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Ocular Diseases Detection Using Machine Learning, Deep Learning and Artificial Intelligence Based Techniques

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Abstract: Glaucoma is one the most common and rapidly increasing eye disease. Glaucoma is a condition which affects the retina and is the most common reason for blindness. Glaucoma cannot be detected in its initial stages as it does not show any of its symptoms. Glaucoma was estimated to affect 60 million people in 2010. In 2020,the glaucoma disease affects around seventy-six million people more, which is expected to rise to 111.8 million by 2040. Early diagnosis and treatment is necessary. Along with expert doctors and health professionals, computer aided techniques will be more useful for early and accurate diagnosis and certainly a great help for the medical professionals.Hence, there are many techniques such as deep learning, machine learning and artificial intelligence techniques to detect glaucoma. For glaucoma classification and identificationthereare different deep learning modelsthat have been reviewed in this work which are Inception-V3, Vgg-16, ECNET, Convolution Neural Network (CNN), Deep-Belief Network, EffcientNet and UNet++ models. Machine learning models have also been reviewed in this work for glaucoma diagnosis which are LSSVM(Least Square-Support Vector Machine), XGboost model, Fundus and OCT, SVM.To the best of our knowledge, this is the only comprehensive study which encapsulates various computer-vision based techniques for glaucoma disease detection.

Keywords: Glaucoma; Deep Learning; Artificial Intelligence; Machine Learning; Retinal Images; Fundus Images; Classification.

1. Introduction

The human eye is one of the major organs of human body that provides humans with the ability of vision. Retina plays an essential role in the visual system. There are many eye diseases which affect the visual system and glaucoma is one of them. Glaucoma is a condition that affects the retina and is the most common reason of blindness. The rise in fluid pressure can originate glaucoma[1]. Glaucoma is frequently termed as a ”quiet thief of sight” [2].

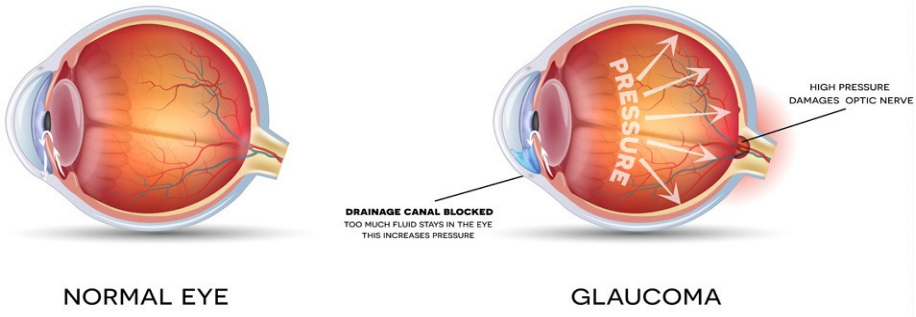

Figure 1. Differentiation between Normal and Glaucoma Eye

Figure 1 demonstrates the difference between normal eye and effected eye. In glaucoma eye, it is evident that the fluid stays in the eye due to the blockage in the drainage canal which later on causes an increase in its pressure. The optic nerve is damaged as a result of the excessive pressure. Most of the time, Glaucoma occurs because of the high pressure on the eye that is known as the intraocular pressure and then it becomes the cause of damaging the optic nerve existing on the retinal part of the eye. The retinal part is made up of many parts like macula, exudates ,fovea etc. [3]. Glaucoma being present on, one of the above-mentioned parts of the eye, the (OD) optic disc. The anatomy of the retina is mentioned in Figure 2.

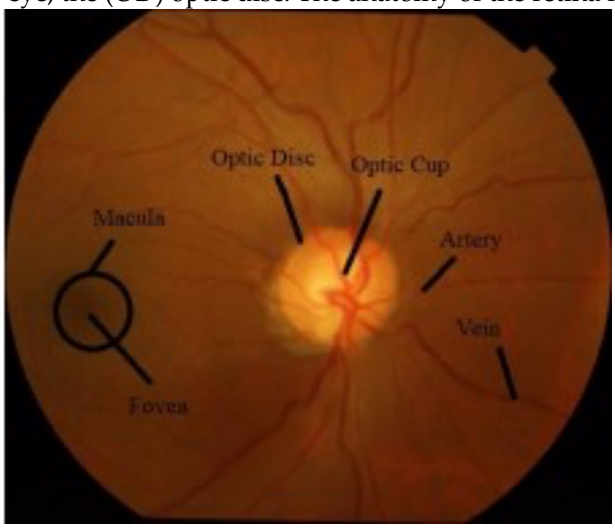

Figure 2. Anatomy of Retina

One of the two major categories of **glaucoma** is the open-angle glaucoma and the second one is the close-angle glaucoma. The basic category which is open-angle glaucoma defined as the painless condition that results in the unexpected visual loss[4].The danger of developing glaucoma becomes enormous because the pressure of eye in terms of sensitivity is increased. Close angle glaucoma which is other prevalent kind in which the drainage angle of the eye and the iris are near to each other.

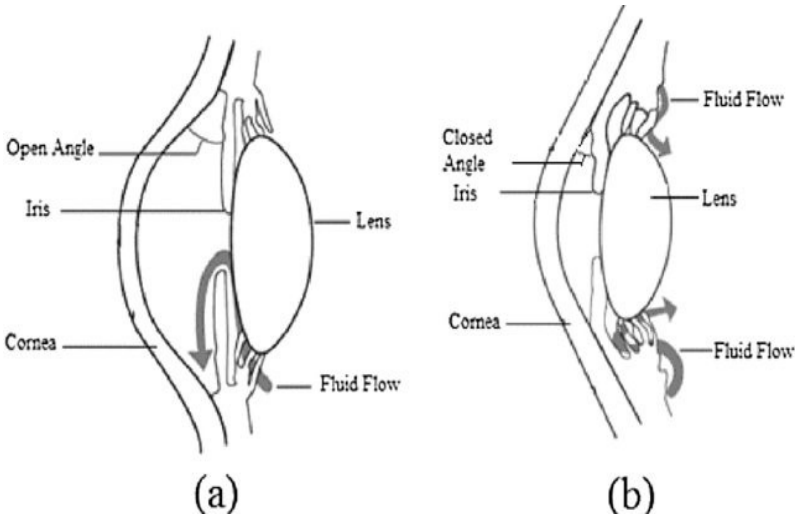

Figure 3. (a) Open-Angle Glaucoma (b) Close-Angle Glaucoma

Based on this activity, an acute attack can potentially result in the permanent loss of the vision. There can be multiple symptoms of such an attack, including nausea, vomiting, hazy vision, and extreme eye discomfort. The detection of Glaucoma on an initial stage can make it is possible to avoid blindness. The major concern while diagnosing the disease is that it don't show the symptoms at initial stages. The disease becomes visible in the latest phase while the patient have missed more than 50 percent of eyesight[5]. Therefore, regular eye screening is required for the early diagnosis of glaucoma.

Glaucoma was estimated to affect 60 million people in 2010.Glaucoma is about to affect 64.3 million people which are in age group of40and so on in globally. In 2020,the glaucoma disease is affect around seventy-six million people more which is rising to 111.8 million by 2040[6], [7].

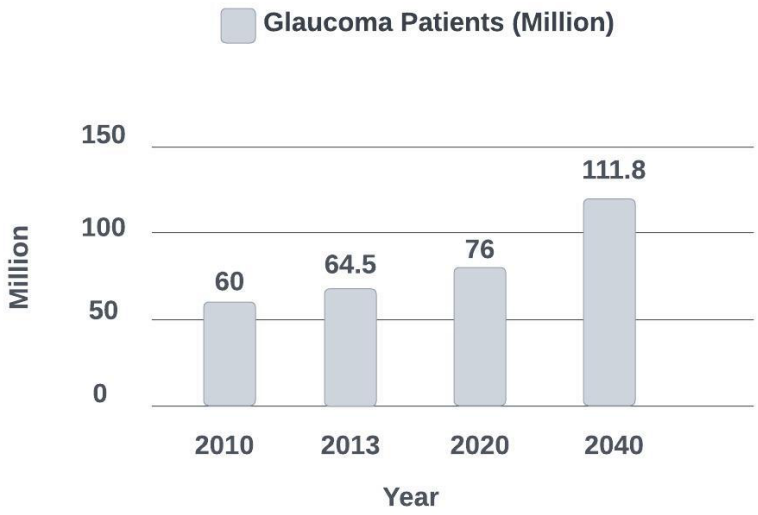

Figure 4. Glaucoma Patients affected in recent years

Figure 4. Shows the number of patients affected through glaucoma in 2010 to 2040.This graph shows how increasingly glaucoma disease is affecting the people. Glaucoma is becoming more common, even in urban areas.

There are several tests in medicine that are designed to help with the diagnosis and check out of this disease, such as the test of visual field. Visual field test is the most significant which provides a direct measurement of visual function. Recently, computer-aided diagnostic technology has been utilized to diagnose glaucoma by using machine learning classification algorithms to analyze the visual field test, optic nerve, corneal thickness, and intraocular pressure [8].

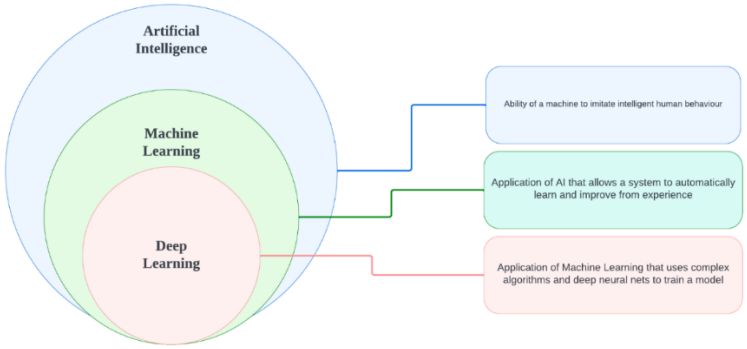

Figure 5. Relationship Between DL, ML and AI

These are various deep learning models used in computer vision and image analysis tasks[9]. The models listed variations of these models, such as Inception ResNet, ResNet50v2, and DenseNet[10]. They are utilized for the variety of jobs such as image segmentation (UNet++), object classification (AlexNet, GoogleNet), and medical image analysis (Retinal nerve fiber layer (RNFL) segmentation).

In this work, glaucoma classification has been performed using deep learning, artificial intelligence, and machine learning. This work presents a survey of glaucoma detection through various methodologies. The survey presented the accuracy and other performance measures of various methodologies.

2. Challenges and Limitation

This work presents classification of glaucoma in deep learning, machine learning, CNN and artificial intelligence models which evaluate various performance measures like accuracy, sensitivity, specificity and precision. Following are the challenges regarding these factors are mentioned below:

One of the challenges to detect glaucoma is the image quality provided in the datasets. The limitation of Deep learning model Inception v3 to detect glaucoma is that it is computationally quite expensive and

requires many resources for computations which cause time consuming. The limitation of Machine learning model SVM is that it doesn't work well for noisy datasets. One of the limitations to detect glaucoma through deep learning model of Vgg16 is that it does not work on the sensitivity and specificity parameter of proposed research. One limitation of glaucoma detection using smartphone ophthalmoscope is that it does not work on Brazil glaucoma. Another limitation of glaucoma detection using analysis of RNFB is that will work only on the dataset of ORIGA. One limitation of glaucoma detection using machine learning is that it will work only on the dataset of MIAG.

3. Taxonomy of Glaucoma Detection

There are many ways to detect glaucoma. This work provides glaucoma classification using deep learning, artificial intelligence and machine learning techniques. For glaucoma classification and identification there are different deep learning models that have been reviewed in this work such asInception-V3, Vgg-16, ECNET, Convolution Neural Network(CNN), Deep-Belief Network, EfficientNet and UNet++ models, Multi-layer Perceptron(MLP), OC and OD Segmentation, DenseNet, MobileNet, Inception ResNet, Resnet50v2, Resnet101, Xception , AAA(Artificial Algae Algorithm),Retinal nerve fiber layer (RNFL),AlexNet, GoogleNet.

Similarly, Machine learning models have also been reviewed in this work for glaucoma diagnosis which are LSSVM (Least Square-Support Vector Machine), XGboost model, Fundus and OCT, SVM, Neural Network, Ad boost, UNet, OCT as shown in Table1.

Artificial Intelligence models which have been reviewed in this work for glaucoma detection are GlauNet, Segmentation of OD figure 5.

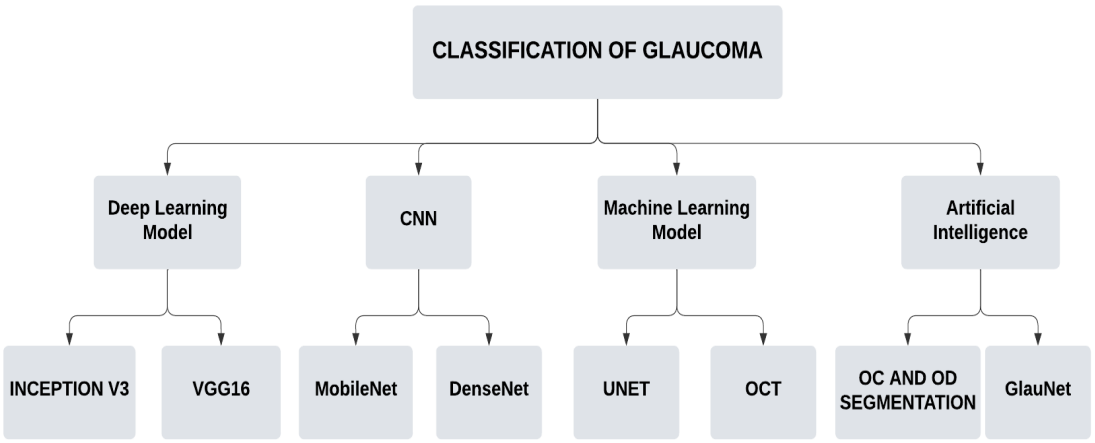

Figure 6. Classification of Glaucoma

3.1. Inception V3

Inception V3 is model of deep learning which is used for image classification[11]. Inception V3 is a better version than the basic version of Inception V1 and Inception V2. Inception V3 has 48 layers and it is quite efficient. It is less expensive in terms of computing. The proposed work has two distinct neural networks of deep learning which are named as Inception-V3 and the other is Vgg-16. The research contains 508 fundus photos from 25 different classes. For our Machines, the dataset was categorized into training (about 70%) and testing (around 30%). Examined two approaches and compared their accuracy, and the proposed methods, InceptionV3, produced good outcomes rather than Vgg-16. Inception-V3 accuracy of testing was approximately 90.01% whereas Vgg-16 testing accuracy was 83.46%. Inception-V3 produced a better outcome than Vgg-16 because it has a more convolutional layer.

In[12]a dataset for glaucoma assessment which is known as Brazil classified in the two categories one with glaucoma around 50 percent and the other without 50 percent. Novelty in dataset was used as input to an ensemble based convolutional neural network in order to construct deep learning technique. The outcomes demonstrated the suggested technique can correctly detect glaucoma by using fundus images

with accuracy of 90%. The sensitivity obtained from this study is 0.850 and the specificity is 0.960.The study proposed a method for diagnosing glaucoma. It used nine deep learning models for the classification stages. Pre-trained models such as AlexNet, Google Netetc.

3.2. VGG16

VGG16 refers to the VGG model, commonly known as VGGNet. It is a 16-layer convolution neural network (CNN) model based on convolutional layers of thirteen and 3 layer of entirely connected. The VGG16 algorithm detects and classifies objects. It is a popular image classification technique that works well with transfer learning. The drawback is that it takes a long time to train. It also consumes a lot of memory space and bandwidth, making it inefficient. The proposed work has two distinct neural networks of deep learning which are named as Inception-V3 and the other is Vgg-16.The publication contains 508 fundus photos from 25 different classes[13].

3.3. CNN

CNN model is frequently used for image processing which are based on one or more layers of convolutional. ConvNet is another name for it. The benefit of this model is that it can explore essential features of image processing without being involving the aid of human. CNN limitations include the fact that a big data of training is needed for CNN to be effective and that they fail to encode the position and orientation of objects. Glaucoma detection through the network of deep belief[14].There are 1338 retinal pictures in the dataset. The effectiveness of proposed model can be evaluated using performance criteria such as sensitivity, specificity, and accuracy, precision. Results of model demonstrated the performance measures involving precision of 87.05% and specificity of 97.35% and sensitivity of 82.48% and accuracy of 88%.The study[15], entropy-based assessment used to determine OC, OD boundary. The approach assessed the performance measures to diagnose glaucoma. The model reports the results which can detect glaucoma with an accuracy of 98% for OC and 99% for OD, a sensitivity of 0.987 for OC and 0.9931 for OD, and a specificity of 100% for OC and 100% for OD. The efficient glaucoma structure is used to calculate CDR. In order to provide more accurate result, proposed method utilizes different architectures. The dataset used for this purpose is DRISHTI and database of GS which provides accuracy for OD is 98%and for OC provides accuracy is 97%.The dataset of Brazil glaucoma used for this methodology which comprises 2000 pictures. Results of proposed methodology demonstrated that proposed technique will give90.0% accuracy and a specificity of 0.960 and sensitivity of 0.850and a precision of0.955.

3.4. UNET

In 2015 presented the model of U-net. The u-net is a fast and precise picture segmentation tool. U-Net is a semantic segmentation technology that was developed first for medical imaging segmentation. The work presented inEfficientNet and UNet++ models are used to detect glaucoma. The data sets utilized are DRISHTI-GS, RIM-ONE. The outcomes of models demonstrate the accuracy of 88.5%.The methodology is the combination of deep learning with image processing and machine-based learning. Architecture of the model which is LE-NET used for the purpose of validation of picture while the brightest spot technique is used for ROI recognition. The classifiers such as Neural Network and Adaboosting SVM are utilized for the classification purpose. For input picture validation, Le-Net achieves 99% accuracy. The methodology achieved performance measures such as accuracy with 100% with the usage of proposed classifiers.

3.5. OC and OD Segmentation

For glaucoma identification, the segmentation technique is quite efficient. In this process, a network is used for detection of objects. The presented methodology which is based on segmentation to detect glaucoma[17]. To provide more accurate results, the presented method utilizes the two models which employ the dataset DRISHTI with database of GS, yielding with 98% accuracy for OD and for OC yields 97% accuracy. The proposed method suggests detection of glaucoma which is based on Artificial Intelligence. Two networks are proposed for improving the performance which are named Slsrnet and Sls-net. Results of proposed technique showed accuracy of 99.6% and 99.7% for OC99.8% and 99.8% for OD. Sensitivity are 0.930 and 0.947 for OC, 0.957 and 0.986 for OD while specificity are 0.998 and 0.998 for OC, 0.999 and 0.999 for OD.

3.6. Densenet

A DenseNet is a sort of convolutional neural network in which each layer receives additional inputs from all previous layers and sends them on to all succeeding layers[18].The presented methodology is based on smartphone ophthalmoscope. The dataset of Brazil Glaucoma comprises of 2000 pictures. Results demonstrated that technique gives 90.0% accuracy and a specificity of 0.960 and sensitivity of 0.850and a precision of0.955.The presented work diagnosing glaucoma disease by assessing retinal nerve fiber layer damage (RNFL). A new step-by-step preprocessing strategy. It used nine deep learning models for the classification stages. Pre-trained models used are AlexNet, GoogleNet and so on. In ORIGA dataset, it tested the proposed technique and attained the best accuracy of 92.88%.

3.7. Mobilenet

The framework of MobileNet is simplest which is defined as small, low-latency, and low-power and can be used for segmentation, identification, and other common tasks. The work presented in [19] based on smartphone ophthalmoscope. The dataset of Brazil Glaucoma used for this methodology which comprises 2000 pictures. Results demonstrated that the technique gives 90.0% accuracy and a specificity of 0.960 and sensitivity of 0.850and a precision of0.955.

3.8. Inceptionresnet

Inception ResNet is a convolutional neural network trained on over a million images in the ImageNet collection. It can categories images into 1000 different object categories. Smartphone ophthalmoscope based approach is presented in[20].The dataset of Brazil Glaucoma used which comprises 2000 pictures. Results demonstrated that the technique will give 90.0% accuracy and a specificity of 0.960 and sensitivity of 0.850and a precision of0.955.

Diagnosing glaucoma disease by assessing retinal nerve fiber layer damage (RNFL)[21]. Step-by-step preprocessing strategy is presented. It used different deep learning models for the classification stages. Pre-trained models used are AlexNet, GoogleNet and so on. In ORIGA dataset, this technique attained the best accuracy of 92.88%.

3.9. OCT

In OCT images are created of back of your eye using reflected light. It can be used to diagnose and treat disorders such as diabetic retinopathy and glaucoma[22].According to [23] DBN based technique is proposed to identify glaucoma. There are 1338 retinal pictures in the dataset. The effectiveness can be evaluated using performance measures including precision and sensitivity and accuracy and specificity. Results show that the Glaucoma-DBN model reports with 82.48% sensitivity and 88% accuracy and 87.05%precision and 97.35%specificity.

Entropy-based assessment[24] used to determine OC, OD boundary. The approach assessed the performance measures to diagnose glaucoma. The model reports the results which can detect glaucoma with an accuracy of 98% for OC and 99% for OD, a sensitivity of 0.987 for OC and 0.9931 for OD, and a specificity of 100% for OC and 100% for OD.

4. Performance Matrix

Performance Metrics are the quantitative assessments used to assess the impact of research outcomes. To evaluate classification models following matrices including and Accuracy, Specificity and Sensitivity are used as shown in Table1.

Accuracy is used to assess model performance by calculating true positive ration by true negatives based on all predictions made.

$$ACC=\frac{TP + TN}{TP + FP + TN + FN}$$

In equation (1) TP represents the number of True Positive, TN illustrates the number of True Negatives. FP indicates the false positive and FN indicates the false negative.

Sensitivity is used to assess performance of the models as it indicates how many positive instances the model accurately identified.

$$SEN=\frac{TP}{TP + FN}$$

Specificity defined as proportion of true negatives properly detected by the model.

$$SPE = \frac{TN}{TN + FP}$$

The values of accuracy, sensitivity and specificity are defined in terms of low, medium and high in the above table. The term "Low" defined the values between 83-88%. The term "medium" defined the values between 89-94% and the term "high" defined the values between 95-100%.

5. Discussion and Future Work

This work presents a comprehensive review of machine learning, deep learning and artificial intelligence-based approaches of glaucoma detection. For glaucoma classification and identification there are different deep learning models that have been reviewed in this work which are Inception-V3, Vgg-16, ECNET, Convolution Neural Network (CNN), Deep-Belief Network, EfficientNet and UNet++ models. Machine learning models have also been reviewed in this work for glaucoma diagnosis which are LSSVM (Least Square-Support Vector Machine), XGBoost model, Fundus and OCT, SVM.

In future multiple works on various directions can be performed. Detection of glaucoma on the bases of deep learning models reviewed in this work lacks image enhancement, similarly deep learning model which is Inception v3 has expensive computational cost. Deep learning model such as Vgg16 lacks in sensitivity and specificity parameter. Machine learning model SVM lacks the ability to work with noisy datasets.

6. Conclusion

This work presents glaucoma classification based on deep learning, artificial intelligence, and machine learning approaches. For glaucoma classification and identification, different recent deep learning models that have been reviewed in this work such asInception-V3, Vgg-16, ECNET, Convolution Neural Network(CNN), Deep-Belief Network, EfficientNet and UNet++ models, Multi-layer Perceptron(MLP), OC and OD Segmentation, DenseNet, MobileNet, Inception ResNet, Resnet50v2, Resnet101, Xception , AAA(Artificial Algae Algorithm),Retinal nerve fiber layer (RNFL),AlexNet, GoogleNet. Similarly, Machine learning models have also been reviewed in this work for glaucoma diagnosis which are LSSVM (Least Square-Support Vector Machine), XGBoost model, Fundus and OCT, SVM. Comparison of various techniques have been presented along with pros and cons of latest techniques have been discussed.

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