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A Survey on Early Diagnosis of Retinal Disorders using Deep Learning Techniques

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Abstract: Deep Learning has recently gained a high interest in ophthalmology due to its extraordinary ability to detect clinically significant features for diagnosis and prognosis in the human eye. Retina plays a vital role in visual recognition. Damage to it, can cause permanent blindness. Retinal disorder can affect infants through adolescents in many ways. Major retinal diseases include Retinopathy of Prematurity (ROP), Macular degeneration and Diabetic Retinopathy (DR). Among various retinal disorders, Retinopathy of Prematurity (ROP) and Diabetic Retinopathy (DR) cause blindness in Infants and adults respectively. ROP requires immediate precautionary measures to prevent infants from blindness.

There are different methodologies available to treat Retinopathy of Prematurity (ROP) for infants and Diabetic Retinopathy for adults, using machine learning and deep learning algorithms like Convolution Neural Network (CNN), SVM (Support Vector Machine), Deep Neural Network (DNN) and so on. A survey has been taken on these algorithms which have its own potential challenges to prevent the child from blindness with accuracies ranging from 74% to 98.8%, specificity, sensitivity and their limitations. Based on the comparisons made, one can choose the algorithm that best fit their need and also, can diagnose ROP and Diabetic Retinopathy (DR) in its early stage.

Keywords: Retinopathy of Prematurity (RoP), Diabetic Retinopathy, Machine Learning (ML), Deep Learning (DL).

I. INTRODUCTION

India has the highest number of preterm childbirths in the world, where one out of six babies were born within gestational weeks (<37 weeks) and 28% of babies were born with low birth weight. These babies were more prone to be affected by retinal disorders. Major retinal diseases include Retinopathy of Prematurity (ROP), hereditary retinal dystrophy, retinal dysplasia's, macular degeneration and diabetic retinopathy in adults. Among these diseases, ROP affects the preterm birth infants which lead to blindness, if untreated earlier.

The incidence of ROP in India was 51.9%. The risk factors of ROP include Preterm birth, Low birth weight and unblended oxygen. In India, every year, 500 children were estimated to become blind from ROP. Early screening and timely intervention were the key factors in preventing blindness due to ROP. Moreover, the trained ROP specialists were less in number and the pediatricians were not aware of the severity of ROP. And many underprivileged and remote areas had no adequate facilities available to screen/test the incidence of the ROP of preterm birth babies. So, it is at most important to diagnose the presence and severity of ROP.

Diabetic Retinopathy (DR) affects the working age adults, causing serious complications of low vision and blindness. According to International Diabetes Foundation's (IDF) estimation, nearly 451 million and over one-third of the population was affected by Diabetic Retinopathy (DR) [1], which leads to high risk of visual impairment or blindness. The existence of DR in the world is expected to increase to 693 million people by 2045[1]. It has been noticed that almost half (49.7%) of affected people were undiagnosed as there is no symptoms in the early stage [1]. Hence, Detection and treatment of DR in the early stage was the major challenge for the ophthalmologists to prevent its growth which can be performed through retinal classification.

Deep Learning (DL) has emerged with new automated tools allowing ophthalmologists to diagnose ROP and Diabetic Retinopathy in the early stage and thereby preventing from blindness. There are various DL algorithms like Convolution Neural Network (CNN), Deep Neural Network (DNN), SVM (Support Vector Machine), DCNN that can diagnose ROP and its severity. Hence, a Non-ophthalmologist can predict ROP and advise them according to its severity level.

The study focuses on the methods for diagnosing Diabetic Retinopathy for adults using Deep Convolutional Neural Network (DCNN) with fractional max-pooling [1].

It also focuses on various methods prevailing in Deep Neural Networks (DNN) to detect the existence of ROP, severity of ROP [3]. The performance of DNN for automated screening of ROP can be evaluated using transfer learning algorithm [2]. A tool for detecting the stage and zone of ROP in infants at the earliest has been provided [4]. The occurrence of ROP with plus disease using the Gabor Filter approach [7] has also been discussed.

In summary, based on machine learning and deep learning algorithms, a comparative study on each algorithm has been prepared focusing on the methodology, accuracy, specificity and sensitivity, thereby, diagnosing Retinopathy of Prematurity and Diabetic Retinopathy has made easier and prevents from blindness by choosing the algorithm that best fits. Section II consists of a survey of various algorithms / models used in detecting ROP and Diabetic Retinopathy. Section III focuses on the statistical diagram for various approaches. Section IV concludes the paper. Section V gives comparison of papers studied with their approaches.

II. LITERATURE SURVEY

A. Deep Convolutional Neural Network (DCNN) with fractional max-pooling

Yung-Hui Li [1] introduced a Deep Convolutional Neural Network(DCNN) based algorithm to detect Diabetic Retinopathy(DR) in its early stage.

Max-pooling layers in traditional DCNN approach was replaced with a fractional max-pooling layers thereby making the size of the output matrix to be equivalent to fractional times that of the input matrix after pooling. Two DCNNs with fractional max pooling were trained to derive more discriminative features for classification. SVM classifier was trained to learn the underlying distribution boundaries for each class.

An app called “Deep Retina” has been developed that classifies the stages of DR into five categories ranging from level zero to four. The accuracy of 86.17% has been achieved for five class classifier. Accuracy of 91.05%, sensitivity of 89.3% and specificity of 90.89% has been achieved for binary class classification.

B. Transfer Learning

Yinsheng Zhang and Li Wan[2] developed an automated screening system for detecting ROP in wide angle retinal image using Deep Neural Network(DNN). System of transfer learning was introduced to train DNN classifier. Unqualified images are removed in preprocessing stage.

Then the qualified images are transferred to five different opthalmologists to categorize the images into ROP positive and negative using DNN classifier via AlexNet, VGG-16 and GoogleNet. The classification accuracy, sensitivity and specificity of each DNN classifier is noted and ROC curve has been plotted based on the results achieved. Among the three DNN classifiers, VGG-16 gives the best performance.

Its limitations lie in the fact that it is transparent and needs more clear information like how it works internally. It does not include zones, stages of ROP and more complex ROP, AP-ROP.

C. Deep Neural Network(DNN) Model

Jianyong Wang[3] developed an automated diagnosing ROP system named ‘Deep ROP’ using Deep Neural Network(DNN). The system has two DNN models namely Id-Net for ROP Identification and Gr-Net for Grading tasks. Id-Net was used to check whether the patient has ROP or not.

Gr-Net was used to check the severity level of ROP. It was graded as “Minor ROP” or “severe ROP”. Deep ROP system has achieved sensitivity of 84.91% and specificity of 96.90% for ROP Identification. Whereas, for ROP grading, sensitivity and specificity achieved was 93.33% and 73.63% respectively.

D. Staging and Classification for ROP

Deepthi Badrinath and Chaitra[4] introduced a tool for diagnosing the stages and zones of ROP, thereby, preventing the child from blindness at the earliest. There are 5 stages and 3 zones in ROP. The severity of ROP can be found by knowing, on which stage the ROP is present.

The extent and location of ROP can be sought out using zone level. Therefore both stage and zone determines the overall severity level of ROP. The distance between the optical disc and ridge i.e. Euclidean Distance evaluates the stage, Stage 1 consists of a thin line of demarcation named Ridge, which is not severe. Stage 2 consists of a thick ridge. In stage 3, ridge contains a fibro vascular proliferative tissue which can be extended into Vitreous. Stage 4 and stage 5 requires immediate surgery. Overall severity level has been classified into four levels ranging from very mild(1), mild(2), moderate(3) and severe(4).

E. Deep Neural Network with Feature Aggregate Operator

Jungie Hu[5] proposed a methodology in combination with Convolutional Neural Networks (CNNs) to diagnose the existence and severity of ROP called Deep Neural Network. The methodology consists of three stages, namely Feature Extraction, Feature aggregation and Classification. Feature extraction allows the images of the fundus to extract high-level features. The resulting high-level features from all the images are aggregated using an aggregate operator and the output of an aggregate operator was passed into a subnetwork to predict its class of ROP. The classification accuracy of 97% (Normal & ROP) and 84% (Mild & severe) was achieved. The sensitivity and specificity of DNN are 82% and 64% respectively.

F. Support Vector Machine (SVM)

Santhakumar. R[6] proposed a screening tool that works under the principle of Patch level prediction algorithm. The algorithm uses Support Vector Machine (SVM) model in order to diagnose the region of Diabetic Retinopathy and classify them as Normal, Hard Exudates and Hemorrhage. The patch level classifier performed well with an accuracy of 96 % in the case of Exudates and 85% in the case of Hemorrhage. It has reached the specificity of 96% and a sensitivity of 94%

G. Multiscale Gabor Filter Approach

Sivakumar R[7] introduced a computer aided screening of ROP using Multiscale Gabor Filter approach. The occurrence of plus disease indicates the presence of Rop. The methodology consists of image enhancement, segmentation of retinal blood vessel, optic disc removal, binarization and skeleton extraction, calculation of total length of tortuous vessel segments, finding the width of a blood vessel and evaluation of the presence of ROP. The severity of Plus disease was identified by increasing the length of tortuosity and large blood vessel width. The blood vessel is delineated from retinal images using GF approach, thereby helped clinicians to detect blood vessels accurately in the initial screening of ROP. Images are classified as either plus, preplus or normal by measuring the amount of tortuosity and width from the vessel map of each image. An overall sensitivity of 1.0 and specificity of 0.92 has been achieved. Selection of suitable scale and execution time are the major problem, as the number of scale value increases execution time also increases.

III. STATISTICS ON VARIOUS APPROACHES

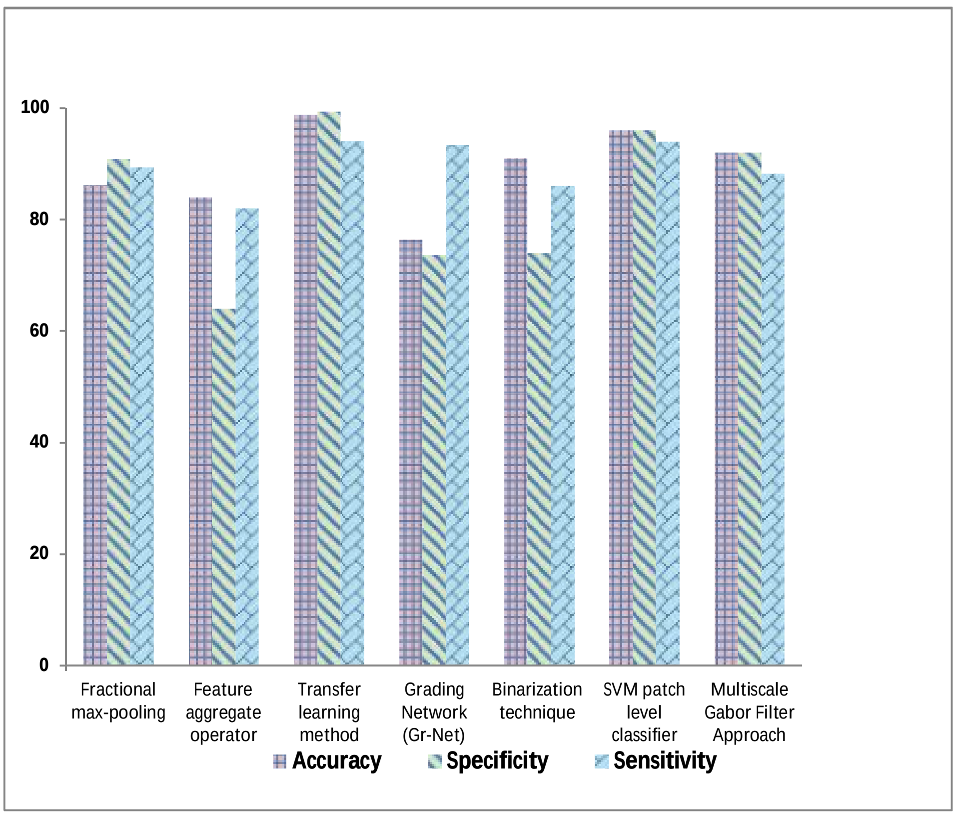

Figure 1. Performance measures of algorithms studied

IV. CONCLUSION

Deep Learning has achieved tremendous growth in the field of medicine. The study outlined the various deep neural network approaches that are available to diagnose ROP and DR in its early stage. Each approach has its own performance measures and limitations. Based on the comparative study, one can choose the approach that best suits their need.

Deep Neural Network with transfer learning produces high accuracy, specificity and sensitivity compared to other methods. The presence of ROP & DR from normal eye and its severity can be found using Deep Convolutional Neural Network (DCNN/ DNN). One can also include findings of stage, zone and presence of plus disease using binarization technique and by calculating the centroid and Euclidean distance. Finally, the developed automated deep learning screening system of ROP and Diabetic retinopathy can be deployed in cloud environment thereby enabling non-ophthalmologists and neonatal centers in underprivileged and remote areas to diagnose ROP / DR in its early stage. Tremendous amount of training data is needed to develop such system. Deep learning becomes challenging with more image data, thereby increasing the performance effectively and efficiently.

V. COMPARITIVE STUDY OF LITERATURE SURVEY

TABLE 1. Comparison of Different Approaches and Their Performance

S.No	Title of the Paper	Methodology/ algorithm used	Performance Measures	Limitation of the paper
1	Computer-Assisted Diagnosis for Diabetic Retinopathy Based on Fundus Images Using Deep Convolutional Neural Network	Deep Convolutional Neural Network (DCNN) with fractional max-pooling	Accuracy : 86.17% Specificity : 90.89% Sensitivity : 89.30%	Difficulty in training the data with one or more convolutional layers. Hence, the numbers of images trained are not sufficient.
2	Development of an Automated Screening System for Retinopathy of prematurity Using a Deep Neural Network for Wide-Angle Retinal Images	Deep Neural Network using transfer learning method	Accuracy : 98.8% Specificity : 99.3% Sensitivity : 94.1%	Its black box, Not transparent. It does not include acute ROP, AP-ROP, Stages, and zones as well as plus disease.
3	Automated retinopathy of prematurity screening using deep neural networks	Deep Neural Network models with Identification Network (Id-Net) and Grading Network (Gr-Net)	Accuracy : 95.55% 76.42% Specificity : 96.90% 73.63% Sensitivity : 84.91% 93.33%	Number of severe ROP was not enough. It does not include stage, zone and plus disease of ROP.
4	Study of clinical staging and classification of Retinal Images for Retinopathy of Prematurity Screening	Binarization technique and calculation of Euclidean distance	Accuracy : 91% Specificity : 74% Sensitivity : 86%	Number of sample images taken was very less.
5	Automated Analysis for Retinopathy of Prematurity by Deep Neural Networks	Deep Neural Network with feature aggregate operator	Accuracy : 84% Specificity : 64% Sensitivity : 82%	High computation
6	Machine Learning Algorithm for Retinal Image Analysis	Support Vector Machine (SVM) patch level classifier	Accuracy : 96% 85% Specificity : 96% 85% Sensitivity : 94% 77%	It works well with hard exudates but quite low for haemorrhage and normal images.
7	Computer Aided Screening of Retinopathy of Prematurity- A Multiscale Gabor Filter Approach	Multiscale Gabor Filter Approach	Accuracy : 92% Specificity : 92% Sensitivity : 88.16%	The execution time increases as the scale value increases. Also, selection of suitable scale value was difficult.

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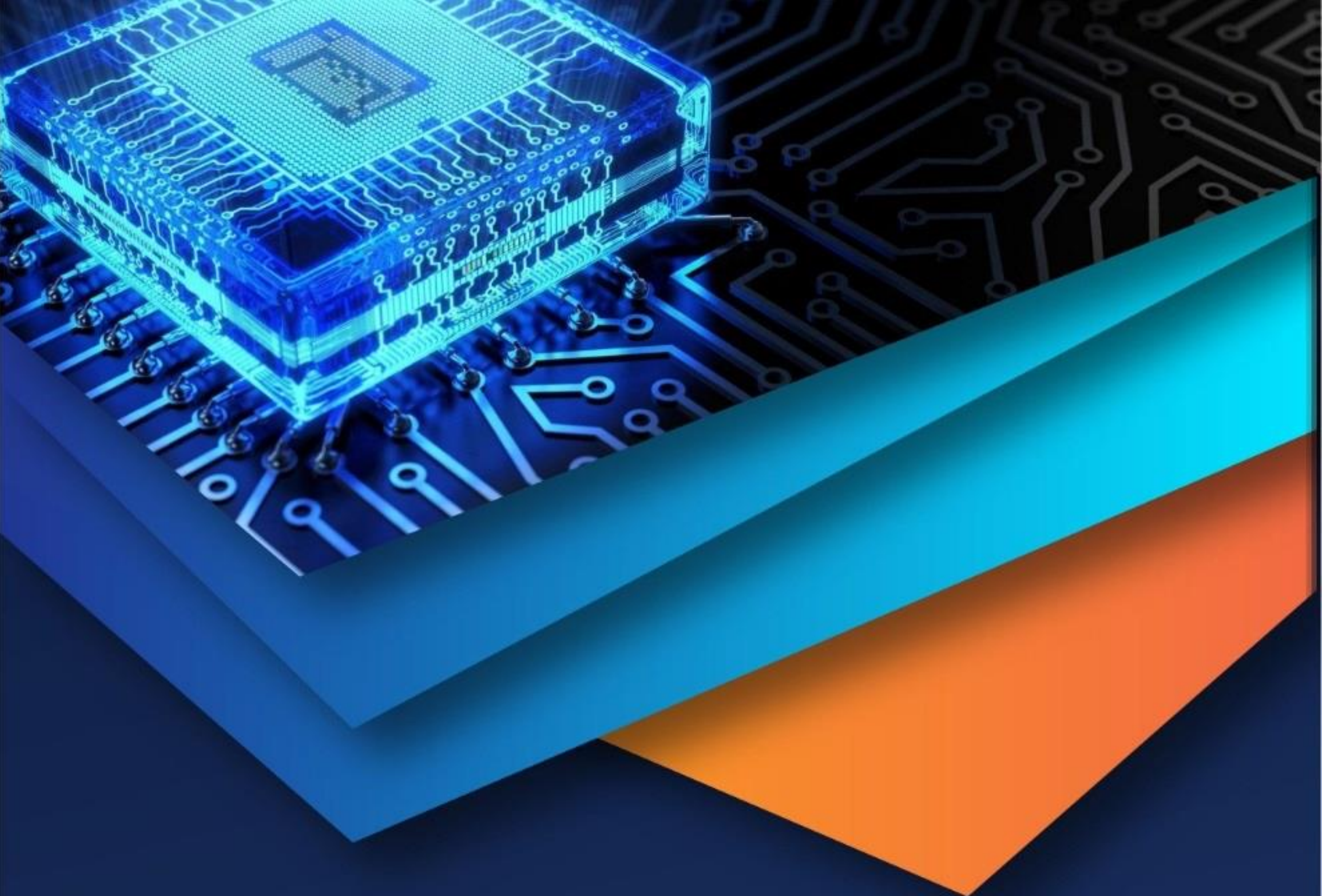

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