor vision in the diabetic patients. It is estimated that at least 2% of the world population by 2020 is affected by the disease. The bright area in the fundus eye image, which is composed of the optic cup and the optic disk, is called the optic nerve head region. Diabetic retinopathy symptoms are between the retina and the cataract in diabetic macularedema. The problem with it is that, as the disease progresses in asymptomatically the patient gradually loses sight. So it is important to identify the patient's stage to give suitable treatment, which helps patients from losing the eye sight. The various characteristics of the nervous system help in diagnosing Diabetic retinopathy. The following are few characteristics,

1) Microanurysms (MA) is in the walls of the blood vessels and forms a balloon like structure;
2) Capillaries may bleed;
3) The leakage from blood vessels called Exudates.

2. Literature Survey

M. N. Nikhil, Angel Rose [1] have used color fundus retinal images for the classification of Diabetic Retinopathy (DR). A Convolutional Neural Network based approach is used for stage classification. Three Convolutional Neural Networks are used together for stage classification and better accuracy has been achieved.

Prabhjot kaur, et. al., [2] proposed a Neural Network Technique for Diabetic Retinopathy Detection. The diabetes retinopathy is the application of medical image processing. The retinal images are evaluated to diagnose the DR. Grading manually is a tedious task and require more resource to define the severity of DR. When the tiny blood vessels present within the retina are damaged, only then can one notice this problem. Blood will flow from this tiny blood vessel and features are formed from the fluid that exists on retina. The kinds of features involved here due to the leakage of fluid and blood from the blood vessels are considered to be the most important factors to study this problem. The diabetes retinopathy detection

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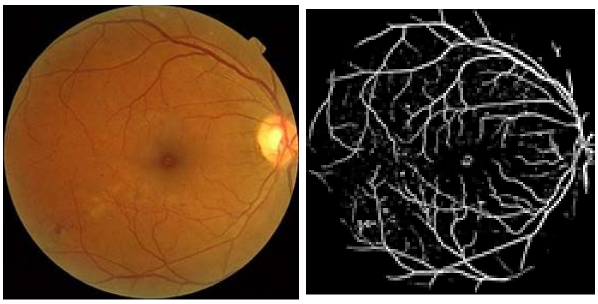
techniques has the three phase which pre-processing, segmentation and classification. The CNN approach used for classifying the image has given better results and was analyzed in terms of certain parameters.

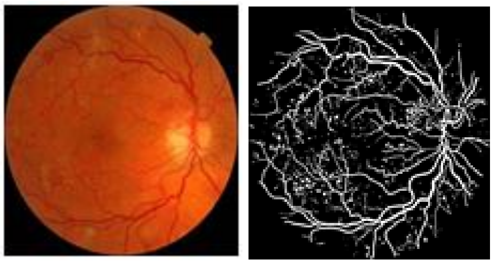
Alexander Rakhlin [3] has proposed a classification framework using Convolutional Neural Network for the detection of diabetic retina. Eye fundus images form Kaggle dataset[5] is taken for training and testing of the classification performance. The author has claimed that the results obtained are closer to recent state-of-the-art models trained on much larger data sets and exceed the average results of diabetic retinopathy screening when done manually.

Vijay Kumar Gurani, et.al.,[4] has proposed a method for classifying Diabetic Retinopathy using Neural Network. The images of diabetic retinopathy are fed as input for the artificial neural networks. The neural network is trained and further test for its classification accuracy. The classification is done based on four classes such as (i) no diabetic retinopathy, (ii) mild non-proliferative diabetic retinopathy, (iii) severe non-proliferative diabetic retinopathy and (iv) proliferative diabetic retinopathy. The authors claim that the results achieved are better compared to the state of the art methods.

Here we have only summarized the method, for a detailed description; please refer to the honorary paper. During the pre-processing phase, the green channel is extracted from the RGB images due to the channel providing reliable contrast between the structures in the fundus images. Then the pixel level features are calculated. In the post processing phase, we place binary connected units of more than 100 pixels. The morphological closure is applied with a radius disc formation factor of 2 pixels to eliminate the pores in the main arteries and connect the individual elements with the vascular structure due to the central reflex. Then, all connected units of more than 200 pixels are placed to protect pathological areas. It is worth noting that the partition used here is for ship disassembly and skeletonization sections. From the figure, we can see that figure 1 (a) and (c) are fundus images, then by using partitioning methods, a detailed vessel and skeleton of the fundus images are obtained as shown in figure 1 (b) and (d).



(a) (b)



(c) (d)

Figure 1: (a) the healthy subjects fundus image (b) healthy subjects segmented images (c) diabetic retinopathy patient fundus image (d) diabetic retinopathy patient segmented images

3. Proposed Methodology

A diabetic retinopathy classification method for classifying healthy eyes and diseased pathologic eyes using fractal analysis as a feature extraction and convolutional neural network classification is proposed. Initially the images are sorted; fractal dimensional features are calculated and extracted. The extracted features are fed to the traditional convolutional neural network classifier. The classes are not diabetic, slightly diabetic, medium and highly diabetic. The details of this classification are shown in the following table 1.

Table 1: Criteria for Classification

Class	Criteria
Not Diabetic	No micro aneurysms
Slightly diabetic	Only micro aneurysms (MA) are present
Medium	Beside the micro aneurysms MA, haemorrhagic HMA is present, each HMA and MA is less than 20 in each quadrant
Highly diabetic	More than 20 for bleeding HMA in each quadrant

Fractal materials are commonly used in the biomedical field. The creation of fractal objects continues in a multitude of ways. Furthermore, the retinal vasculature can be characterized using the fractal dimension. Therefore, fractal dimensions are the most common features used pathologically in the retinal vasculature. For example: Aliyamad et al and Mudigonda et al reported that there is a difference between healthy subjects and diabetic patients, which can be seen from fractal dimensions.

Although fractal dimensions have been reported to be able to differentiate between healthy subjects and diabetic patients, a detailed analysis on fractal dimensions is able to differentiate diabetic retinopathy grades, particularly from grade 1 to grade 3, which is mild to severe. The following figure 2 shows the working process of the proposed method.

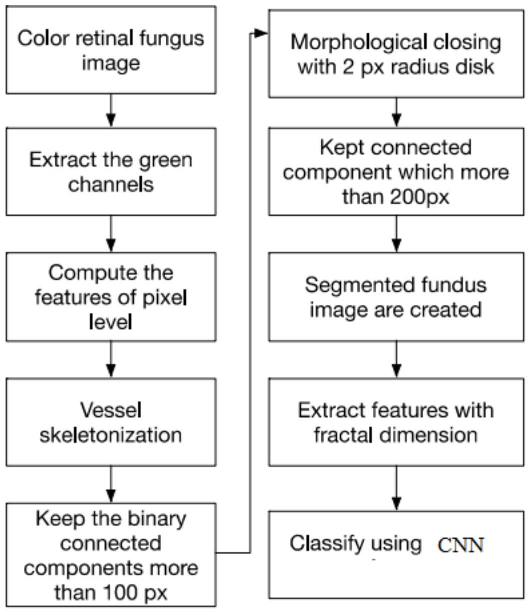


Figure 2: Schematic flow diagram

CNN Classification:
In deep learning [7], the convolutional neural network uses stacked layers, which is a complex architecture but well suited for image classification. For the cases like multi-class classification, this architecture robust and sensitive to each feature present in the images.
The stacked layers commonly used in deep convolutional neural network are:

- Convolutional layer
- Pooling layer
- ReLU layer

Convolution Layer: [5, 6] The first and foremost layer laid after the input image which wants to be classified is the convolutional layer. There are two fields (i) Local Receptive Fields (ii) Shared Weights acts as the backbone of the convolutional neural network.
Pooling Layer: It is one of the most significant layer which help the network from avoiding over-fitting by reducing the parameters and computation cost in the network.
Pooling partition and mapping to rectangular sub region of rectangles is a of non-linear down sampling. It is merely the downsize of the pixels with features. For instance, if NxN input layer, that will give output layer of N/K x N/K layer.
ReLu Layer: Rectified Linear Unit (ReLU) sets all negative values in the matrix x to zero and all other values are kept constant. It is computed after the convolution and therefore a nonlinear activation function like tanh or sigmoid.

$f(x) = \max(0,x)$ or
$f(x) = \ln(1+e^x)$

4. Experimental Results

Accuracy is used as a performance measure for analysing the performance of the classifier.

$$\text{Accuracy} = \frac{TP + TN}{TP+TN+FP+FN}$$

It is obtained by using confusion matrix (Table 2) as follows:

Table 2: Confusion matrix

	Total population	True Condition	
		Positive condition	Negative condition
Prediction condition	Positive prediction condition	True positive (TP)	False positive (FP)
	Negative prediction condition	False negative (FN)	True negative (TN)

In the MESSIDOR dataset, the Diabetic retinopathy is divided into 5 grades, but for the work proposed here, only 4 grades are used which is shown in the following table 3.

Table 3: Diabetic Retinopathy Grades in MESSIDOR

Grade	**Description**	**Number of images**
G0	MA=0&HMA=0	500
G1	(0<MA≤5) & HMA = 0	150
G2	(5<MA<15)&(0<HMA<5)	240
G3	(MA≥15) or (HMA≥5)	233

In the above table grade G0 is considered as healthy subjects, and grades G1 to G3 is considered as diabetic retinopathy subjects with illness degrees. The images are segmented according to the above grades and are processed using fractal dimension for feature extraction.

The extracted features are then fed into convolutional neural network (CNN) for classification.

The following table 4 and figures 3 and 4 shows the performance comparisons of the proposed and other existing methods [8,9].

Table 4: Comparison between algorithms based on accuracy of diabetic retinopathy

Model	**Algorithms compared**	**Accuracy**
Image Processing	Support Vector Machine	88%
Neural Networks	Local Texture Classifiers based on Multilayer Perceptron	91%
Deep Learning	Convolutional Neural Network	93.4%

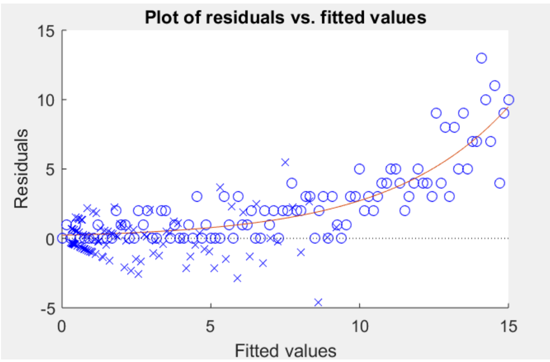


Figure 3: Residuals vs. Fitted Values

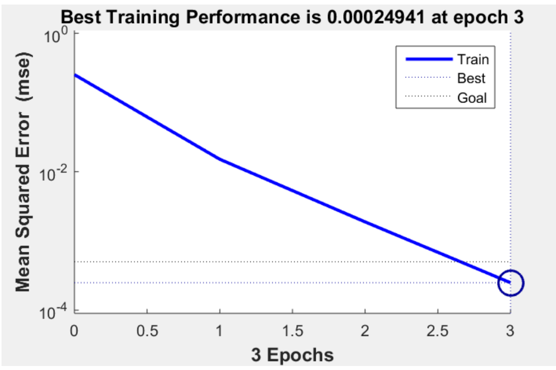


Figure 4: Error Rate

There is no big difference in using the different fractal dimension techniques such as the box fractal dimension, information fractal dimension, correlation fractal dimension, or a combination of those three. All three features exhibit the same characteristics, so it is sufficient if any one of the technique is used. The fractal dimension is able to distinguish between healthy subjects and diabetic retinopathy patients.

In the previous section, it was possible to obtain number of findings on the fractal dimension. Due to the fractal dimension disability in grading diabetic retinopathy, it is required to move in other directions such as statistical features, monopoly and multivariate features for extracting the better features.

The extracted features are then given to the optimized Convolutional Neural Network as discussed earlier. The results obtained are satisfactory and better when compared with the results of other methods.

5. Conclusion and Future Work

A fractal analysis for the classification of diabetic retinopathy is discussed. The trial concluded that fractal analysis was able to differentiate healthy subjects and patients with diabetic retinopathy, along with detailed analysis on classification of mild diabetic retinopathy to severe diabetic retinopathy. The fractal dimension technique is not efficient in grading diabetic retinopathy. This means that the fractal dimension alone is not sufficient to distinguish diabetic retinopathy grade from G1 to G3.

In future features such as monopoly and multivariate or statistical features can also be considered for effective grading of diabetic retinopathy. The images can be further pre-processed for red lesion detection, so that more features can be extracted from the input images. It is worth noting that the segmentation satisfied the requirement to a certain extent. But the research continues further in another direction to divide the image of the retinal fundus that gives more information about the grade level.

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