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## CHAPTER 2

### REVIEW OF LITERATURE

#### 2.1 Introduction

This chapter articulates about the existing literature relating to Diabetic Retinopathy (DR) disease classification using deep neural network and optimization techniques. The digital retinal image processing and image analysis techniques are performed for screening DR disease. The abnormalities in the retinal images are detected at the early stages by identifying the quality, right or left eye, structural types such as optic disc, macula, blood vessels or fovea and disease types like exudates are articulated. Digital image processing techniques have been improved for screening DR diseases. Literature reviews related to enhance the screening techniques are introduced along with the novel methods to enhance the performances are discussed.

This chapter investigates the existing techniques and algorithms related to DR disease classification based on the types and the stages using deep neural network techniques. This chapter discusses the numerous challenges in classifying DR disease during digital image processing and analysis. The Neural Network (NN) and optimization technique aids in identifying the normal and abnormal fundus images by using different classifiers are discussed in the subsequent sessions. There are different classifiers such as NN classifiers, fuzzy classifiers etc., used in digital image processing for the classification purpose. Each one has a specific function. The function of each classifier depends on the application usage which depends on the blood vessel thickness and grading of retinal image.

This chapter begins with the background information of classifying DR disease based on severity levels using machine learning techniques. Review related to the preprocessing phase consists of histogram-based methods followed by wavelet-based techniques are presented. Review related to deep learning ensemble classification approach and regression model for enhancing DR disease classification are presented. Finally, this chapter discusses the literature related to the optimization techniques on DR disease detection with ensemble classification model.

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## 2.2 Related work on Histogram and Wavelet-based techniques for Preprocessing

Generally, to enhance the contrast in digital images Histogram equalization (HE) method is applied. The side effect of this method is the image brightness saturation. Kawakami T *et al.* (2009) came up with a protective bi-HE method to avoid the saturation effect. A variable enhancement degree and variable separation strength methods are combined to control the enhancement degree and tune the parameters. The image's mean value is conserved which aids to improve the image quality.

Khan M. F. *et al.* (2014) came up with a new change to the existing HE method. To conserve the vividness and natural form of the digital image, decomposing the input image into multiple segments with a threshold median value. The segments with high probability areas are identified and assigned with new dynamic range. The other segments are not altered. HE is applied to the segments with high probability to minimize the algorithm complexity. Finally, both the segments are combined and normalized. The result enhances the image differences whereas conserving the vividness and natural form.

The digital image brightness is altered after HE process which leads to improper diagnosis of diseases in medical images. Kim Y. T. (1997) proposed a novel extension of HD process to eliminate the problems in typical HD. The input image is decomposed by utilizing the independent HD distinctly over two sub-images based on the mean with restrictions that the output sub-images are bounded with each other around the input mean. The mean brightness of the image is preserved and compared with the typical HD. The natural appearance and the brightness is enhanced.

HE technique is an operational way to enhance contrast of the digital images. The reduction of image brightness and the natural appearance in HE method is the main drawback. Khan M. F. *et al.* (2014) proposed a Bi and multi HE techniques to overcome these drawbacks. The Bi-HE method enhances the image contrast and preserves the image brightness, but the image's natural form is unmaintained due to strength saturation. A Multi-HE approach is proposed to improve the contrast while preserving the vividness and natural form. Decomposing the input image into numerous parts with the mean or medium threshold values. Before applying HE, narrow sections are recognised and assigned active range to each section distinctly. The saturation intensity is avoided by combining the histogram equalization. The results of 120 images are optimal compared to the typical HD method in

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terms of quality and quantity. Sim K. S. *et al.* (2007) came up with a new recursive sub-image histogram equalization (RSIHE) technique to prevent the shortcomings of conventional HE method. The result of RSIHE is better than the bi-HE and Multi-HE methods.

Jintasuttisak T. & Intajag S. (2014) came up with an enhancement model to retain color information of retinal images. The proposed non-linear hue-saturation-intensity color model improves the intensity component by Rayleigh transformation. The algorithm improves the contrast and the overall appearance of DR fundus images. The proposed approach preserves the hue component because the hue information present in the fundus image is vital for the ophthalmologist to diagnosis DR disease.

Pisano ED *et al.* (1998) came up with a model to discover abnormalities in mammogram images for CLAHE approach. Images with the appearance of lines indicating the malignancy in mammogram images and film images without CLAHE are compared. Simulation is performed using mammogram images composed of diverse fusion of area size and clip levels. The CLAHE settings and no CLAHE are tested based on the region sizes. The CLAHE settings of the digital mammogram provide improved results compared to no CLAHE. Xu Z *et al.* (2009) eliminated the fog effect in digital image. CLAHE method minimizes the noise by maximizing the contrast. Initially, RGB image is altered to hue saturation intensity (HSI) image. Next, CLAHE processes the HSI image. Finally, conversion of HSI image to RGB image is done. Experiments are conducted in color image with fog effect. The optimal results are produced when matched with conventional methods.

Chang S. G. *et al.* (2000) developed a threshold for image denoising which is a wavelet-based thresholding. Bayesian framework is applied with wavelet coefficients in General Gaussian Distribution (GGD) for applications related to image processing. The threshold is adaptive, simple and is in closed form consisting of data-driven parameters. The Bayes Shrink method results show less than 5% of the threshold benchmark images. To validate the claims of the lossy compression for denoising, the proposed threshold aids in parameter selection. This denoising and compression are performed simultaneously. Donoho D. L. (1995) came up with a procedure called Sure Shrink to reduce the noise by thresholding. The threshold value is assigned based on the wavelet coefficients. The proposed procedure is adaptive, optimal and smooth based on the interval levels specified. The merits

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of this method are obvious when the function has hurdles in discontinuities on a flat background. Donoho D. L. (1995) developed a reconstruction function for denoising the data that are independent and identical to the standard random variables. The reconstruction is defined in the wavelet domain by translating the empirical wavelet with coefficients. The results that are obtained develop facts about the inference and the connection to optimal recovery.

Beck A. & Teboulle M. (2009) came up with a technique for denoising and de-blurring issues in the total variation minimization model with constraints. Acceleration is combined with the monotone version of the threshold algorithm. The gradient based methods are better than the existing gradient projection methods. The result shows the feasibility and competence of the proposed technique to avoid denoising and de-blurring issues. Buades A. *et al.* (2005) came up with a new measure for image denoising. Local smoothing filters, non-local means algorithms are compared and analysed. The averaging of all pixels in the image is performed for some experiments by comparing Local smoothing filters and non-local means.

Image denoising is critical in image processing which involves segmentation, and reconstruction. Non-local means denoising exploit the redundancy patterns in the image. A weighted average pixel patches are performed to reduce the noise while maintaining the image contents. Sutour C. *et al.* (2014) introduced a variation approach to rectify the over smoothness and minimize the residues of noise in the non-local means methods. A different noise strategy is applied in this model to adapt to the fast changing of solutions. This technique can be applied to video denoising with 3D patches. Gu S. *et al.* (2014) developed a denoising algorithm named as weighted nuclear norm minimization (WNNM) by assigning different weights. The algorithm is applied by exploiting the image with non-local and self-similarity. The denoising approach is superior to the other denoising techniques with respect to quantity and quality.

Church J. C. *et al.* (2008) proposed an image filtering algorithm to reconstruct images affected by noise. During the transmission of an image the noise is removed from the signal. The median filter is applied in algorithm and compared with the current image smoothing approaches. A modified filtering algorithm is also proposed to enhance the accuracy of reconstructions. Mallat S. G. (1989) designed a model for resolution and scale of the image

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using wavelet theory. The algorithm analyses the image at the resolution level to eliminate the redundant values. The signals are processed at the resolution level to analyse the details of high-resolution components. The decomposing of signals on the wavelet is calculated effectively. This decomposition is suitable for computer vision applications such as edge detection, signal coding and matching algorithms. Mohideen S. *et al.* (2008) developed a denoising approach for natural images with Gaussian noise using wavelet approach. The energy is captured with signal waves to transform the values with different wavelet base. The image denoising algorithm adapts to the size of different neighbourhood.

### 2.3 Related work on Neural Networks for DR disease classification

Sreejini K. S. & Govindan V. K. (2019) proposed an automatic system for identifying and retrieving pathological retina images. The manual system is not suitable due to large number of images consisting of diseases with symptoms in the pathological images. The structure, color and shape of the lesions are few features that confuse the manual interpretations and consequent assessment of the disease stage. A machine learning approach is proposed to identify the diseased images from the normal image using a probabilistic Latent Semantic Analysis (pLSA) along with a visual words container. The proposed technique was validated with standard retina fundus images that are available in public database.

In diabetic patients, the vital reason for blindness is DR, a common eye disease. Regular screening and suitable intervention are an actual way to manage the disease. Automated computer aided diagnosis is needed during the screening process among the huge population of diabetic patients. Gao Z. *et al.* (2018) developed a DR fundus image dataset with the help of deep neural network model. Training the dataset with the NN models to grade fundus images is an effective method. The classification accuracy is 88.72%. The deployment is performed on the cloud platform for DR analytical services in hospitals. 91.8% consistency rate is achieved with ophthalmologists.

Eszes D. J. *et al.* (2021) came up with an investigation of different grades of diabetes mellitus (DM) and DR in patients located in Hungary. DR disease risk factors are detected based on the screening patterns and frequencies related to factors such as DM patient's health and performance. A study using handheld fundus screening camera for adults above 18 years

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of age. The image is assessed using Spectra DR software. Questionnaires related to the health status which includes the visual sharpness, DM type, attendance of healthcare services and few others are recorded. The total number of participants with known diabetes considered in this study is 848. About 787 participants' fundus camera images were available. About 138 participants were classified as DR, 286 participants were classified as Non-DR and 363 participants' were not assessable to images. Data analysis is performed on the participants with known diabetes and assessable fundus camera images were around 386. The DM and DR occurrence is slightly higher than the previous reports. The use of camera screening is simple and vibrant. The issues related to optic clarity needs training and experience of image assessment and artificial intelligence screening can be incorporated.

Solomon S. D. & Goldberg M. F. (2019) reviewed an article that delivers history of growth, modification and inherits the primary treatment for DR disease classification. The DR disease has been described and classified by the retinopathy scale. The classification system Early Treatment Diabetic Retinopathy Study (ETDRS) is based on assessment of photographically documented fundus features and associated with regular color fundus photographs.

Blindness due to diabetes in senior persons is a worldwide disease known as DR. The retinal blood vessel complication happens due to diabetes without any warnings. Aatila M. *et al.* (2021) introduced a screening process with the help of intelligent system to classify DR at an early stage. Deep learning tools present in NN are introduced that aids the ophthalmologists to take primary decisions by classification methods. The experiment results are based on the classification accuracy. The study models considered in this study are VGG-16 and ResNet-50 networks for DR classification. The classification accuracy of 25% and 70% for VGG-16 and ResNet50 models are obtained using the color retinal background images.

Chen Y. *et al.* (2017) came up with a new topology of dual trail NN model for image grouping for internal paths. The HORNNs framework consists of Residual Network (ResNet) and Densely Convolutional Network (DenseNet) learning models. The ResNet model uses the feature reuse concept and DenseNet model permits new features in dual trail exploration. The dual topology shares common features to discover novel features. ImagNet-1k,

Places365 and PASCAL VOC are the benchmark datasets for conducting the experiments. The performance of the proposed dual path network model is superior for the three datasets used. The ImageNet-1k surpasses the ResNet with 26% lesser size, the computational cost is less by 25% and memory consumption is less by 8%. The training speed of the single model is two times faster. Experiments conducted with large dataset shows consistently better results for Places365 and PASCAL VOC datasets.

Kornblith S. *et al.* (2019) discussed the ImageNet model's efficiency by evaluating the architecture and transfer relationship. The hidden theory in modern research is that models that accomplish enhanced ImageNet perform better on other tasks. The model is verified on 12 images with 16 classification networks. There is a relationship between ImageNet and transfer accuracy with fixed networks. The network is trained on ImageNet to enhance the accuracy of features in transfer learning. The results illustrate that the architecture of ImageNet is general for all the datasets, but a small number of features are considered.

Saeed F. *et al.* (2021) proposed an automatic DR screening on retinal images using deep learning approaches. A two-step transfer learning approach is employed using a pre-trained neural network for DR screening of fundus images. Based on the regions of interest of lesions, a pre-trained neural network model is tuned in the first layer and the lower-level layers are learnt using the local structures. The complete layer is encoded with features and the new complete layer is replaced with the principal component analysis (PCA). This process minimizes the complexity and over fitting issues. DR features are detected, and gradient boosting classification layer is included.

Kassani S. H. *et al.* (2019, December) came up with an improved Xception architecture for extracting novel features while screening for DR disease. Multilevel features are combined to form deep layers for DR classification. Improved version of Xception architecture is assessed with the existing feature extractors such as MobileNet, Inception V3, Xception architecture and ResNet50. The learning process is improved by aggregating the neural network layers and adding the transfer learning method and tuning the hyper parameters to enhance the classification performance. The classification accuracy is 83.09%, sensitivity is 88.24% and specificity is 87% when compared to the first version of Xception architecture.

Harangi B. *et al.* (2019) proposed a combined technique of neural networks and hand-crafted features for DR disease classification. The training of neural network and weighted hand-crafted features are tuned to predict the DR disease. The DR classification and Diabetic Macular Edema (DME) are automated along with fundus image grading based on DME and DR severity levels. The classification accuracy is 90.07% for DR and 96.85% for DME. Wang L & Schaefer A (2020) came up with a model by considering a 3-channel image to predict the severity of DR disease.

Li X. *et al.* (2020) developed an automated cross-disease attention network (CANet) for DR and DME diseases based on the working age population. The grading is performed with the aid of location information such as macula, soft and hard remarks. First module is disease specific, aids in learning about the features of the disease and the second module is disease dependent attention. The deep neural network aids in integrating the modules to attain the maximum performance in grading DR and DME diseases. The results of IDRiD outperforms former approaches in Messidor dataset. Abdel Maksoud E. *et al.* (2020) proposed computer aided analysis using deep learning for screening the pathological abnormalities of DR disease. Depending on the multi-label classification, a system customised for EfficientNet model to identify the DR disease in early and advanced grades using transfer learning. The accuracy is 86% and the similarity is 78.45% for IDRiD.

NN models can classify and identify the DR disease efficiently by reducing the classification cost. Liu H. *et al.* (2020) developed a hybrid structure model to classify the DR disease by combining EfficientNetB4, EfficientNetB5, NASNetLarge, Xception, and InceptionResNetV2 neural network basic models. The output of the basic models is given as the input to the hybrid structure model. DR classification performance is enhanced in the hybrid model structure. The results of hybrid model are compared with the best basic models referring to accuracy, sensitivity, precision, F1 score and specificity.

Automatic detection of DR disease from colour fundus images is a challenging process. Gayathri S. *et al.* (2020) came up with a novel neural network model to retrieve features from fundus image for classification of DR disease. The classifiers such as SVM, AdaBoost, Naive Bayes, Random Forest, and J48 are used to classify IDRiD, MESSIDOR, and KAGGLE. The efficiency of the classifier is assessed by recall, accuracy, sensitivity,

precision, false positive rate and specificity. The result of the proposed technique is superior to former classifiers.

DR disease has increased due to rising number of diabetic patients. Detecting DR using artificial intelligence to automate the diagnosis process aids millions of diabetic patients. Sikder N. *et al.* (2021) developed a novel approach for detecting DR disease using an ensemble learning approach. The grey-level and surface features are removed from the fundus image. Blindness Detection (APTOS 2019 BD) dataset is used in this study which incorporates feature extraction, feature selection and image processing methods. The accuracy is 94.20% for classification and F-measure is 93.51%.

Bodapati J. D. *et al.* (2021) created an architecture using Deep Neural Network (DNN) with gated-attention method for automatic discovery of DR disease. Spatial pooling techniques are applied to obtain the reduced illustrations of the fundus images. The DNN learns from the representations using different channels and enhances to improve the model. The lesion part of the retinal images was emphasized in the proposed model. Experiments are conducted on APTOS-2019 Kaggle dataset and the performance is compared with the existing methods. Multi-modal and uni-modal representations are compared. The DNN accuracy is 82.54%.

Tariq H. *et al.* (2021) proposed an automated DNN for classifying DR disease using deep transfer learning model. The DR images are collected, labeled and the treatment approach is automated which assists the patients to undergo therapies. DR severity level is classified with an accuracy of 97.53% for all the pre-trained models. 84.01% is the minimum accuracy achieved in five-degree classification.

Dekhil O. *et al.* (2019) came up with a diagnosis tool using CNN model to classify fundus images in to five stages. The CNN model consists of a preprocessing stage, convolutional, rectified linear, pooling layers and complete connected layers. Transfer learning training model minimizes the over fitting of the fundus image datasets. The accuracy rate is 77% in the proposed model which aids in early diagnose and staging of DR disease automatically.

Alyoubi W. L. *et al.* (2021) designed an automated system for DR disease classification based on the five stages. The affected lesions on the retinal surface are also

detected. The DL model, CNN, is proposed. In the first model the entire image is taken as input to classify based on the five stages and in the second model, only the DR lesions are localized and detected from the datasets. The accuracy rate is more than 88% for the DDR datasets. The proposed structures are combined to classify DR images and limit lesions with an overall accuracy and sensitivity of 89% and specificity is 97.3%.

Majumder S. & Kehtarnavaz N. (2021) created a deep learning model with multi-task features to grade the DR disease. The multi-task model comprises of classification model, regression model and loss function to extract the features. A multi-layer perception network is created using a modified squeeze excitation closely connected DNN to perform the multi-task approach. This approach is applied to APTOS and EyePACS datasets. The results of weighted score obtained in the proposed multitask model are 0.90 and 0.88 for the APTOS and EyePACS datasets. The receiver operating characteristic (ROC) curve value is higher than existing methods.

Gangwar AK & Ravi V (2021) developed a hybrid deep learning model to automatically detect DR disease. A pre-trained Inception-ResNet-v2 model in the transfer learning is built. The performance is evaluated on the Kaggle dataset, and it was found that the test accuracy is 72.33% and 82.18% for the dataset. Sheikh S. & Qidwai U. (2021) proposed a training model that has four different algorithms to classify RF images. The hyper parameters are tuned for the image preprocessing techniques and the best model achieves a sensitivity of 90% and specificity of 87%. An android application used to predict the severity of retinal fundus images.

Al-Antary M. T. & Arafa Y. (2021) created a method for DR classification using multi-scale attention network. The features are extracted using the neural networks for classification of lesions. The encoder network is implanted in the high-level representation where the features are combined to enhance the representation. A cross-entropy method training is given to categorise the severity of the DR disease. Additional tasks in the model categorises healthy and non-healthy retina images. The outcomes of the model are outstanding for EyePACS and APTOS datasets.

Early detections of DR disease, proper treatments and disease severity assessment are considered in this study. Sakaguchi A. *et al.* (2019) developed a Graph Neural Network

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(GNN) technique to enhance the accuracy of severity classification. The first feature is to extract the Region-Of-Interest (ROI) from the retinal images. The second feature is to apply GNN for image classification. Accuracy is improved by 2.9% when matched with the standard method.

#### **2.4 Related work on ensemble learning algorithms and GAN-based image creation for DR Classification**

Hilgert G. R. *et al.* (2019) discussed about the effective use of handheld fundus camera for screening DR disease. Around 51 diabetic patients were evaluated for DR disease using pre and post dilation of fundus images. The images are captured, analysed, and graded by specialists and classified as normal, initial DR, moderate DR and severe DR. Sensitivity, specificity, predictive values are determined and compared to for IMAGENet image results. Nakayama L. F. *et al.* (2022) compares and discusses about the DR grading using artificial intelligence algorithms and manual annotations for the datasets available publicly.

Costa P. & Campilho A. (2017) proposed a neural network method for DR detection using a method called as bag-of-visual-words (BoVW). The model is trained to perform feature extraction, feature encoding, and classification. Vikramathithan A. C. *et al.* (2022) discusses about the various methods to detect the abnormal retinal images at the early stage using geometric relation, multiple thresholding methods and neural network. Pires R. *et al.* (2019) proposed a novel coding method to enhance the lesion detection. For referral decisions, an effective data driven model is proposed to enhance the performance and design.

Tamim N. *et al.* (2021) proposed an accurate system to identify DR and glaucoma diseases. The system initially calculates the hybrid features in first order, high order and histogram groups. Then the features are minimized using genetic algorithm to choose the relevant and vital features. The selected features are classified as DR, glaucoma or normal. The classifiers are decision tree (DT), naive Bayes (NB), k-nearest neighbor (kNN), and linear discriminant analysis (LDA). The result shows that the high accuracy of 96.7% is achieved using DT for DR disease identification, accuracy of 100% for glaucoma, and 96.67% for normal. Arcadu F. *et al.* (2019) designed a Deep Learning (DL) model to predict DR disease progression. The performance of the prediction model is highlighted with predictive signal based on the abnormalities of images. Large and diverse datasets are given as input to the proposed model.

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Mushtaq G. *et al.* (2021) designed a deep learning method named as Densely Connected Convolutional Network DenseNet-169 for early detection of DR disease. Fundus images are classified based on the severity levels. The Aptos 2019 dataset from Kaggle is used for validation. The steps involved in classification are data collection, preprocessing, augmentation, and modeling. The accuracy of 90% is achieved in the proposed model. The Regression model accuracy is 78%.

Automatic detection of DR disease by classifying the stages of retina images using the computer-based techniques provides low accurate results. Qummar S. *et al.* (2019) came up with a novel model to train an ensemble of CNN using the publicly available Kaggle datasets. Resnet50, Inceptionv3, Xception, Dense121, Dense169 models are encoded with rich features to enhance the classification of DR disease. The model's outcome identifies all the stages of DR disease unlike the existing methods available and the performance is better for same Kaggle dataset.

If the DR disease is detected early, more than 90% of the new occurrences are eliminated which can prevent blindness. Machine learning and digital image processing techniques are applied to deal with early detection. Sikder N *et al.* (2020) came up with an early blind detection technique using ensemble learning algorithm. It works with the color information that is retrieved from the retinal images. Algorithm is validated with a set of retinal images and the classification accuracy rate is 91%. Yu Z. *et al.* (2019) proposed a method to address the imbalance in medical datasets particularly medical images. GANs are used to synthesise medical images to maximize the training datasets for image analysis. The quality of the synthetic images is enhanced with these concepts like input mask, GANs architecture and resolution. A multi-channel preprocessing pipeline is proposed to synthesize color fundus images. The proposed method is superior to the other images with high resolutions. HaoQi G. & Ogawara K. (2020) came up with a simulated learning model which learns to map from the retinal fundus image to segment the images and the learning model is trained to produce synthetic images. The results outperform in quantitative and qualitative aspects.

## **2.5 Related work on DR disease detection using Optimization techniques with ensemble classification models**

DR disease identification is a challenging task that needs routine diagnosis and screening tasks. Ullah N. *et al.* (2022) came up with a DNN and Genetic Algorithm (GA)

feature selection. The NN models like AlexNet, ShuffleNet are used to mine features followed by GA for selecting and ranking the features. Optimal feature indicates high rank and unsatisfactory features indicates low rank. SVM classifier is used to develop the DR recognition model. The datasets used for validating are Kaggle and a self-generated custom dataset. Data augmentation is performed to remove the noise in fundus images. The accuracy obtained from these datasets is 97.9%, 94.76%, and 96.4% respectively.

Butt M. M. *et al.* (2022) developed a hybrid technique to classify DR disease using CNN models. Transfer learning is applied on a pre-trained CNN model to retrieve features and is combined to produce a feature vector. The vector is passed on to binary and multiclass classifiers. The performance is measured, and it is found to enhance the DR detection for binary classification. The accuracy is 97.8% and 89.29% for multiclass classification.

Jayanthi J. *et al.* (2021) developed a novel Particle Swarm Optimization (PSO) based CNN model to detect and categorise DR images. The noise is removed in the preprocessing stage. PSO-CNN model is applied for feature extraction and finally decision tree model is applied to classify the set of DR images. The model is simulated with a set of benchmark DR datasets. The result of PSO-CNN model has obtained maximum output.

Many machine and deep learning models are available to detect the DR disease. Optimal results in terms of accuracy during preprocessing, feature extraction and classification are not obtained. To eliminate these issues, Gundluru N. *et al.* (2022) came up with an optimization algorithm to optimize the feature extraction and classification process. DR disease dataset from UCI and deep learning model with PCA are used for reducing the dimension and extract the vital features. The results of specificity, precision, recall, and accuracy is satisfactory for the optimized model.

The drawbacks in the existing study are high feature dimension, execution time, computational cost and hyper-parameter tuning. Hyper parameters like hidden layer, learning rate and other complexities are addressed by Priya R. P. *et al.* (2021). A NN model with Red Fox algorithm for DR classification is proposed. Initially, an adaptive HD and HD model does the preprocessing for fundus image. Next, the lesion areas are segmented using watershed segmentation model related to size and color. Then, features such as intensity, statistical, color and shape are extracted. Finally, classification is performed based on normal and abnormal classes using the optimization algorithm. The experiments are performed in

MESSIDOR, STARE, and DRIVE datasets. The proposed model's classification is superior in terms of 98.45% specificity, 96.78% sensitivity, 97.92% precision, 96.89% recall, and 97.93% F-score.

The early detection of DR disease plays a vital role in preventing the vision loss. Machine and DL techniques have been implemented for DR disease classification. Gadekallu T. R. *et al.* (2020) implemented firefly optimization technique for dimension reduction in DR disease classification. The reduced dataset is given as input to the DNN model for classification. The dataset from the UCI repository is used in this study. The results produced from this model are superior with respect to accuracy, precision, recall, sensitivity, and specificity.

In electronic health records maintenance, the block chain technology is viewed as a secure form of data-sharing medium. The combination of machine learning and block chain technology deals with data analysis and prediction along with data security. Uppamma P. & Bhattacharya S. (2023) focused on early detection of DR disease and its prediction using the datasets that are available in IEEE data portal. Median filtration technique and lesion segmentation are performed in the data preprocessing stage. Then the hyper-parameters are tuned using the African Vulture Optimization (AVO) algorithm. Finally, the blockchain architecture ensures authorized access by the electronic health record manager. The classifier results are superior to the existing models in terms of 94.2% accuracy, 94.8% sensitivity and 93.4% specificity.

Cordero Martinez R. *et al.* (2022) discusses and compares four preprocessing techniques and selects the best technique for DR disease detection. Preprocessing of dataset is vital to enhance the accuracy of DR disease. Optimization algorithms like Hierarchical GA (HGA) are applied to enhance the accuracy of classification of CNN model. The results obtained by HGA in binary and multi-class study case outperform the existing models in terms of mean accuracy and SD.

Dayana A. M. & Emmanuel W. S. (2022) proposed an optimized DNN with Chronological Tunicate Swarm Algorithm (CTSA) for classifying DR severity. The fundus images are pre-processed and segmented. The hybrid entropy model segments optic disc and blood vasculatures. The lesion area is detected, and the features are extracted. Finally, CTSA

is applied in the classification process. The proposed model obtains an average accuracy of 95.9%. The outcome of this model is robust and effective in DR disease classification.

Aljehane N. O. (2022) came up with an Intelligent Moth Flame Optimization with Inception Network-DR (IMFO-INDR) model for DR classification and detection. The model aims to detect lesions and assign labels according to classes. The model involves HD segmentation to define lesion areas. For feature extraction, Inception v4 model is applied and to tune the hyper parameters MFO algorithm is applied. Finally, softmax classifier allocates the class labels to images based on feature extraction. Results reveal that the IMFO-INDR model is optimal in DR diagnosis. Table 2.1 illustrates the literature review using DL techniques for DR predictions.

**Table 2.1: Literature Review on DR Prediction and Classification  
Using Deep learning Techniques**

Author	Technique used	Methodology used	Limitations
Jena P. K. <i>et al.</i> (2023)	Asymmetric deep learning feature	U-Net segmentation of OD & blood vessels.	Other kinds of medical image segmentation
Sebastian A. <i>et al.</i> (2023)	Survey based on DR detection and DR grading	Binary CNNs, and DNNs.	Cloud enabled systems. An automated system for detecting more than one eye disease.
Aziz T. <i>et al.</i> (2023)	Automated DL based hemorrhage detection	Deep features are generated using the Hemorrhage net.	Complex Hemorrhage Net classification problems. Feed forward approach might be effective
Ozbay E. (2023)	DL techniques using Artificial bee colony for identifying retinal lesions.	Active DL and CNN methods for automated retinal feature extraction.	Applied to specific datasets such as EyePACS.

Author	Technique used	Methodology used	Limitations
		Segment areas and Lesion features are used in the model for two stage processing.	
Saranya P. (2023)	Advanced convolutional layer architecture	U-Net segmentation architecture for red lesions. Red lesions are detected using CNN to train and classify input images.	Other kinds of retinal disorders related to lesions are not detected.
Maaliw R. (2023)	Multiple preprocessing to extract the relevant features.	DR-UNet Image segmentation architecture using deep learning CNN.	Advanced stages of DR detection are not completely reinforced.
Beevi S. Z. (2023)	Hybrid optimization algorithm which uses war strategy and fractional calculus. Second level severity decomposition using Battle Royale optimization.	Deep CNN for multilevel severity DR classification. DCNN weight adjustment is performed in the hybrid optimization.	Other criteria for severity level detection in abnormal images.
Das D. <i>et al.</i> (2022)	A hybrid DL and ML techniques for DR detection	DL models for high dimensional data for ensemble-based classification and feature extraction. SVM, NN and decision tree models are featured.	Deep feature extraction, balanced data procurement can be reinforced.
Gundluru N. (2022)	Harris Hawks's optimization using DL models.	Principle component analysis for feature extraction.	For low dimensional dataset causes the possibility of over fitting.

Author	Technique used	Methodology used	Limitations
		Dimensionality reduction technique using Harris Hawks optimization method. Compared with ML models like KNN, SVM and other classification algorithms.	
Abbood S. H. (2022)	Hybrid DL model for retinal image enhancement	Noise reduction, contrast improvement using DL models. Image cropping to eliminate irrelevant contents. Noise reduction by shape cropping and Gaussian blurring.	Colored patterns and real time DR screening of the fundus images.

## 2.6 Related work on interdisciplinary application

Mall PK et al.(2023) came up with a comprehensive review of medical imaging studies. This review examines the techniques for breast cancer classification and diagnosis, focusing on five groups of medical images: mammography, ultrasound, MRI, histology, and thermography. It discuss the use of five popular machine learning techniques, including Nearest Neighbor, SVM, Naive Bayesian Network, DT, and ANN, as well as deep learning architectures and convolutional neural networks.

Ahmed H et al.(2024) came up with a systematic review of ophthalmology using deep learning for denoising tomography images. Imaging from optical coherence tomography (OCT) is widely used for detecting retinal diseases, localization of intra-retinal boundaries, etc. It is, however, degraded by speckle noise. Deep learning models can aid with denoising, allowing clinicians to clearly diagnose retinal diseases. Deep learning models can be considered as an end-to-end framework. It is selected denoising studies that used deep learning models with retinal OCT imagery.

Paletta Q et al. (2023) came up with a solar forecasting computer vision model using deep learning. Renewable energy forecasting is crucial for integrating variable energy sources into the grid. It allows power systems to address the intermittency of the energy supply at different spatiotemporal scales. To anticipate the future impact of cloud displacements on the energy generated by solar facilities, conventional modeling methods rely on numerical weather prediction or physical models, which have difficulties in assimilating cloud information and learning systematic biases.

## **2.7 Summary**

This chapter briefs about the classification of DR disease based on severity levels using ML and DL techniques. Literature related to the preprocessing phase using histogram-based methods and denoising the fundus images using wavelet-based techniques are discussed. The research works including neural networks for DR disease classification, ensemble learning algorithms and GAN-based image creation for DR classification, DR disease detection using Optimization techniques with ensemble classification models and DR prediction and classification using deep learning techniques were discussed. An elaborated review related to deep learning using ensemble classification approach and regression model for enhancing DR disease classification was presented. A thorough survey on the optimization techniques for tuning hyper parameters, to detect and classify DR disease was presented.