Diagnosis of Diabetic Retinopathy using Deep Learning

Poonam Shelke
Department of Computer Engineering
PICT, Pune.

Abstract—**Retina is light-sensing tissue that resides in the back of the human eye. Retina is the one which relays the image to brain. Visual impairment and blindness is caused due to many retinal diseases such as Glocoma, Macular Degeneration(MD) and Diabetic Retinopathy(DR). The patients having DR is more than patients having other retinal diseases. Expert ophthalmologists are required to detect DR. Even these experts need to spend lot of time to screen the images and diagnose the disease. Thus automated system can help ophthalmologists not only save screening time but also to diagnose the disease with more accuracy. Proposed work is aimed at automating DR detection using deep learning algorithms. Convolution Neural Network(CNN) is used for this purpose. To detect DR, it may not be effective with few number of features and as CNN can create more number of features leading to accurate prediction. In this proposed work, Different CNN architectures are used to detect diabetic retinopathy. Proposed work is to prepare input images for CNN using image preprocessing techniques such as image contrast enhancement, Median filter. Total 516 images are used for training and testing. CNN with 16 layer architecture is used for classification.The performance of system gives 60% of accuracy on IDRiD dataset.**

Index Terms—**CNN, Deep Learning, Diabetic Retinopathy, Image Processing, Retinal Disease.**

I. Introduction

Vital organ failure can be caused by diabetes as it is a chronic disease and the number of diabetic patients is increasing alarmingly. The historical data shows the predominant effect of eye diseases in diabetic patient. In Diabetes, body is unable to produce insulin which eventually increases the glucose level in the blood. This may result in eyesight problem such as blur image vision. The vision may even get completely lost, if the glucose level in retinal blood vessels become too high. This process of damage within retina is called Diabetic Retinopathy(DR)[1].

According to a study which was conducted by the world health organization, it shows that the number of diabetic patients will increase from 130 million to 350 million over the next 20 years[13]. In developed countries, one of the major cause of blindness is DR. As diabetic patients are increasing, possibly results in more number of DR patients. Skilled ophthalmologists required more amount of time to diagnose a single fundus image. Thus automatic DR detection system can be used to replace this manual screening process of diagnosis.

A. Retinal Diseases

The common retinal diseases which may lead to complete blindness are discussed in following sections:

Macular Degeneration(MD) is an age-related condition of the retina that causes central vision loss. It is very common in individuals over the age of 55, with approximately 10 million people in the United States suffering from the condition. The symptoms tend to involve blurry central vision, warped straight lines, or difficulty focusing on fine details. Blind spots can develop as the condition worsens. Fortunately, there are treatments, such as an antioxidant supplement that can slow the progression, blocking unhealthy blood vessel development.

Glaucoma is a group of related eye disorders that cause damage to the optic nerve that carries information from the eye to the brain. In its early stages, glaucoma usually has no symptoms, which is what makes it so dangerous by the time you notice problems with your sight, the disease has progressed to the point that irreversible vision loss has already occurred and additional loss may be difficult to stop.

Chronically high blood sugar from diabetes is associated with damage to the tiny blood vessels in the retina, leading to Diabetic Retinopathy(DR). The retina detects light and converts it to signals sent through the optic nerve to the brain. Diabetic retinopathy can cause blood vessels in the retina to leak fluid or hemorrhage (bleed), distorting vision. In its most advanced stage, new abnormal blood vessels proliferate (increase in number) on the surface of the retina, which can lead to scarring and cell loss in the retina.

B. More about DR

Diabetic retinopathy may progress through four stages namely, Mild, Moderate, Severe and PDR.

- Mild nonproliferative retinopathy is a beginning stage of diabetic retinopathy in which Small areas of balloon-like swelling in the retinas tiny blood vessels, called microaneurysms, occurs at earliest stage of the disease. These microaneurysms may leak fluid into the retina.
- Moderate nonproliferative retinopathy is the second class of diabetic retinopathy in which as the disease progresses, blood vessels that nourish the retina may swell and distort. They may also lose their ability to transport blood. Both conditions cause characteristic changes to the appearance of the retina and may contribute to DME.

- Severe nonproliferative retinopathy is the third class of diabetic retinopathy in which many more blood vessels are blocked, depriving blood supply to areas of the retina. These areas secrete growth factors that signal the retina to grow new blood vessels.
- Proliferative diabetic retinopathy (PDR) is the last stage of diabetic retinopathy. At this advanced stage, growth factors secreted by the retina trigger the proliferation of new blood vessels, which grow along the inside surface of the retina and into the vitreous gel, the fluid that fills the eye. The new blood vessels are fragile, which makes them more likely to leak and bleed. Accompanying scar tissue can contract and cause retinal detachmentthe pulling away of the retina from underlying tissue, like wallpaper peeling away from a wall. Retinal detachment can lead to permanent vision loss.

C. Current Status on DR

Patients for diabetic retinopathy are increasing at a high rate [13], no automatic DR diagnosis system is currently used by an ophthalmologist. The current overall accuracy for binary classification is 73% on IDRiD[1][11]. There is need to improve functionality of the system that system should give the diagnosis of image with five categories. DR is a type of disease which is growing with diabetic and Because of such type of diagnosis, patient may get into sever condition if they don't know about their disease at an early stage. For this purpose deep learning algorithm, CNN architecture, CNN with 16 layers is used.

II. Related Work

Many researchers have done some work in this domain. Survey of their work is explained below:

Alireza osareh at el. [4] proposed a system which can detect hard exudates automatically using fuzzy c-means clustering algorithm. Retinal images are classified into exudates and non-exudates based on features such as size, edge strength, and texture. Features are selected using the genetic algorithm. CNN algorithm is used to classify the image into defined classes with 96% sensitivity.

Purabi Sharma at al. [5]proposed a two steps process to detect exudates in a retinal image. In the first step, the optic dist was removed. In the second step, bright lesions were detected using image processing techniques. Depending on the presence of lesions, images are classified into normal and abnormal categories. The system is tested on DRIVE, STARE, DIARETDB1 datasets. The system performed with 98

Roychowdhury S at al. [14] started detection of DR using machine learning algorithms. Gaussian mixture model and kNN classifier are found to be the best classifier for bright and red lesion detection. The number of features is reduced which is used for lesion classification using the AdaBoost algorithm. The top 30 features are selected among 78. The two-step model has proposed wherein the first step, the fault positives are rejected and in the second step, lesions are classified.

Proposed system tested on a publicly available dataset which is Messidor. The system's performance is 80% of sensitivity and 53.6 % of specificity. The proposed system is able to classify the image in two categories that is DR or No DR.

DR has many more severity vise categories such as mild, moderate, severe, PDR. The multi-class classification is needed. The deep learning algorithm, CNN is used to detect DR with all the possible categories. The proposed system was tested on retinal fundus image dataset with 38% of accuracy[6]. The performance of the system is low, so there is a need to enhance it.

To improve the accuracy of the existing system, the deep CNN architecture was used. The features were reduced using principal component analysis. The system performance for multiclass classification is 88% of accuracy [7] which is quite impressive but the dataset was not used standard and also there is need to enhance accuracy

A deep multiple instance learning [10] model was proposed to detect the lesion very clearly and to increase the accuracy of classification accuracy, which jointly learns features and classifiers from data and achieves a significant improvement on detecting DR images and their inside lesions. Specifically, a pre-trained convolutional neural network is adapted to achieve the patch-level DR estimation, and then global aggregation is used to make the classification of DR images. For this experiment, the DIARETDB1 dataset was used. The system performance was 86% of precision and 92.4% of f1score for the binary classification.

Arkadiusz Kwasigroch at al. [8] they proposed a deep learning approach detect DR. The CNN algorithm was used to classify images into defined categories. The system was trained over 88000 retinal images. To enhance the performance of the system, they proposed a special class coding technique that enabled to include the information about the value of the difference between predicted score and target score into the objective the function being minimized during the training of the neural networks. The best-tested model achieved an accuracy of about 82% in detecting diabetic retinopathy.

The deep CNN model was proposed to detect DR[1]. In this work, the standard dataset namely, Indian Diabetic Retinopathy image Dataset(IDRiD)[11] is used. First the images were preprocessed using filtering technique and then resized. For classification, the model makes use of a 28 layer CNN model with relu activation function at each convolution layer. The system performance is 73.3% of accuracy.

III. Problem Definition

To design and develop an automatic system which will give a diagnosis of Diabetic Retinopathy in less time compared to a manual screening of retinal image.

IV. System Architecture

A. Dataset Collection

Indian Diabetic Retinopathy Image Dataset (IDRiD): This dataset is used for for Diabetic Retinopathy classification. Total set of 516 images are mentioned [11].

1) *Sample Dataset:* Normal image with no DR shown in 1

Fig. 1. No DR

2) *Images with DR based on severity level:* Images are categories into four-part shown in figure 2.

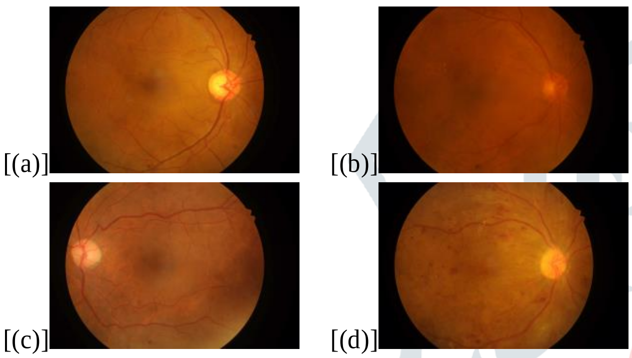

Fig. 2. (a) Mild DR, (b) Moderate DR, (c) Sever DR, (d)PDR

B. System Overview

Architecture design of the system is shown in figure 3. In this, to implement predictive model we are using python language for developing the system. Model building used python packages of machine learning algorithm.

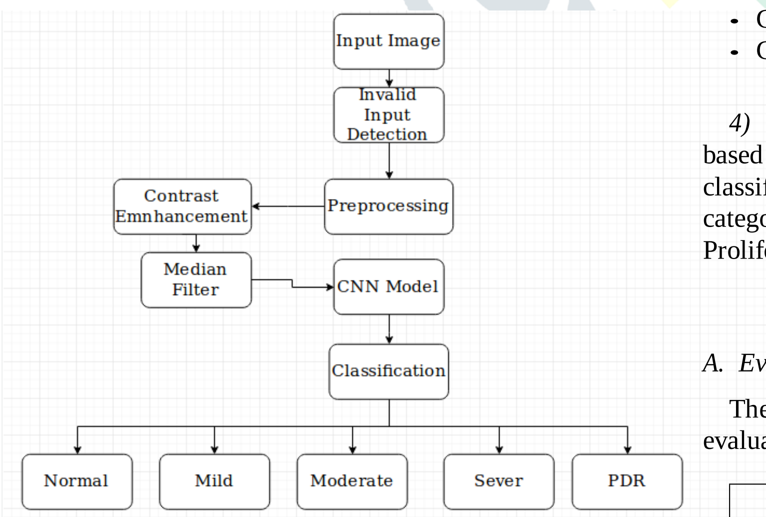

Fig. 3. System Architecture

1) Retinal fundus image is an input given to the proposed system. Retinal image is preprocessed using image contrast enhancement and median filter. Preprocessed images are given to the CNN architecture to classify the image into five different classes i.e normal, mild, moderate, severe, Porofirative Diabetic Retinopathy(PDR).
2) Architecture consists of various modules based on the functionality related to the system. Invalid input detection, Pre-processing and classification of retinal image are the main components of this system architecture.
3) Pre-processing creates data in suitable format for the further process. And other concentrate on classifying data accurately. The modules are developed using anaconda an open source packages.

This section describes implementation details of modules in the system.First module is of input, were fundus retinal images are given as input. The following steps are followed as the input is given:

1) Invalid Input Detection:: This model accepts the input image and checks whether the image is a retinal image or not. If an image is a retinal image then give it to the next module otherwise reject and raise an error as Invalid input.

2) Image Pre-processing: In this module, the retinal image is accepted as an input. The preprocessed image will make system data independent. Initially, Contrast enhancement is applied to the original image to improve contrast in color image. Then median filter is used for noise removal.

3) Classification Model- CNN model: Convolution Neural Network(CNN) is made up with neurons. CNN is work with different multiple layers such as convolution layer, pooling layer, and an output layer. As CNN is capable of automatic feature extraction, the more number of features can be extracted which will lead to accurate prediction [8]. For this work, CNN architecture is used which is especially for image classification. The following CNN architectures are used to detect DR category:

- CNN with 8 Convolution Layers
- CNN with 16 Convolution Layers

4) Classification: Classification of a retinal image is done based on the output layer of CNN. In which images is classified into five categories based on DR severity. Five categories are No DR, Mild DR, Moderate DR, Sever DR, Proliferative Diabetic Retinopathy(PDR).

V. Result and Discussion

A. Evaluation Method Used

The accuracy is one of the evaluation method used to evaluate the system performance.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

where:

- TP = True positive: These are cases in which system predicted yes (they have the disease), and patient do have the disease.
- FP = False positive: System predicted yes, but patient don't actually have the disease.
- TN = True negative: System predicted no, and patient don't have the disease.
- FN = False negative:System predicted no, but patient actually do have the disease.

B. Results

1) Template Matching Result: The template shown in **??** is used to detect the image is retinal or not. The python template matching library is used for this detection. The result of the system is shown in figure 4and the matched area is shown using rectangle drawn on the input image shown in figure 5.

```
(array([327, 327, 327, ..., 769, 769, 769]), array([2065, 2066, 2067, ..., 2074, 2075, 2076]))
Retinal Image
```

Fig. 4. System result for template matching

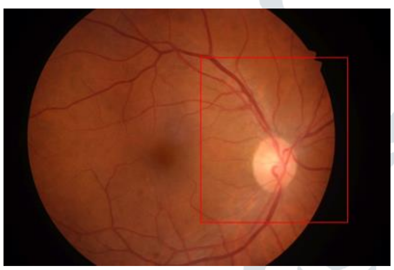

Fig. 5. Matched part

2) Image Preprocessing: This experiment is done with python 2.7 and available image processing python libraries such as PIL and numpy. Image preprocessing is done with two steps, firstly contrast is improved by contrast enhancement technique. In second step median filter is applied to remove noise. After that image is resized to (150,150). The image after preprocessing is shown in 7.

Fig. 6. Input Image

3) Classification Model- CNN model: Convolution Neural Network(CNN) is made up with neurons. CNN is work with different multiple layers such as convolution layer,

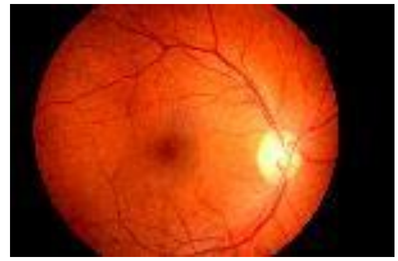

Fig. 7. Preprocessed Image

pooling layer, and an output layer. As CNN is capable of automatic feature extraction, the more number of features can be extracted which will lead to accurate prediction [8]. For this work, CNN architecture with 16 layers is used which is especially for image classification. In this CNN architecture, 16 convolution layers are used to create features with (3,3) kernel size. Low-level to high-level features extracted from test image are shown in 8, 9, 10, 11, 12.

Fig. 8. Level 1: Visualization of the Feature Maps Extracted From test Image

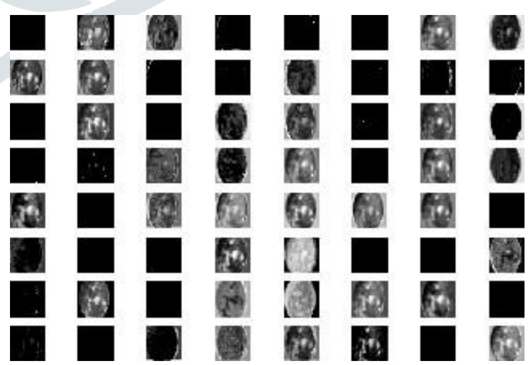

Fig. 9. Level 2: Visualization of the Feature Maps Extracted From Test Image

The detailed summary of the algorithm is shown in 13.

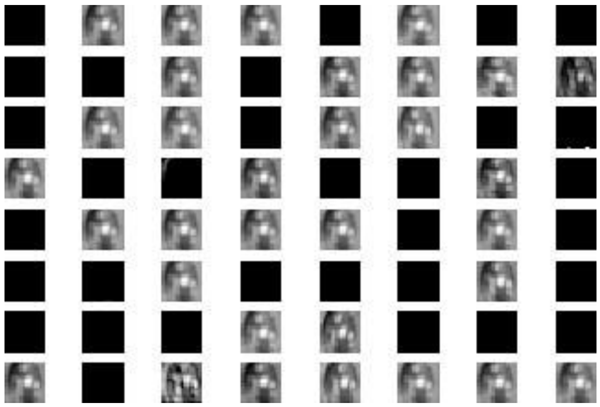

Fig. 10. level 3:Visualization of the Feature Maps Extracted From Test Image

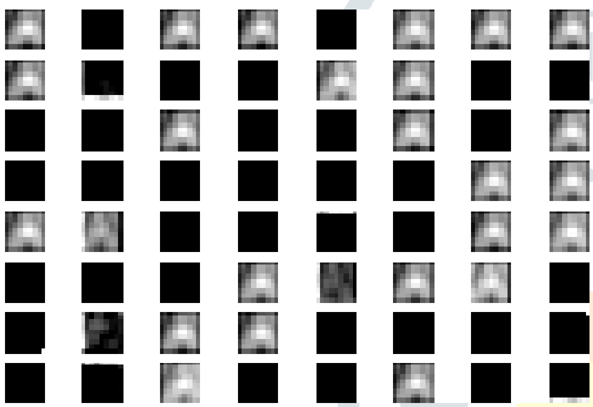

Fig. 11. Level 4: Visualization of the Feature Maps Extracted From Test Image

Fig. 12. Level 5: Visualization of the Feature Maps Extracted From Test Image

Layer (type)	Output Shape	Param #
conv2d_46 (Conv2D)	(None, 150, 150, 64)	1792
conv2d_47 (Conv2D)	(None, 150, 150, 64)	36928
max_pooling2d_18 (MaxPooling	(None, 75, 75, 64)	0
conv2d_48 (Conv2D)	(None, 75, 75, 128)	73856
conv2d_49 (Conv2D)	(None, 75, 75, 128)	147584
max_pooling2d_19 (MaxPooling	(None, 37, 37, 128)	0
conv2d_50 (Conv2D)	(None, 37, 37, 256)	295168
conv2d_51 (Conv2D)	(None, 37, 37, 256)	590080
conv2d_52 (Conv2D)	(None, 37, 37, 256)	590080
max_pooling2d_20 (MaxPooling	(None, 18, 18, 256)	0
conv2d_53 (Conv2D)	(None, 18, 18, 512)	1180160
conv2d_54 (Conv2D)	(None, 18, 18, 512)	2359808
conv2d_55 (Conv2D)	(None, 18, 18, 512)	2359808
max_pooling2d_21 (MaxPooling	(None, 9, 9, 512)	0
conv2d_56 (Conv2D)	(None, 9, 9, 512)	2359808
conv2d_57 (Conv2D)	(None, 9, 9, 512)	2359808
conv2d_58 (Conv2D)	(None, 9, 9, 512)	2359808
conv2d_58 (Conv2D)	(None, 9, 9, 512)	2359808
max_pooling2d_22 (MaxPooling	(None, 4, 4, 512)	0
conv2d_59 (Conv2D)	(None, 4, 4, 512)	2359808
conv2d_60 (Conv2D)	(None, 4, 4, 512)	2359808
conv2d_61 (Conv2D)	(None, 4, 4, 512)	2359808
max_pooling2d_23 (MaxPooling	(None, 2, 2, 512)	0
flatten_4 (Flatten)	(None, 2048)	0
dense_7 (Dense)	(None, 64)	131136
dense_8 (Dense)	(None, 5)	325

Total params: 21,925,573
Trainable params: 21,925,573
Non-trainable params: 0

Fig. 13. CNN architecture with 16 convolution layer

4) *System Output:* The output of the system is a category of DR among others for test image. An array of probabilities for five class is displayed and one with the maximum probability is selected as DR class.

The following table I shows the performance of different CNN algorithms used to classify DR.

Sr.no	CNN Architeture	Dataset	Acurracy
1	CNN With 1 convolution layer	IDRiD	50%
2	CNN With 3 convolution layer	IDRiD	50%
3	CNN With 8 convolution layer	IDRiD	55%
4	CNN With 16 convolution layer	IDRiD	60%

TABLE I
RESULT TABLE

The proposed work makes use of a total of 516 retinal images for training and testing. Out of the total, 413 used for training and 103 used for testing. The system firstly detects the invalid input that is test image is a retinal or not. For that, a template matching python library is used to match the specified template with the part of the test image shown in 4. After that, preprocessing steps are performed on a test image. Preprocessed image is more bright and noise-free compared with the input test image shown in 7. Then the preprocessed image is given to the CNN model and calculates the probability of test image for five categories. And according to probability, the category of DR is selected. The result is shown in **??**. The level-wise features used to detect DR categories are shown in 8, 9, 10, 11, 12. To evaluate the system, the accuracy measure is used. The proposed model gives 60 % of accuracy over the multiclass classification of DR. Comparative analysis with other CNN models on the IDRiD is shown in I. Table I consist of three attributes namely CNN architecture, Dataset and Accuracy. The batch size and epoch size are parameters, based on the accuracy of CNN is calculated. According to the experiment, when the epoch size is 400 and batch size is 2 the accuracy of the CNN1 is 50% , CNN2 is 50% and CNN3 is 55% and CNN4 is 60% . The maximum number of convolution layers can create a number of features which is leading to high accuracy. CNN with 16 layers that is CNN4 is more accurate compared to other.

VI. CONCLUSION AND FUTURE WORK

The presented work is developed as an automated system to detect the category of diabetic retinopathy among diabetic patients and is aimed at helping ophthalmologists to detect early symptoms of diabetic retinopathy. The system is developed using different CNN architectures that are, CNN with 1 layer, CNN with 3 layers, CNN with 8 layers and CNN with 16 layers. CNN with 16 layers giving more accuracy compared with other CNN architecture. The overall accuracy of the system is 60% for multiclass classification. In Future, we can use other CNN architectures to improve existing results.

REFERENCES

[1] Shorav Suriyal, Christopher Druzgalski, Kumar Gautam, ”Mobile assisted diabetic retinopathy detection using deep neural network”, 2018 Global Medical Engineering Physics Exchanges/Pan American Health Care Exchanges (GMEPE/PAHCE), pp.19-24, 2018.

[2] Harini R, Sheela N, ”Feature Extraction and Classification of Retinal Images for Automated Detection of Diabetic Retinopathy”, Second International Conference on Cognitive Computing and Information Processing (CCIP), pp. 1-4, 2016.

[3] mer DEPERLOLU, Utku KSE, ”Diagnosis of Diabetic Retinopathy by Using Image Processing and Convolutional Neural Network”, 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), pp. 1-5, 2018.

[4] Alireza Osareh, Bita Shadgar, and Richard Markham, ”A Computational-Intelligence-Based Approach for Detection of Exudates in Diabetic Retinopathy Images”, IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE, VOL. 13, NO. 4, 2009.

[5] Purabi Sharma, S. R. Nirmala, Kandarpa Kumar Sarma, ”Classification of Retinal Images Using Image Processing Techniques”, Journal of Medical Imaging and Health Informatics, pp.341-346, 2013.

[6] Darshit Doshi, Aniket SheQoy, Deep Sidhpura, Dr. Prachi Gharpure, ”Diabetic Retinopathy Detection using Deep Convolutional Neural Networks”, pp.261-266, 2016.

[7] Yashal Shakti Kanungo, Bhargav Srinivasan, Dr. Savita Choudhary, ”Detecting Diabetic Retinopathy using Deep Learning”, 2017 2 nd IEEE International Conference On Recent Trends in Electronics Information Communication Technology (RTEICT), May 19-20, 2017, India, pp.801-804 , 2018.

[8] Arkadiusz Kwasigroch , Bartlomiej Jarzembinski , Micha Grochowski, ”Deep CNN based decision support system for detection and assessing the stage of diabetic retinopathy”, 2018 International Interdisciplinary PhD Workshop (IIPhDW), pp. 111-116, 2018.

[9] juan shan, Lin Li, ”A Deep Learning Methods for Micro aneurysms Detection in Fundus Image” , IEEE First International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE), pp.357-358 ,2016. Year: 2016

[10] Lei Zhou ,Yu Zhao, Jie Yang, Qi Yu, Xun Xu , ”Deep multiple instance learning for automatic detection of diabetic retinopathy in retinal images”, IET Image Processing, Vol. 12 Iss. 4, pp. 563-571, 2018.

[11] Prasanna Porwal, Samiksha Pachade, Ravi Kamble, Manesh Kokare Girish Deshmukh, Vivek Sahasrabuddhe, Fabrice Meriaudeau, ”Indian Diabetic Retinopathy Image Dataset (IDRiD): A Database for Diabetic Retinopathy Screening Research”, 2018.

[12] Avula Benzamin, Chandan Chakraborty, ”Detection of Hard Exudates in Retinal Fundus Images Using Deep Learning”, 2018 IEEE Interna- tional Conference on System, Computation, Automation and Networking (ICSCA), pp.1-5, 2018.

[13] https://www.who.int/diabetes/en/

[14] Sohini Roychowdhury, Dara D. Koozekanani, Keshab K. Parhi, ”DREAM: Diabetic Retinopathy Analysis Using Machine Learning”, IEEE JOURNAL OF BIOMEDICAL AND HEALTH INFORMATICS, pp.1717-1728, VOL. 18, NO. 5, 2014.