



## DETECTION OF DIABETIC RETINOPATHY

<sup>1</sup>Dr.Vijayalaxmi Mekali, <sup>2</sup>Nithya S N, <sup>2</sup>Nethra R, <sup>2</sup>Priya E, <sup>2</sup>Shanvi B P

<sup>1</sup>Associate Professor, Dept of Computer Science and Engineering, K S Institute of Technology, <sup>2</sup>Student of K S Institute of Technology, Bengaluru, Karnataka, India

**Abstract:** Diabetic Retinopathy is a complication of diabetes that targets the eyes by damaging the retinal blood vessels. Initially, it is asymptomatic or causes fluctuating vision problems. As it becomes severe, it affects both eyes and eventually causes partial or complete vision loss. Primarily occurs when the blood sugar level is unmanageable. Therefore, a person with diabetes mellitus is always at a high risk of acquiring this disease. Early detection can deter the contingency of complete and permanent blindness. Thus, requires an efficient screening system. The present work considers a deep learning methodology specifically a residual network (ResNet-50), a deep Convolutional Neural Network, which is applied for the early detection of diabetic retinopathy. It classifies the fundus images based on their severity levels as No DR, Mild, Moderate, Severe and Proliferative DR. The datasets that are taken into consideration are Diabetic Retinopathy detection 2015 and Aptos 2019 blindness detection which are both obtained from Kaggle. The proposed method is accomplished through various steps: Data collection, Pre-processing, Augmentation, and Modelling. The main aim of this work is to develop a robust system for detecting DR automatically.

**IndexTerms - Diabetic Retinopathy (DR), Convolutional Neural Network(CNN), Deep Learning, ResNet-50, Fundus images, Classification, Pre-processing.**

### I. INTRODUCTION

According to International Diabetics Federation (IDF) Diabetics Atlas 2021, around 463 million people are affected by diabetes. The statistics show an increase of 38 million cases in the past 3 years. As of 2019, it was reported 425 million. The IDF expects the number to rise to 595 million by 2035 when one in every 10 people will have the disease. Approximately 80% of the people living with diabetes are in low- and middle-income countries.

Diabetes is one of the most common diseases and its prevalence has increased worldwide. It is primarily associated with the production of insulin and high blood sugar in the body resulting in anomalous metabolic functions and complications like cardiovascular diseases, kidney failures, neural disorders, diabetic retinopathy, etc. Diabetic Retinopathy is a crucial eye condition that results in 1 loss of vision that cannot be reversed or corrected once experienced. No matter whether a person is type 1 or type 2 diabetic, the probability of the disease increases with age. According to WHO, DR is an intense eye disease that requires urgent contemplation at an international level.

The diagnosis of DR mostly depends on the observation and evaluation of fundus photographs which can be time-consuming even for experienced experts. Therefore, computer aided diagnosis approaches, which can accurately detect DR in a short time, have great potential in clinical analysis to improve the screening rate of DR and reduce the number of DR cases.

Diabetic retinopathy progresses through four clinical stages mild non-proliferative, moderate non-proliferative, and severe non-proliferative, as shown in Figure 1.

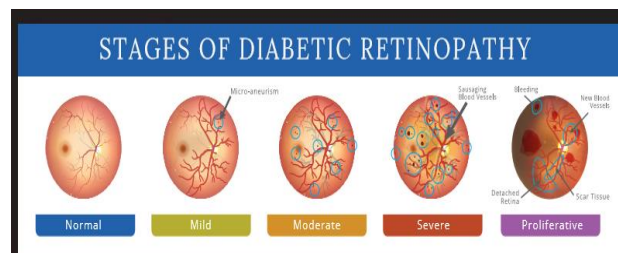


fig.1 stages of diabetic retinopathy

Most research in the area of DR was carried out on the basis of feature extraction using machine learning approaches, but the problem rose with the manual feature extraction which prompted researchers towards deep learning. Further research in medical fields paved the path for many computer-aided technologies like data mining, image processing, machine learning, and deep learning. However, Deep Learning has gained popularity in recent years in various fields like sentiment analysis, handwritten recognition, stock market prediction, medical image analysis, etc. CNN in deep learning tends to provide constructive results when it comes to the job of image classification. CNN variant, Residual Network (ResNet) is a deep learning model used for computer vision

applications, designed to support hundreds or thousands of convolutional layers, for the classification of fundus (eye) images based on the severity level.

## II. RELATED WORK

Diagnosis of pathological findings in fundoscopy, a medical technique to visualize the retina, depends on a complex range of features and localizations within the image. The diagnosis is particularly difficult for patients with early stage diabetic retinopathy as this relies on discerning the presence of microaneurysms, small saccular outpouching of capillaries, retinal hemorrhages, ruptured blood vessels— among other features—on the fundoscopic images.

Many studies have been conducted and still continue in this field with an aim to ease the lives of both doctors as well as patients. This section provides a review of many research works in the area of Diabetic retinopathy.

Sudha V et al.,[1] have proposed a system for Diabetic Retinopathy detection based on the presence of the feature that shows the symptoms of the disease. The system makes use of fundus images, the bright lesions on the retina, and the exudates extracted as they indicate the symptoms of the disease. Based on the features extracted various stages of the disease are detected using hierarchical classification. They have emphasized the need for a detection system due to the increased number of cases and fewer ophthalmologists to treat, and the system has resulted in high accuracy in sensitivity and specificity.

Imran Qureshi et al., [2] have a review of CAD systems in diagnosing Diabetic Retinopathy. They have also discussed all the CAD systems which have been developed for various needs such as computation Intelligence and Image processing techniques. They also conducted a survey on screening algorithms various research papers in detection and their challenges and results. Demonstration the challenges and automated DR methodologies along with possible solutions were demonstrated.

J.calleja et al., [3] in their work used a two-staged method for Diabetic retinopathy detection: LBP (Local Binary Patterns ) for feature extraction and Machine Learning specifically Support Vector Machine(SVM) and Random Forest for classification purposes. The results obtained by the random forest outperformed the SVM with an accuracy of 97.46%. However, the dataset used in this study was quite small with 71 images.

Mohan Hajabdollahi et at., [4] the Hierarchical pruning for simplification of CNN was proposed to classify DR. As a result, 97.3 % validation accuracy was achieved and the proposed hierarchical pruning can be employed to simplify other CNN structures as well.

Jiaxi Gao et al.,[5] , in their work proposed a deep-learning approach for DR disease classification. After some pre-processing, computationally efficient CNN models were used to classify the disease in image dataset with 83% validation accuracy.

I.Sadek et al.,[6] in their work automatically detected diabetic retinopathy using deep learning approach. They used the four convolutional neural networks to classify the diabetic retinopathy into three classes as Normal, Exudates, Drusen. This method outperforms the Bag of words approach and achieved an accuracy of 91%-92%.

Tiken Mirangthem Singh et al.,[7] in their work they used CNN to classify fundus retinal images and accurately categorize them into five stages of the disease. As a result of their experiment, 71% validation accuracy was achieved

M.Voets et al.,[8] in their study used a Kaggle dataset EyePACS for the detection of diabetic retinopathy from retinal fundus images. However, this study is the re-implementation of already existing work but on different data sets which provided 95% of AUC. The difference in AUC between the original and the re-implemented method tends to be very large.

Carson Lam, Darvin Yi, et al.,[9] In this paper, we demonstrate the use of convolutional neural networks (CNNs) on color fundus images for the recognition task of diabetic retinopathy staging. Our network models achieved test metric performance comparable to baseline literature results, with a validation sensitivity of 95%.

R. Raja Kumar, R. Pandian, et al.,[10] The proposed method has three convolutional layers and a fully connected layer. This method gives higher accuracy (94.44%) with reduced hardware requirement than conventional approaches to detect and classify DR into five stages, namely no DR, mild, moderate, severe, and proliferative DR.

Mounia Mikram, Chouaib Moujahdi, et al.,[11] These studied models perform two main tasks: deep feature extraction and then the classification of diabetic retinopathy according to its severity. The models were trained and validated on a publicly available dataset of 80,000 images and they achieved an accuracy of 80.7%.

Chandra Satapathya, Steven Lawrence, et al.,[12] In this paper, we propose a transfer learning-based CNN architecture on color fundus photography that performs relatively well on a much smaller dataset of skewed classes of 3050 training images and 419 validation images in recognizing classes of Diabetic Retinopathy from hard exudates, blood vessels, and texture. This model is extremely robust and lightweight, garnering the potential to work considerably well in small real-time applications with limited computing power to speed up the screening process. The dataset was trained on Google Colab. We trained our model on 4 classes - i) No DR ii)Mild DR iii)Moderate DR iv)Proliferative DR, and achieved a Cohens Kappa score of 0.8836 on the validation set along with 0.9809 on the training set.

Anitha T. Nair; Anitha M. L et al.,[13] This paper compares and analyses various deep neural networks to grade the disease based on the severity levels like mild, moderate, severe, and proliferative. Pre-trained architectures such as VGG16, EfficientNetB5, and ResNet50 provide 76.47%, 90.2%, and 97.2% accuracies on the kaggle (APTOS) data set.

Sabiha Gungor Kobat,Nursena Baygin et al.,[14] In this study, a new method based on horizontal and vertical patch division was proposed for the automated classification of DR images on fundal photographs.

Two datasets are used to test the model: a newly collected three-class dataset comprising 2355 DR images and the established open-access five-class Asia Pacific Tele-Ophthalmology Society (APTOS) 2019 dataset comprising 3662 images. Five classes (normal, mild DR, moderate DR, severe DR, and proliferative DR), respectively, were derived from the APTOS 2019 dataset. By applying transfer learning, the last fully connected and global average pooling layers of the DenseNet201 architecture were used to extract deep features from input DR images and each of the eight subdivided horizontal and vertical patches. The model attained 87.43% and 84.90% five-class classification accuracy rates using 80:20 hold-out validation.

Kangrok Oh, Hae Min Kang et al.,[15] The proposed DR detection system requires an automatic segmentation of the ETDRS 7SF to remove undesirable components such as eyelashes and skin. Using the segmented ROI image, they have employed the deep learning architecture, the residual network with 34-layer (ResNet-34) model21 as a classifier for the DR detection task. The 90% and 10% of images in the training set are utilized for training and validation tasks. From ten runs of ten-fold stratified cross-validation tests with a single run of ten-fold validation, DR detection system based on the ETDRS 7SF images extracted from the UWF photography achieved a sensitivity of  $83.38\pm 0.48\%$ , a specificity of  $83.41\pm 0.42\%$ , an accuracy of  $83.38\pm 0.47\%$ , and an AUC of  $91.50\pm 0.48\%$ .

Muhammad Shoaib Farooq, Ansif Arooj et al.,[16] This study aims to systematically find and analyze high-quality research work for the diagnosis of DR using deep learning approaches. This research comprehends the DR grading, and staging protocols and also presents the DR taxonomy. It identifies, compares, and investigates the deep learning-based algorithms, techniques, and, methods for classifying DR stages. This study shows that in the last few years there has been an increasing inclination towards deep learning approaches. 35% of the studies have used Convolutional Neural Networks (CNNs), 26% implemented the Ensemble CNN (ECNN) and, 13% of Deep Neural Networks (DNN) are among the most used algorithms for DR classification.

Zehao Yu, Xi Yang, Gianna L. Sweeting et al.,[17] This study demonstrated the efficiency of transformer-based NLP models for clinical concept extraction and relation extraction. Natural Language Processing (NLP) models, including BERT and RoBERTa, compared with a recurrent neural network. The BERT model pretrained with the MIMIC III dataset achieved the best performance (0.9503 and 0.9645 for strict/lenient evaluation). This study demonstrated the efficiency of transformer-based NLP models for clinical concept extraction and relation extraction. The results show that it's necessary to pretrain transformer models using clinical text to optimize the performance for clinical concept extraction.

Muhammad Kashif Yaqoob,Syed Farooq Ali et al .,[18] In this paper, a deep learning-based approach is proposed ResNet-50 and passes it to Random Forest for the classification and grading of diabetic retinopathy. The proposed approach was compared with six state-of-the-art approaches and yielded better results. The proposed approach achieved an accuracy of 96% on the Messidor-2 dataset (two categories) including 'Referable DME' and 'No Referable DME'. It obtained 75.09% accuracy on the EyePACS dataset with five classes, namely: 'Proliferative diabetic retinopathy', 'Severe', 'Moderate', 'Mild', and 'No diabetic retinopathy'.

AT Nair ,ML Anitha et al.,[19] This paper compares and analyses various deep neural networks to grade the disease based on the severity levels like mild, moderate, severe, and proliferative. Pre-trained architectures such as VGG16, EfficientNetB5, and ResNet50 provide 76.47%, 90.2%, and 97.2% accuracies on the kaggle (APTOS) data set.

Al-Omais Asia,Sara A.Althubiti et al.,[20] This work utilizes a deep learning application, a convolutional neural network (CNN), in fundus photography to distinguish the stages of DR. The images dataset in this study is obtained from Xiangya No. 2 Hospital Ophthalmology (XHO), Changsha, China, which is very large, little and the labels are unbalanced.

They first solve the problem of the existing dataset by proposing a method that uses preprocessing, regularization, and augmentation steps to increase and prepare the image dataset of XHO for training and improve performance. Then, it takes the advantage of the power of CNN with different residual neural network (ResNet) structures, namely, ResNet-101, ResNet-50, and VggNet-16, to detect DR on XHO datasets. ResNet-101 achieved the maximum level of accuracy, 0.9888, with a training loss of 0.3499 and a testing loss of 0.9882.

table I. related work summary

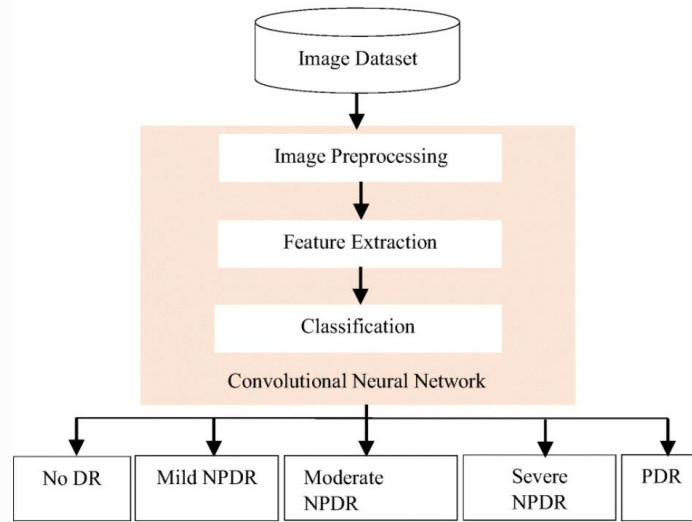
Authors	Published	Year	Method	Dataset	Acc	Sens	Spec
Sudha V et al., [1]	IJEAT	2020	CNN	50 images	95%	N.A	N.A
Imran Qureshi et al., [2]	MDPI	2019	CAD	11,200 images	93.46%	96.1%	92.2%
J.calleja et al., [3]	Springer	2018	SVM, Random Forest	71 images	97.46%	92%	82%
Mohan Hajabdollahi et al., [4]	PubMed Central	2019	CNN	ImageNet	97.3%	N.A	N.A
Jiaxi Gao et al., [5]	IEEE	2019	CNN	28,104	83%	N.A	N.A
Ibrahim Sadek et al., [6]	Journal of Medical Imaging, SPIE	2017	CNN	1,113 images	91.23% - 92.00%	N.A	N.A
Tiken Mirangthem Singh et al., [7]	IEEE, ICACCP	2019	CNN	Kaggle	71%	N.A	N.A
Gazala Mushtaq et al., [8]	ICRIET 2020	2021	DenseNet-169	Kaggle	90%	N.A	N.A
Carson Lam et al., [9]	PubMed Central	2018	CNNs	Kaggle	95%	N.A	N.A
R. Raja Kumar et al., [10]	Springer	2021	CNN	2,300 images	94.44%	N.A	N.A
Mounia Mikram et al., [11]	Springer	2022	CNN	kaggle	80.7%	N.A	N.A
Abhishek Samanta et al., [12]	IEEE	2022	CNN	3,469 images	84.10%	N.A	N.A
Anita T. Nair et al., [13]	IEEE	2022	VGG16, Resnet50	Kaggle	76.47%, 97.2%	N.A	N.A
Sabiha Gungor Kobat et al., [14]	MDPI	2022	DenseNet201	6,017 images	94.06	N.A	N.A
Kangrak Oh et al., [15]	Scientific Reports	2021	Resnet34	11,734 images	83.38%	83.86%	83.41%
Muhammad Shoaib Farooq et al., [16]	MDPI	2022	CNN	Kaggle	80.8%	80.28%	92.2%
Zehao Yu et al., [17]	BMC series	2022	NLP	536 images	95.03%-96.45%	N.A	N.A
Muhammad Kashif Yaqoob et al., [18]	MDPI	2021	ResNet50, Random Forest	Kaggle	96%	N.A	N.A
AT Nair et al., [19]	ICCMC	2022	Vgg16, EffNetB5, ResNet50	Kaggle	76.47%, 90.2%, 97.2%	N.A	N.A
Al-Omais Asia et al., [20]	MDPI	2022	ResNet101	XHO images	98.8%	N.A	N.A

### III. OBJECTIVES

- To implement a Computer-aided diagnosis system that can help alleviate the burden on ophthalmologists by automatically detecting DR on retinal images.
- To provide medical support to rural areas where the availability of medical screening and experienced doctors are limited.
- To allow early detection of Diabetic Retinopathy which allows medication or laser therapy to be performed to prevent visual loss.
- To differentiate different clinical stages of DR.
- To identify systemic risk factors, like having diabetes for a long time, poor control of your blood sugar level, High blood pressure, and High cholesterol.

### IV. METHODOLOGY

The main objective of this work is to build a stable and noise-compatible system for the detection of diabetic retinopathy. This work employs the deep learning methodology for detecting diabetic retinopathy based on severity level (No DR, Mild, Moderate, Severe and Proliferative DR). In order to assess the strengths and limitations of CNNs, several architectures were trained and tested with particular focus on a 50 layers deep model called ResNet50.



**fig.2** Detection of DR

#### 4.1 CNN

A Convolutional Neural Network (CNN) architecture usually consists of convolutional layers, pooling layers or subsampling layers, fully connected layers and the classification layer. CNN is the most widely used neural network for identifying the existence of Diabetic Retinopathy (DR) and classifying its severity in a funduscopy. The primary task is to select an appropriate CNN architecture and fine-tuning its parameters to achieve optimal results. We decided to experiment with Resnet 50 model (pre-trained network). With the help of keras framework, running on top of a TensorFlow backend, the necessary Resnet50 architecture was implemented.

#### 4.2 ResNet50

In ResNet the residual block was used successfully trained 152 layers with an error rate of 4.49% for a single model on the ImageNet validation set, and 3.57% error on the test validation set. Even though it has lower complications the Resnet has better conduct. It is one of the most powerful deep neural networks. There are many variants of ResNet architecture available some of them are ResNet-18, ResNet-34, ResNet-50, ResNet-101, and ResNet-110. In our work to detect Diabetic retinopathy (DR), we are going to use ResNet-50 which is one of the most vibrant networks on its own. ResNet50 uses an input size of 229 x 229.

#### V. DATASET

Fundus photography provides a color or red-free image of the retina. It is primarily digital, which has many advantages compared with its predecessor, color photographic film. Digital retinal imaging provides rapidly acquired, high-resolution, reproducible images that are available immediately and easily amenable to image enhancement. . It was designed to image the inside of the eye primarily the retina, optic disc, macula and posterior pole.

The present works consists of the DR classification using the Diabetic Retinopathy Detection 2015 challenge dataset available in ([Diabetic Retinopathy 2015 Data Colored Resized | Kaggle](#)) Retinal images were provided by EyePACS, a free retinopathy screening platform. There is a large set of high-resolution retinal images taken under various imaging conditions. A left and right field is provided for each subject. Images are tagged with a subject id as well as either left or right (i.e 1\_left.png is the left eye of patient id 1). The dataset consists of 35126 retinal images to detect diabetic retinopathy and all images are resized into 224x224 pixels. A clinician-rated the presence of diabetic retinopathy in each image on a scale of 0 to 4, according to the scale mentioned previously. The number of images for each stage of infection is presented in table II below :

**table II.** Description of the dataset

<b>Class</b>	<b>Stage</b>	<b>Number of Images</b>	<b>Size in percentage</b>
0	Normal eyes	25810	73%
1	Mild DR	2443	7%
2	Moderate DR	5292	15%
3	Severe DR	873	2%
4	Proliferative DR	708	2%

## VI. CONCLUSION

This study uses the free and open-source Diabetic Retinopathy Classification Dataset to train transfer learning CNN models. With the aid of transfer learning, performance on the task of classifying diabetic retinopathy is evaluated using a variety of performance indicators. The Resnet50 V2 is the subject of the study. The investigation of architectural performance shows that Transfer Learning on the ResNet50 V2 architecture, has an accuracy of 93%. We can assert that increasing the number of trainable layers in the ResNet50 model will improve performance since they support the maintenance of a low error rate far further into the network. By enabling this additional short-cut conduit for the gradient to flow through, ResNet's skip connections address the issue of disappearing gradients in deep neural networks. The suggested method seeks to improve the resnet50 model in order to classify retinal fundus images more accurately and achieve higher accuracy rates.

## REFERENCES

- [1] Sudha V, K Priyanka, "Diabetic retinopathy detection", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-9 Issue-4, April 2020  
Website link:  
[https://www.researchgate.net/publication/349534303\\_Diabetic\\_Retinopathy\\_Detection](https://www.researchgate.net/publication/349534303_Diabetic_Retinopathy_Detection)
- [2]Imran Qureshi, Jun ma, Qaisar Abbas, " Recent Development on Detection Methods for the Diagnosis of Diabetic Retinopathy",3 June 2019  
Website link:  
[https://www.researchgate.net/publication/333585523\\_Recent\\_Development\\_on\\_Detection\\_Methods\\_for\\_the\\_Diagnosis\\_of\\_Diabetic\\_Retinopathy](https://www.researchgate.net/publication/333585523_Recent_Development_on_Detection_Methods_for_the_Diagnosis_of_Diabetic_Retinopathy)
- [3]Jorge De Calleja, Lourdes Tecuapetla, "LBP and Machine Learning for Diabetic Retinopathy Detection", International Conference on Intelligent Data Engineering and Automated Learning , 2018.  
Website link:  
[https://link.springer.com/chapter/10.1007/978-3-319-10840-7\\_14](https://link.springer.com/chapter/10.1007/978-3-319-10840-7_14)
- [4]Mohse Hajabdollahi, Kayvan Najarian, "Hierarchical Pruning for simplification of CNN in Diabetic Retinopathy Classification",Annu Int Conf IEEE Eng Med Biol Soc.2019 Jul.  
Website Link:  
<https://pubmed.ncbi.nlm.nih.gov/31946055/>
- [5]Jiayi Gao, Cyril Leung, Chunyan Miao, " Diabetic Retinopathy Classification Using an Efficient Convolutional Neural Network", IEEE International Conference on Agents(ICA), 18-21 Oct.2019.  
Website link:  
<https://ieeexplore.ieee.org/document/8929191>
- [6]Ibrahim Sadek, Mohamed Elawady, "Automatic Classification of Bright Retinal Lesions via Deep Network Features", Journal of Medical Imaging ,SPIE, Jul 28, 2017.  
Website link:  
<https://arxiv.org/abs/1707.02022>
- [7] Tiken Moirangthem Singh, Parismita Bharali, Chandrika Bhuyan, "Automated Detection of Diabetic Retinopathy", IEEE 2019 Second International Conference on Advanced Computational and Communication Paradigms (ICACCP),25-28 Feb.2019.  
Website link:  
<https://ieeexplore.ieee.org/xpl/conhome/8869569/proceeding>

[8]Gazala Mushtaq,Farheen Siddiqui , “Detection of Diabetic Retinopathy Using deep learning methodology”, IOP Conference Series Materials Science and Engineering, February 2021.

Website link:

[https://www.researchgate.net/publication/349531969\\_Detection\\_of\\_diabetic\\_retinopathy\\_using\\_deep\\_learning\\_methodology](https://www.researchgate.net/publication/349531969_Detection_of_diabetic_retinopathy_using_deep_learning_methodology)

[9]Carson Lam,Darvin Yi , “Automated detection of Diabetic Retinopathy Using Deep Learning”, AMIA Jt Summits Transl Sci Proc. 2018; 2018: 147–155,18 May 2018.

Website link:

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5961805/>

[10] R. Raja Kumar, R. Pandian, T. Prem Jacob, A. Pravin & P. Indumathi, “R. Raja Kumar, R. Pandian, T. Prem Jacob, A. Pravin & P. Indumathi”,15 Jun 2021.

Website link:

[https://link.springer.com/chapter/10.1007/978-981-33-6862-0\\_34](https://link.springer.com/chapter/10.1007/978-981-33-6862-0_34)

[11]Mounia Mikram, Chouaib Moujahdi, Maryem Rhanoui, Majdouline Meddad, Asmaa Khallout , “Hybrid Deep Learning Models for Diabetic Retinopathy Classification” ,03 July 2022.

Website link:

[https://link.springer.com/chapter/10.1007/978-3-031-07969-6\\_13](https://link.springer.com/chapter/10.1007/978-3-031-07969-6_13)

[12]AbhishekSamantaa, AheliSahaaSuresh, “Automated detection of diabetic retinopathy using convolutional neural networks on a small dataset”, IEEE , 17 April 2022.

Website Link:

<https://www.sciencedirect.com/science/article/abs/pii/S0167865520301483>

[13] Anitha T. Nair; Anitha M. L; Arun Kumar M. N, “Disease Grading of Diabetic Retinopathy using Deep Learning Techniques”, IEEE,2019

Website Link:

<https://ieeexplore.ieee.org/abstract/document/9754113>

[14] Sabiha Gungor Kobat,Nursena Baygin “Automated Diabetic Retinopathy Detection Using Horizontal and Vertical Patch Division- Based Pre-Trained DenseNET with Digital Fundus Images” , 15th august 2022.

Website link:

<https://www.mdpi.com/2075-4418/12/8/1975>

[15] Kangrok Oh, Hae Min Kang, “Early detection of diabetic retinopathy based on deep learning and ultra-wide-field fundus images”, Scientific Reports, 21 January 2021.

Website Link:

<https://www.nature.com/articles/s41598-021-81539-3>

[16] Muhammad Shoaib Farooq , Ansif Arooj, “

Untangling Computer-Aided Diagnostic System for Screening Diabetic Retinopathy Based on Deep Learning Techniques”, IEEE Multidisciplinary Digital Publishing Institute,26 Feb 2022 .

Website Link:

<https://www.mdpi.com/1424-8220/22/5/1803>

[17] Zehao Yu, Xi Yang, Gianna L. Sweeting, “Identify diabetic retinopathy-related clinical concepts and their attributes using transformer-based natural language processing methods”, BMC Medical Informatics and Decision Making Volume 22 Supplement 3, 27 September 2022.

Website Link:

<https://bmcmmedinformdecismak.biomedcentral.com/articles/10.1186/s12911-022-01996-2>

[18] Muhammad Kashif Yaqoob,Syed Farooq Ali, “ResNet Based Deep Features and Random Forest Classifier for Diabetic Retinopathy Detection”, IEEE Multidisciplinary Digital Publishing Institute”, 4 June 2021

Website Link:

<https://www.mdpi.com/1424-8220/21/11/3883>

[19] AT Nair ,ML Anitha, “Disease Grading of Diabetic Retinopathy using Deep Learning Techniques”, published IEEE, 2022 6th International Conference on Computing Methodologies and Communication (ICCMC),29-31 March 2022.

WebsiteLink: <https://ieeexplore.ieee.org/abstract/document/9754113>

[20] Al-Omaisi Asia, Sara A.Althubiti, “Detection of Diabetic Retinopathy in Retinal Fundus Images Using CNN Classification Models”, IEEE,MDIP, 31 August 2022 .

Website Link:

<https://www.mdpi.com/2079-9292/11/17/2740>