

Survey on Automatic Detection of Glaucoma through Deep Learning Using Retinal Fundus Images

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ABSTRACT

Glaucoma - a disease which causes damage to our eye's optic nerve and subsequently blinds the vision. This occurs due to increased intraocular pressure (IOP) which causes the damage of optic nerve axons at the back of the eye, with eventual deterioration of vision. Presently, many works have been done towards automatic glaucoma detection using Fundus Images (FI) by extracting structural features. Structural features can be extracted from optic nerve head (ONH) analysis, cup to disc ratio (CDR) and Inferior, Superior, Nasal, Temporal (ISNT) rule in Fundus Image for glaucoma assessment. This survey presents various techniques for the early detection of glaucoma. Among the various techniques, retinal image-based detection plays a major role as it comes under non-invasive methods of detection. Here, a review and study were conducted for the different techniques of glaucoma detection using retinal fundus images. The objective of this survey is to obtain a technique which automatically analyze the retinal images of the eye with high efficiency and accuracy.

Index Terms— Glaucoma, Cup to disk ratio, classification, retinal fundus images, Optic disk segmentation, Optic cup segmentation

1 Introduction

Glaucoma is a chronic eye disease that leads to irreversible vision loss. The Cup-to-Disc Ratio (CDR) serves as the most important indicator for glaucoma screening and plays a vital role in clinical screening and early diagnosis of glaucoma [1]. It is mainly characterised by optic nerve fibre loss and that is given by the increased intraocular pressure (IOP) and/or loss of blood flow to the optic nerve. In a fundus image, the optic nerve head or optic disc can be visually separated into two zones, a bright and central zone called optic cup and a peripheral part called neuro-retinal rim [2] See Fig.1

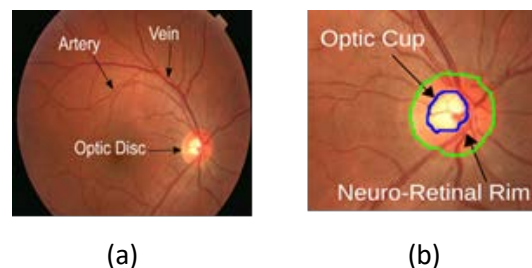


Fig. 1. Digital fundus images. (a) Main structures of an original fundus image and (b) Main structures of the optic disc region.

Clinically, there are three examinations practiced to screen glaucoma: intraocular pressure (IOP) measurement, function-based visual field test, and optic nerve head (ONH) assessment [3].

Glaucoma can be classified into two as open angle and angle closure glaucoma (Fig. 1). Open angle glaucoma is the most common one and it happens when the channels, which drain fluid inside the eye, become blocked due to the increase of intraocular pressure (IOP). It develops slowly and shows only a few signs. So the people may unaware about their sight loss for a long time. Angle-closure glaucoma (ACG) occurs very quickly and produces headaches, blurred vision and pain in the eye. Since ACG happens by a closed or narrow angle between the iris and the cornea, an immediate medical attention is needed [4].

In its early stages, there is no pain and patients often have no symptoms. Over time glaucoma starts to affect your side/peripheral vision and slowly works its way to the middle if left undetected. Early detection is the key to preventing sight loss. It is described by the dynamic degeneration of optic nerve strands and prompts auxiliary changes of the optic nerve head, which is known as an optic plate, the nerve fiber layer and a synchronous practical disappointment of the visual field. Movement of the infection prompts loss of vision, which happens step by step over a drawn-out stretch of time. Glaucoma Hence, recognizing glaucoma in time is basic.

2 Glaucoma Detection – A Survey

The retinal images used are fundus image. Pre-processing of retinal image leads to improvement of image data by suppressing unwanted distortions and by enhancing some image features for further processing. Feature extraction from retinal image incorporates algorithms designed and developed to detect various desired features (shapes) from the retinal images. Retinal image classification analyzes various image features extracted and organizes the data into categories: Non-Glaucoma or Glaucoma affected. The following papers used different methods on the fundus images to detect glaucoma.

2.1 Direct CDR Estimation for Glaucoma Screening Via Semi-Supervised Learning Method

In paper [1], a direct CDR estimation method is proposed based on the well-designed semi-supervised learning scheme, in which CDR estimation is formulated as a general regression problem while optic disc/cup segmentation is cancelled. The method directly regresses CDR value based on the feature representation of optic nerve head via deep learning technique while bypassing intermediate segmentation. The scheme is a two-stage cascaded approach comprised of two phases: unsupervised feature representation of fundus image with a convolutional neural network (MFPPNet) and CDR value regression by random forest regressor. They used, a set of (934 in total) fundus images from 934 different eyes and 443 clinical subjects collected from the second XiangYa hospital and Center for ophthalmic image analysis (Central South University). Among the 934 eyes, 280 are diagnosed as glaucomatous by ophthalmologists, accounted for 30%, which matches the actual results of epidemiological studies. There are only 421 images are given with manual labeled CDR value by trained. Meanwhile, the public datasets, consisting 650 fundus images, is also used in our experiments to validate the performance of our proposed method. The ORIGA consists of 168 images from all glaucomatous eyes and 482 images from normal eyes. The proposed scheme is validated on the challenging glaucoma and provided the improvement in AUC is 25% and 15.38% compared with ASM+CNN and Superpixel, while the improvement (7.14%) is relatively smaller when compared with the reconstruction-based method.

2.2 Retinal Image Synthesis and Semi-supervised Learning for Glaucoma Assessment

In paper [2], a retinal image synthesizer and a semi-supervised learning method for automatic glaucoma assessment using an adversarial model on a small glaucoma-labelled and large unlabelled database were proposed. This system is trained on an unprecedented number of publicly available images (86926 images). This system, hence, is not only able to generate images synthetically but to provide labels automatically. Synthetic images were qualitatively evaluated using t-SNE plots of features associated with the images and their anatomical consistency were estimated by measuring the proportion of pixels corresponding to the anatomical structures around the optic disc. The resulting image synthesizer is able to generate realistic (cropped) retinal images and, subsequently, the glaucoma classifier is able to classify them into glaucomatous and normal with high accuracy (AUC=0.9017). The obtained retinal image synthesizer and the glaucoma classifier could be used then to generate an unlimited number of cropped retinal images with glaucoma labels.

2.3 Disc-aware Ensemble Network for Glaucoma screening from Fundus Image

In paper [3], a deep learning technique to gain additional image-relevant information, and screen glaucoma from the fundus image directly were introduced. Specifically, a novel Disc-aware Ensemble Network (DENet) for automatic glaucoma screening is proposed, which integrates the deep hierarchical context of the global fundus image and the local optic disc region. Here, three dataset namely ORIGA with 650 fundus images, Singapore Chinese Eye Study (SCES) dataset, which consists of 1676 images and Singapore Indian Eye Study (SINDI) dataset with 5783 eye images were used. From the glaucoma screening results, the IOP performs poorly with 0.66 AUC on the SCES dataset and 0.6233 AUC on the SINDI dataset. The non-deep learning method, Superpixel [10], produces a competitive performance on the SCES dataset (0.8265 AUC) and the SINDI dataset (0.7712 AUC), which is better than IOP. DENet obtains the best performances on the SCES dataset (0.9183 AUC) and the SINDI dataset (0.8173 AUC), which has about 2% improvement on AUC than DeepCDR. In testing, DENet costs only 0:5s to generate the final result for one fundus image including disc localization and glaucoma screening, which is faster than the existing measurement-based methods. This method works only best on the SCES and SINDI datasets.

2.4 Combination of Clinical and multiresolution features for Glaucoma detection and its classification using Fundus Images

In paper [4], a novel method for glaucoma identification based on time-invariant feature cup to disk ratio and anisotropic dual-tree complex wavelet transform features was proposed. Optic disk segmentation is done by using Fuzzy C-Means clustering method and Otsu's thresholding is used for optic cup segmentation. One of the main clustering algorithms is Fuzzy C-Means (FCM) algorithm which gives better results for overlapped dataset compared to k-means algorithm. FCM means which allows one piece of data to belong to more than one cluster. In Otsu's thresholding, found a threshold that maximizes the between class variance and also minimizes the weighted within-class variance. This thresholding approach is applied to the preprocessed green channel of an input fundus image to get OC from disk region. A dataset used for this work, are collected from Venu Eye Institute & Research Centre, NewDelhi India. From different aged patients, total 86 images were collected and used for this work, where 51 are healthy and 35 are glaucoma affected patients. The results show the proposed method achieved an accuracy rate of

97.67% with 98% sensitivity using a multilayer perceptron model that is considered as clinically significant when compared to the existing works.

2.5 Deep Convolutional Neural Network for Accurate Diagnosis of Glaucoma Using Digital Fundus Images

In paper [5], they proposed a novel CAD tool for the accurate detection of glaucoma using deep learning technique. An eighteen layer convolutional neural networks (CNN) is effectively trained in order to extract robust features from the digital fundus images. CAD has a major role in the diagnosis of glaucoma which can bring down the inter-intra observer variability. Also, it requires minimum diagnosis time for more number of patients. In this work, we have decided to obtain the maximum output with minimum number of layers by efficiently choosing the network parameters. The advantage of CNN is that, it doesn't need any pre-processing or handcrafted feature extraction by other methods. In general, features are extracted in a hierarchical manner by mapping raw pixels of the input image and further it is classified using fully connected layers. The network parameters are intelligently tuned to obtain the highest classification performance. Finally, these features are classified into normal and glaucoma classes during testing and achieved the highest accuracy of 98.13% using 1426 (589: normal and 837: glaucoma) fundus images. But, this work fails to focus on early stage detection of Glaucoma.

2.6 Image Processing based Automatic Diagnosis of Glaucoma using wavelet Features of Segmented optic disc from Fundus Image

In paper [7], wavelet feature extraction has been followed by optimized genetic feature selection combined with several learning algorithms and various parameter settings. Unlike the existing research works where the features are considered from the complete fundus or a sub image of the fundus, this work is based on feature extraction from the segmented and blood vessel removed optic disc to improve the accuracy of identification. Experiments have been carried out in a local data base of 63 fundus images. Out of 63 images, 44 images are used to train the classifier and remaining 19 images are used to test the accuracy of classifier. Experiments has been performed for different classifiers using feature vector selected by evolutionary attribute selection method and the feature vector compressed using dimension reduction technique PCA. The experimental results presented in this paper indicate that the wavelet features of the segmented optic disc image are clinically more significant in comparison to features of the whole or sub fundus image in the detection of glaucoma from fundus image. Accuracy of glaucoma identification achieved in this work is 94.7% and a comparison with existing methods of glaucoma detection from fundus image indicates that the proposed approach has improved accuracy of classification.

3 Conclusion

This survey paper presents briefly about the various methods used to detect glaucoma from the fundus images. Each of the method has its own merits and demerits. The future work can be done by using Deep Learning based CNN algorithm for the detection of glaucoma which mainly affects the optic disc by increasing the cup size, which will help the physician during early diagnostic procedure of Glaucoma and also minimize vision loss

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