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Original Paper

STUDY ON PREDICTION OF GLAUCOMA USING FEATURES OF OPTIC NERVE HEAD FROM RETINAL FUNDUS IMAGES OF EYE

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Abstract

Glaucoma is one of the leading causes of blindness because since it is very slow in progress without any symptoms or pain in eyes. It can be diagnosed only by taking proper eye tests like perimetry or OCT at regular intervals. These tests are expensive and available to very few ophthalmologists. In this paper we have reviewed research done in the field of detecting glaucoma and predicting it before it starts damaging the eye. We have observed that deep learning techniques were used by most of the researchers with SD-OCT images and Fundus images as well. In this paper, we try to collaborate all the techniques of deep learning models with different data along with their accuracy. We conclude that all though deep learning is used by many researchers it can be improved with retinal Fundus images to make detection and prediction cost effective and easily available for patients.

Keywords

Fundus Images, RNFL, Optic Cup, Optic Disc, Deep Learning, Glaucoma.

1. Introduction

Glaucoma is one of the most popular diseases leading to blindness in the world. It mostly affects people of age-group more than 40 by its most common form – Open Angle Glaucoma. According to Bright Focus Foundation, 2019, there are more than 3 million people living with Glaucoma in America only, out of which 2.7 million are of age above 40 [1]. In 2020, 80 million people were suffering with glaucoma and this number is likely to get increased to over 111 million by 2040 [1]. Glaucoma not only affects human heath but also results into economic loss to a country by direct cost and productivity losses. Glaucoma damages the Retinal Nerve Fibre Layer (RNFL) which is responsible to send visual signals to the brain because of increased Intraocular Pressure (IOP) [2]. Detection of glaucoma in its very early stage is essential but it becomes challenging because of lack of awareness of the disease. Progression of Glaucoma is examined on the retinal part of the eye by experienced ophthalmologist. It becomes time consuming if done manually and also accuracy depends on the expertise of the ophthalmologist. Optical Coherence Tomography (OCT) images can provide thickness of Retinal Nerves in RNFL and can be very helpful in detecting Glaucoma but taking OCT images at regular interval without any prior symptoms can also be expensive. Glaucoma should be predicted using only retinal Fundus images of eye taken from normal Ophthalmoscope available to most Ophthalmologists and Computer vison techniques to get accurate result which is also cost effective. In this paper, we have studied different approaches

taken for prediction of Glaucoma using either fundus images or OCT images. We have reviewed different Datasets used, Methodologies and different features of fundus or OCT images.

1.1 Retinal fundus image

Retinal Fundus image is taken from widely available ophthalmoscope or sometimes called fundus camera, which takes back view of the eye as shown in Fig-1. This back view image contains features of Optic Nerve Head (ONH) from where the Retinal nerves pass. This ONH and its surrounding area contains important features like Optic Cup (OC), Optic Disk (OD), RNFL Texture, Notching and Blood vessels, which can be used to detect and even predict glaucoma prior to vision loss.

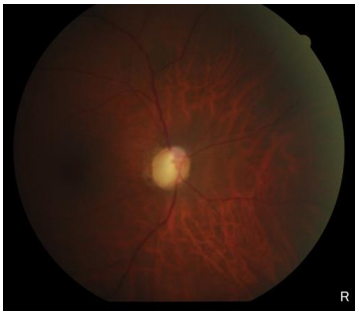

Figure - 1 Retinal Fundus Image

1.2 Glaucoma diagnosis using fundus photograph

Retinal Fundus Images can be used to diagnose Glaucoma using clinical analysis like Cup to Disc Ratio (CDR), Distance between Cup and Disk at Inferior, Superior, Nasal and Temporal (ISNT), Colour Brightness of Optic Cup, Blood Vessel displacement within Optic Cup and some other techniques as well. Some of the techniques like CDR and ISNT cannot be used before Glaucoma starts damaging the nerves and vision loss has taken place at its beginning level. To prevent Glaucoma before partial vision loss, RNFL damage need to get detected at its very early stage. Researchers have performed very important research and we review some of the important research in this paper.

2. Literature review

H. N. Veena et. al. [2] proposed Convolutional Neural Network to detect Optic Cup and Optic Disc to calculate CDR for detection of Glaucoma using retinal fundus images, in 2021. Model was trained and tested on DRASHTI-GS public dataset. They achieved 98% and 97% accuracy in detection of Optic Disc and Optic Cup respectively. Proposed technique uses CDR as a feature, but the accuracy of Glaucoma detection is not mentioned. In addition, results can be improved by adding more features like ISNT measurement and RNFL.

In 2021, Younji Shin et.al [3] evaluated performance of deep learning classifier in detecting glaucoma. Here, wield-field OCT images were used. Method was tested on 675 images that includes 258 healthy images and 417 glaucomatous images and results were compared with diagnosis ability of conventional parameter-based methods. An automated diagnosis system was proposed to detect glaucoma and identify its stage based on images. Methodology achieved an area under the curve (AUC) of 0.987 and an accuracy of 95%. **Gap Analysis:** OCT images can individually detect glaucoma using RNFL thickness features, which gives more accurate results than the proposed method. Also, OCT images are expensive way for detecting glaucoma and cannot be implemented in regular eye check-up.

In the same year, Terry Lee et.al [4], assessed whether the longitudinal changes in a deep learning algorithm prediction of RNFL thickness based on fundus images can predict glaucomatous development or not. The study includes 1072 images of 827 patients with average follow-up of 3-4 years and conclude that RNFL thickness measurements based on fundus photographs can be used to predict risk of glaucoma conversion in eyes.

In 2021, Sampson L. Abu et. al. [5], compared frequency of detecting glaucoma progression using RNFL thickness and Visual Field analysis and conclude that RNFL thickness is more appropriate feature to access compared to Visual Field analysis in Open-angle Glaucoma. The Study was performed on 194 patients with minimum of 9 follow-ups, selected from Diagnostic Innovation from Glaucoma Study (DIGS). Result of this experiment leads to conclusion that RNFL assessment is 33% better than Visual Field assessment and better suited to monitor Glaucoma.

In the year 2020, Anshul Thakur et. al. [6], proposed deep learning model for predicting glaucoma several years before disease onset. Research was conducted using data from a prospective longitudinal study. 66,721 fundus photographs from 3,272 eyes of 1,636 patients were used who participated in Ocular Hypertension Treatment Study (OHTS). Area Under the Curve (AUC) of prediction of glaucoma before 4 to 7 years disease onset was 0.77 and before 1 to 3 years disease onset was 0.88.

In the same year, J. Josphin Mary et. al. [7], proposed deep learning model for predicting glaucoma. Experiments were carried out on ORIGA and SCES datasets. No accuracy is defined in paper, but the result is defined as AUC (Area under the curve) is higher than the state-of-the-art algorithms.

In March 2020, Mark Christopher et. al. [8], proposed another deep learning approach to predict glaucoma using SD-OCT images with features of RNFL thickness map and GVFD (Glaucoma Visual Field Damage). Model was trained using 9,765 pairs of SD-OCT images and result was calculated with measurement of AUC. Researcher shows that RNFL enface image achieve AUC of 0.88 for identifying eyes with GVFD and 0.82 for detecting mild GVFD which is better than RNFL Thickness measurement which results AUC of 0.82 and 0.73 for identifying and detecting mild GVFD respectively, and it is concluded that Deep Learning model outperformed standard RNFL thickness measurements.

In 2019, RishavMukharji et. al. [10], evaluated retinal fundus images for early detection and treatment of Glaucoma using notch along the neuro retinal rim. Methodology was developed to automate prediction of Glaucoma based on focal notching and CDR feature analysis. Algorithm was tested on freely available dataset of 101 images marked with five glaucoma experts returning accuracy of 87.12%. Features used in this methodology was developed once patient is already suffering from Glaucoma so the algorithm can be improved to detect RNFL which can play important role in predicting Glaucoma before it actually starts vision loss.

In 2018, Mark Christopher et. al. [11] applied computational technique to OCT images to identify glaucoma related structural features to predict future progression. SS-OCT Images were used with interval of 3 months for 2 Years from 28 healthy patient and 93 Glaucoma patients. Researcher extracted RNFL thickness maps and used unsupervised machine learning approach based on Principal Component Analysis (PCA) for detecting Glaucoma Progression achieving AUC of 0.83 for prediction. Same technique can be used using structural features from Fundus images which is less expensive with high availability.

3. Deep learning based technique

Michael J.A. Girard et. al [9] reviewed how Artificial Intelligence can tackle many challenges faced in the detection and diagnosis of Glaucoma. Many research have been carried out using Machine Learning to enhance the diagnosis process of Glaucoma, but machine learning still needs human generated patterns and marked features to provide satisfactory results and we can't say that the feature and pattern applied by researcher is optimal for the process and that is why most of the researches have not been utilized in clinical process of Glaucoma detection or prediction[12]. In contrast to machine learning, deep learning is a subclass of machine learning which uses "representation learning". Deep Learning algorithm learns patterns from data automatically if enough data are given to them. Collection of large dataset and recent progress in Artificial Intelligence creates great opportunities in development of Deep Learning Model that can be more accurate and quicker in diagnosing Glaucoma damages compared to subjective evaluation. [12] In this article we reviewed some of the famous Deep Learning models and techniques which use Fundus images, OCT or Standard Automated Perimetry (SAP).

Table 1. Literature Review comparison

Author and Year of Publication	**Features and Purpose**	**Method**	**Data**	**AUC / Accuracy**
Younji Shin, 2021 [3]	SS-OCT Images	Deep Learning Classifier	675 OCT Reports	95.90% Accuracy
Sampson L. Abu et. al., 2021 [5]	RNFL Thickness and VF Analysis	Comparison of RNFL thickness and Visual Field	DIGS Study data with 9 follow-ups	RNFL is 33% more accurate than VF analysis
Anshul Thakur et. al. 2020 [6]	Optic Disc and Optic Cup measurements for Prediction	Deep Learning	OHTS Study Data	0.88 AUC of prediction 1-3 years before onset
Mark Christopher et. al. [8]	RNFL Thickness and GVFD	Deep Learning	SD-OCT images	AUC 0.88 for identification of glaucoma with GVFD.

4. Review Analysis

By reviewing different research taken under the deep learning techniques for glaucoma diagnosis we can understand that deep learning gives satisfactory results when it is done with predefined features like thickness of RNFL and size of Optic Cup and Optic Disc. It becomes more challenging when the same technique is applied on Fundus images because it will not give accurate thickness property of RNFL as SD-OCT image. More research can be done using only Fundus image as data and Deep Learning techniques to get good accuracy for detection of glaucoma and also prediction before it starts damaging vision of the patient. Use of Fundus images is more significant because they are available very easily and cost of taking Fundus image is less than taking OCT reports for each patient.

5.CONCLUSIONS

In this review we have analysed different techniques for diagnosis of Glaucoma and predicting its effect before it actually damages the vision of the eye. In our study we found that deep learning techniques are more feasible for feature extraction and classification of Glaucomatous and Normal images, and it is also helpful to predict the damage it causes in RNFL. We also found that most of the research have been taken using SD-OCT Images as it gives accurate thickness measure of RNFL for analysing damage and easy to experiment in deep learning model. We propose that the same experiment can be performed on normal Fundus image to make it cost effective and also for easy availability.

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