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Grading of Diabetic Retinopathy using Different Machine Learning Algorithm

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Article Info
Volume 83
Page Number: 2124 - 2130
Publication Issue:
March - April 2020

Abstract

Diabetes is a constantly recurring disease. It causes because, pancreas are not efficient enough to produce required amount of insulin. One more reason is that insulin available within the body is not efficiently working. As of 2019, it is projected that around 450 million people had diabetes worldwide, with type 2 diabetes making up about 90% of the cases. Diabetic retinopathy (DR), also referred to as diabetic disease, may be a medical condition during which damage occurs to the retina and it's a number one explanation for blindness. People who have diabetes for more than 20 years, among those diabetic patient, 80% of them suffer from DR. Proposed method works with fundus image and processes it with optic disc detection, vessel segmentation, red lesion detection, and hard exudates evaluation, detection of Proliferative diabetic retinopathy (PDR) and grading of DR. For optic disc segmentation pre-processing method used is adaptive histogram equalization. For better classification, super pixels are generated using simple linear iterative clustering (SLIC) algorithm, and then k-means clustering algorithm is used as classifier. Proposed method is tested on database of 750 images and 98 % samples correctly extracted optic disc region. Blood vessel segmentation plays key role for detection of red lesion. Along with pre-processing method and feature extraction method, Gaussian mixture model is used as a classifier. Same database is used and gives accuracy of 93%. For red lesion detection optic disc region and wide and thick blood vessels are subtracted from original image and further given to Random forest classifier (RFC) for classification giving best result with accuracy of 96%, highest compared to other classifier such as support vector machine(SVM) 89%, k-means clustering 83%. Further hard exudates are evaluated using Convolution neural network (CNN) with accuracy of 99%.For detection of PDR, Matched Filter with Gaussian Kernel & Scale Elimination is used for feature extraction and for classification Thresholding is used based on Vessel Density (Vd) and Tortousity (Vt). Gradation of DR is characterized such as, Normal/Healthy-No lesion, Hard Exudates & Neovascularization present, Mild-0-5 Microaneurysms, Moderate- 5-10 number of Microaneurysms , number of Hemorrhages >0, number of Exudates <=5, Severe- Lesions present are greater than that of moderate NPDR, PDR-Neovascularization Present. Further studies involve assessment with age factors, gender and samples from different living conditions. Use of proposed method will automatically detect and gives prior intimation regarding development of DR with gradation.

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 18 March 2020*

Keywords – *Diabetic retinopathy (DR), Proliferative diabetic retinopathy (PDR), Simple linear iterative clustering (SLIC), Random forest classifier (RFC), support vector machine (SVM), k- means clustering, neural network (CNN).*

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I. Introduction

Diabetes is a constantly recurring disease causes from less produced insulin from pancreas or inefficient use of insulin. Diabetes can be mainly classified into two types i.e. Type1 and Type 2. When human body makes very little or no insulin leads to Type1 diabetes, which can be developed in any age group. To maintain sugar level in human body, insulin injections at regular intervals are suggested by the doctor. In Type2 disease insulin doesn't work properly and so patient unable to maintain the sugar levels. A person having diabetes for more than 20 years leads to diabetic retinopathy and it causes blindness in severe case. So to confirm DR at early stage is essential to avoid blindness. Therefore proposed method gives gradation of Diabetic Retinopathy.

So far 463 million people have diabetes. 80% of them are in the 40 to 60 age group. Half of those people are still undiagnosed. Most of the people have type2 diabetes which is main cause of Diabetic Retinopathy. DR is classified into two types: 1. Non-Proliferative Diabetic Retinopathy (NPDR).2. Proliferative Diabetic Retinopathy (PDR). NPDR is very first stage with very little symptoms or no symptoms; causes because of weakening of retinal blood vessels, leads to tiny bulges on those blood vessels are called micro aneurysms. This causes leakage of blood into the retina, leads to blurry vision. PDR is a next step of the DR. Because of oxygen circulation troubles, new tiny blood vessels begin to grow into the retina, responsible for vision loss.

Different methods were used to diagnose diabetic retinopathy are Red Lesion Detection using Dynamic shape features which uses Candidate Extraction and Random forest Classifier with accuracy about 87.7% comparable to human expert-92.9%[1], Deep multiple instance learning uses Multiple Instance Learning, Deep MIL and CNN based patch level DR Estimation with Sensitivity-0.924 and Precision-0.863[2], Gradation of Diabetic retinopathy on reconstructed image using compressed sensing with use of Compressed sensing for image reconstruction, Fuzzy entropy, Neovascularization detection and Gradation of DR with 94% accuracy [3], A weakly Supervised Framework with techniques used are Visual dictionary learning, Binary classifier Training and Multiple Instance learning with 90% accuracy[4], Automatic Grading of Retinal Blood Vessel Tortuosity in which methods used are Curvature Calculation, Modification of template disc method, Modification based on crossover point with 85% accuracy[6], Deep Neural Networks with 88.72% accuracy[7], The Neural Network of One- Dimensional Convolution which uses CNN, Deconvolution , Network structure BNCNN, Adaptive Learning Rate Algorithm and Super Parameter Optimization with 97.56% accuracy[10] and many more.

Proposed method does optic disc detection, vessel segmentation, red lesion detection, and hard exudates evaluation, detection of Proliferative diabetic retinopathy (PDR) and grading of DR. For optic disc segmentation pre-processing method used is adaptive histogram equalization. For better classification, super pixels are generated using simple linear iterative clustering (SLIC) algorithm, and then k-means clustering algorithm is used as classifier. Blood vessel segmentation plays key role for detection of red lesion. Along with pre-processing method and feature extraction method, Gaussian mixture model is used as a classifier. For red lesion detection optic disc region and wide and thick blood vessels are subtracted from original image and further given to Random forest classifier (RFC) for classification. Further hard exudates are evaluated using Convolution neural network (CNN. For detection of PDR, Matched Filter with Gaussian Kernel & Scale Elimination is used for feature

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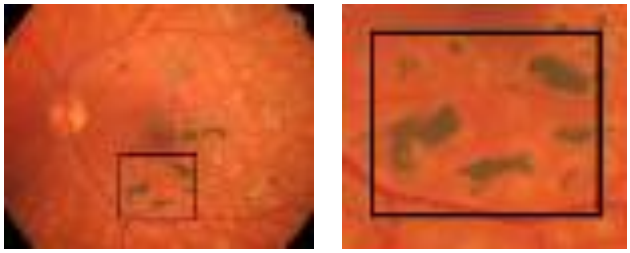
extraction and for classification Thresholding is used based on Vessel Density (Vd) and Tortousity (Vt). Gradation of DR is characterized such as, Normal/Healthy-No lesion, Hard Exudates & Neovascularization present, Mild-0-5 Microaneurysms, Moderate- 5-10 number of Microaneurysms , number of Hemorrhages >0, number of Exudates <=5, Severe- Lesions present are greater than that of moderate NPDR, PDR-Neovascularization Present.

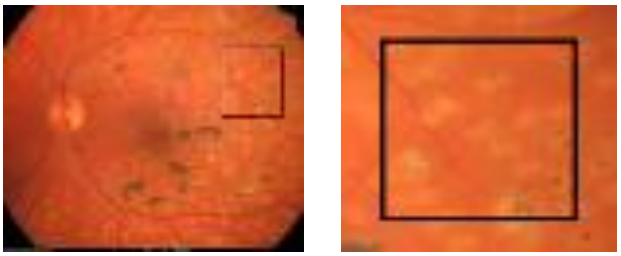
II. METHODOLOGY

a. Background

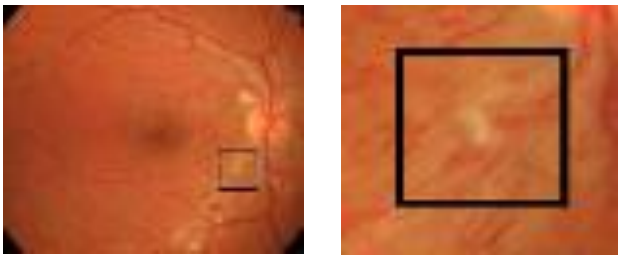
Non-proliferative diabetic retinopathy includes Aneurysm, Hard exudates and Hemorrhage and Proliferative diabetic retinopathy contains abnormal blood vessel. When an artery's wall become weak, it causes an irregular large swellings, which is also called an aneurysm. This can break and cause internal bleeding. Hard exudates are tiny white or yellowish white deposits with sharp margins. Frequently, they come into view glistering, shiny and waxy. They are positioned in outer layers of the retina, deep to the retinal vessels. Bleeding is also referred as Hemorrhages, which is related to blood loss. Bleeding is of two types, internal bleeding and external bleeding. Blood loss can occur in roughly any area of the body. Fig. 1 clearly gives idea of an aneurysm, hard exudates and Hemorrhages in Retinal image. These symptoms cause Non-proliferative diabetic retinopathy.



1. Aneurysm



2. Hard Exudates



3. Hemorrhages

Fig. 1. a. Aneurysm, b. Hard Exudates, c. Hemorrhages

Retinal Neovascularization means growing of new tiny blood vessels from the existing blood vessels in the retina. These abnormal vessels lead to Proliferative diabetic retinopathy. Fig. 2 shows the Retinal neovascularization.

Fig. 2. Retinal Neovascularization[6]

Non Proliferative diabetic retinopathy can be further characterized into four types Normal, Moderate, Heavy and Severe. Respective visual content is given in Fig. 3.

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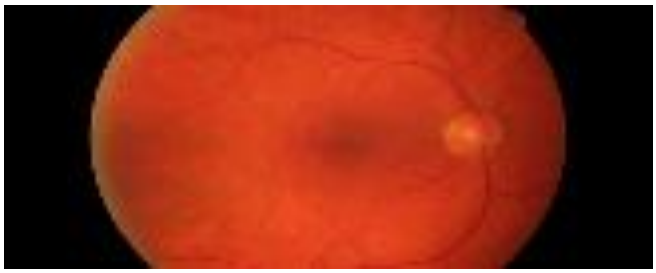
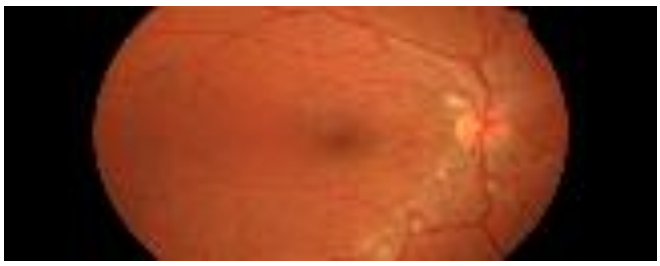
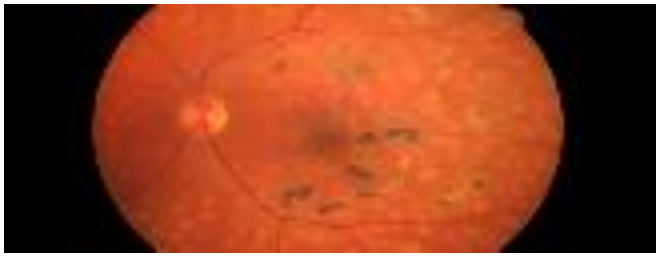
1. Normal



2. Moderate



3. Heavy



4. Severe

Fig.3. Diabetic Retinopathy is characterized as Normal, Moderate, Heavy and Severe.

b. Optic Disc Segmentation

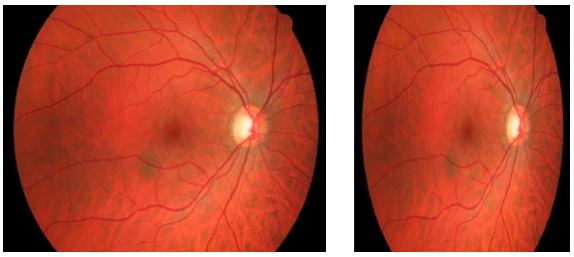
In Fundus image, Optic disc has the highest level of contrast values compared to other images. For detection of Diabetic retinopathy main symptoms are aneurysm, hard exudates and hemorrhages, which are very contrast and color sensitive. Therefore for nullification of an error or to increase sensitivity of the method, first optic disc is located correctly, optic disc is segmented and the respective portion of optic disc is subtracted from the original image.

Optic disc segmentation consists of preprocessing method, Super pixel generation using Simple Linear Iterative Clustering SLIC Algorithm, Classification Algorithm and also Post Processing Methods are used.

a. Preprocessing Methods

i. Resize Image

Every fundus image captured is different from every other image in terms of dimensions. To correctly locate the position of optic Disc region it is important to have resize image which has same number of pixels, vertically as well as horizontally.

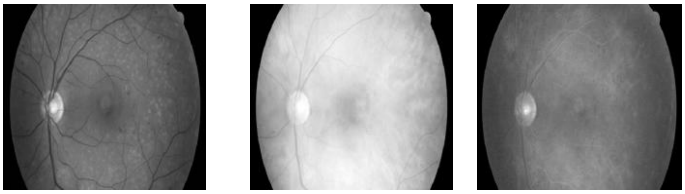


1. Original Image 2. Resize Image

Fig. 4. Difference between original Image and Resize Image.

ii. Green Color Component Separation

Color image has three color components green, red and blue. Out of which, it is observed that green color component gives the best result. From Fig. 5, clearly green component gives best contrast values compared to other two.



1. Green 2. Red 3. Blue

Fig. 5. Three color components - Green, Red and Blue.

iii. Adaptive histogram Equalization

In normal histogram Equalization entire image contrast is equalized and due to which optic disc region high contrast values reflected over entire image. Adaptive histogram on other hand divides the image, and normalized contrast values locally. Therefore optic disc high contrast values don't reflect over entire image. Fig. 6 gives the clear difference between normal and adaptive histogram equalization (AHE). As Green color component gives best results, AHE is applied over Green component.

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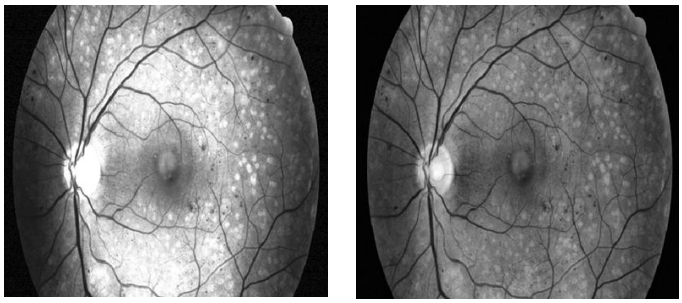
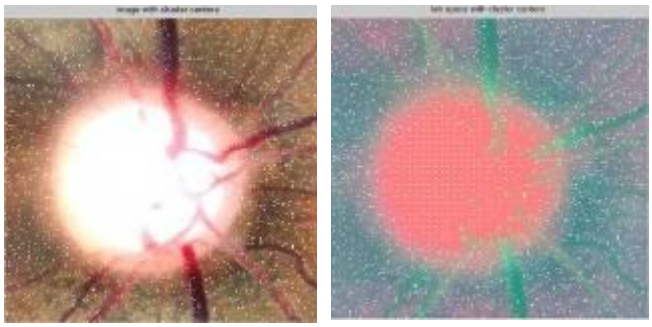


1. Normal HE 2. Adaptive HE

Fig.6. Difference between Normal and Adaptive histogram equalization (AHE). Here AHE is applied over green color component.

b. Simple Linear Iterative clustering (SLIC)

SLIC is easy to use and recognize. The only parameter used in this algorithm is K, which is total number of equal size superpixel. For color images CIELAB color space is used. For clustering, an initialization step is to first locate k initial cluster centers Ci = [li ai bi xi yi]^T and sampled them on a standard grid spaced S pixels apart. Fig. 7 shows the difference between cluster centers with adaptive histogram equalized image and Lab color space image.



1. Cluster centers with AHE 2. Cluster Centers with Lab Color Space

Fig. 7. Figure 1 and 2 shows the cluster centers with adaptive histogram equalized image and Lab color space image.

c. K- Means Clustering and Thresholding

In K-means clustering first step is to select the number of clusters you want to indentify in your data i.e K. second step is to randomly select distinct data points. Nex is to measure the distance between the first point and the other selected initial clusters. Choose and assign to the nearest assigned cluster. Do the same for all the points.

d. Post processing method – Morphological operation

Imfill and Imdilate morphological operations are conducted to remove any irregularities between the images. Fig. 8 give the optic disc segmentation output.

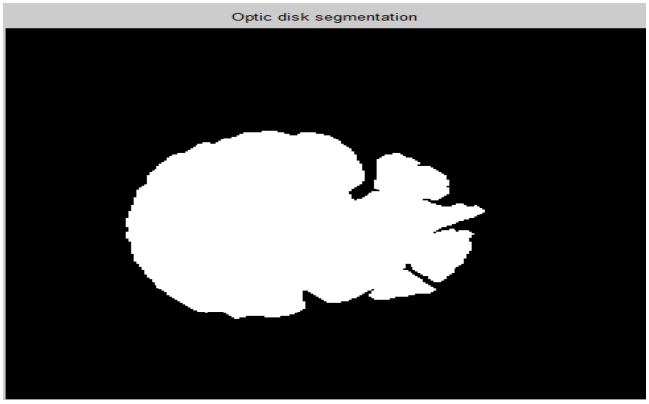


Fig. 8. Optic Disc Region after morphological operation.

c. Vessel Segmentation

There are two types of vessels large and thick vessel and small vessels. Large and thick vessels can create confusion while sorting aneurysm, hard exudates and hemorrhages which is used to detect Non-proliferative Diabetic retinopathy. Also amount of small vessels used to detects proliferative diabetic retinopathy. Therefore classification of large and small blood vessel plays crucial role while gradation of diabetic retinopathy. Preprocessing methods used are Resize Image, Green color component separation, Fundus Mask, Vessel Enhancement Operation, High pass filtered Image. Feature Extraction uses Pixel based classification with parameters F1-Mean, F2-Standard Deviation, F3-Maximum Pixel Intensity, F3-Minimum Pixel Intensity and F5-Relative Neighborhood Discriminator.

Gaussian Mixture Model is use as cluster modeled as Gaussian, not just by their mean. Expectation maximization (EM) algorithm is used in Gaussian mixture model. EM algorithm assigns

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data to cluster with same probability. Fig. 9 shows the result for blood vessel segmentation.

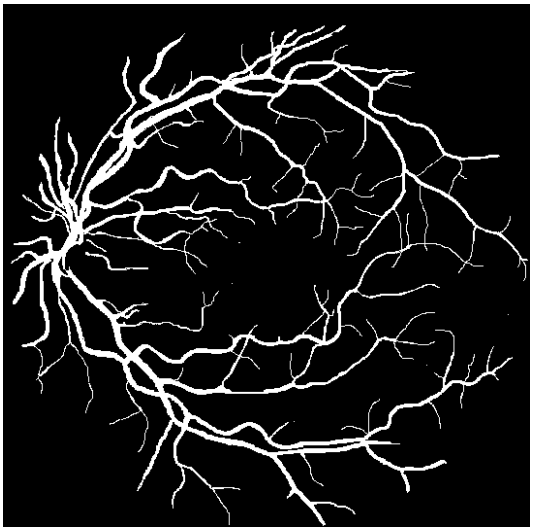

Fig. 9. Vessel Segmentation.

d. Red Lesion Detection and Hard Exudates Evaluation

Red lesion consists of aneurysm and hemorrhages. For red lesion detection and hard exudates evaluation, optic disc region and thick blood vessels are removed from original image. For red lesion detection, pre-processing methods used are Preprocessing Method Spatial Calibration, Illumination Equalization, Denosing, Adaptive contrast Equalization and Color Normalization. For feature extraction, candidate extraction method is used and Random Forest Classifier is used as classification algorithm.

Random forests are prepared through decision trees, but, Decision trees have one characteristic that prevents them from being the best tool for predictive learning. To create random forest tree bootstrap dataset is used. Duplicate entries are allowed in bootstrap dataset. As a result, some entries were not included in bootstrap dataset. This is called the out of bag dataset. Then this out of bag sample runs through all of the other trees that were built without it.

For hard exudates evaluation Gabor filter is used for feature extraction as it gives best result compared to other methods. Also convolution neural network (CNN) is used as classification algorithm. CNN have four layers, convolution, ReLU layer, pulling layer and fully connected layer. In convolutional layer, first step is to move the feature filter to every possible position on the image. After line up the feature and the image, multiply each image pixel by the the corresponding feature pixel. Next step is to add them up and divide by total number of pixel in the feature. Now to keep trap of where that feature was, create a map and put the value of the filter at that place. Similarly move this filter throughout the image and perform the same convolution with every other filters. In ReLU layer every negative values from the filter image is replaced with zeros.

e. Detection of PDR and gradation of DR

For detection of PDR, Feature Extraction technique uses Matched Filter with Gaussian Kernel and Scale Elimination and Classification Algorithm used is Thresholding based on Vessel Density (Vd) and Tortousity (Vt). Vessel Density (Vd) and Tortousity (Vt) indicates the abnormal growth of blood vessels inside the eye which is indication of PDR. Also, Gradation of DR is characterized such as, Normal/Healthy-No lesion, Hard Exudates & Neovascularization present, Mild-0-5 Microaneurysms, Moderate- 5-10 number of Microaneurysms , number of Hemorrhages >0, number of Exudates <=5, Severe- Lesions present are greater than that of moderate NPDR, PDR-Neovascularization Present.

III. Discussion and Conclusion

Proposed method works with fundus image and processes it with optic disc detection, vessel segmentation, red lesion detection, and hard exudates evaluation, detection of Proliferative diabetic retinopathy (PDR) and grading of DR. For optic disc segmentation pre-processing method used is adaptive histogram equalization. For better classification, super pixels are generated using

simple linear iterative clustering (SLIC) algorithm, and then k-means clustering algorithm is used as classifier. Proposed method is tested on database of 750 images and 98 % samples correctly extracted optic disc region. Blood vessel segmentation plays key role for detection of red lesion. Along with pre-processing method and feature extraction method, Gaussian mixture model is used as a classifier. Same database is used and gives accuracy of 93%. For red lesion detection optic disc region and wide and thick blood vessels are subtracted from original image and further given to Random forest classifier (RFC) for classification giving best result with accuracy of 96%, highest compared to other classifier such as support vector machine(SVM) 89%, k- means clustering 83%. Further hard exudates are evaluated using Convolution neural network (CNN) with accuracy of 99%.For detection of PDR, Matched Filter with Gaussian Kernel & Scale Elimination is used for feature extraction and for classification Thresholding is used based on Vessel Density (Vd) and Tortousity (Vt). Gradation of DR is characterized such as, Normal/Healthy-No lesion, Hard Exudates & Neovascularization present, Mild-0-5 Microaneurysms, Moderate- 5-10 number of Microaneurysms , number of Hemorrhages >0, number of Exudates <=5, Severe-Lesions present are greater than that of moderate NPDR, PDR-Neovascularization Present. Further studies involve assessment with age factors, gender and samples from different living conditions. Use of proposed method will automatically detect and gives prior intimation regarding development of DR with gradation.

IV. REFERENCES

[1] Lama Seoud, Thomas Hurtut, Jihed Chelbi, Farida Cheriet and J.M. Pierre Langlois, “Red Lesion Detection using Dynamic Shape Features for Diabetic Retinopathy Screening” IEEE TRANSACTIONS ON MEDICAL IMAGING, 2015

[2] Lei Zhou1, Yu Zhao1, Jie Yang1 , Qi Yu2, Xun Xu2, “Deep multiple instance learning for automatic detection of diabetic retinopathy in retinal images” ISSN 1751-9659 Accepted on 18th November 2017 doi: 10.1049/iet-ipr.2017.0636 www.ietdl.org

[3] Sudeshna Sil Kar1, Santi P. Maity1, “Gradation of diabetic retinopathy on reconstructed image using compressed sensing” ISSN 1751-9659 Accepted on 20th June 2018 doi: 10.1049/iet-ipr.2017.1013 www.ietdl.org

[4] Pedro Costa_, Adrian Galdran, Asim Smailagic, and Aur´elio Campilho, “A Weakly-Supervised Framework for Interpretable Diabetic Retinopathy Detection on Retinal Images” DOI 10.1109/ACCESS.2018.2816003, IEEE Access, JULY 2017.

[5] Romany F. Mansour, “Evolutionary Computing Enriched Computer Aided Diagnosis System for Diabetic Retinopathy: A Survey” DOI 10.1109/RBME.2017.2705064, IEEE Biomedical Engineering

[6] Masoud Aghamohamadian-Sharbaf, Hamid Reza Pourreza, Senior Member and Touka Banaee, “A Novel Curvature Based Algorithm for Automatic Grading of Retinal Blood Vessel Tortuosity” DOI 10.1109/JBHI.2015.2396198, IEEE Journal of Biomedical and Health Informatics

[7] Zhentao Gao1, Jie Li2, Jixiang Guo1,(Member, Ieee), Yuanyuan Chen1,(Member, Ieee), Zhang Yi1,(Fellow, Ieee), Jie Zhong2 .’ “Diagnosis of Diabetic Retinopathy Using Deep Neural Networks” DOI 10.1109/ACCESS.2018.2888639, IEEE Access

[8] Sehrish Qummar1, Fiaz Gul Khan 1, Sajid Shah 1, Ahmad Khan1, Shahaboddin Shamshirband 2,3, Zia Ur Rehman1, Iftikhar Ahmed Khan 1, AND WAQAS JADOON 1 “A Deep Learning Ensemble Approach for Diabetic Retinopathy Detection” Digital Object Identifier 10.1109/ACCESS.2019.2947484

[9] Xianglong Zeng1, Haiquan Chen1, Yuan Luo2 And Wenbin Ye 2, (Member, Ieee), “Automated Diabetic Retinopathy Detection Based on Binocular Siamese-like Convolutional Neural Network” DOI 10.1109/ACCESS.2019.2903171, IEEE Access.

[10] Yunlei Sun’ “The Neural Network of One-Dimensional Convolution-An Example of the Diagnosis of Diabetic Retinopathy” Digital Object Identifier10.1109/ACCESS.2019.2916922