A Deep Learning -based Approach with Automatic Segmentation of Optic Disc for Detecting Glaucoma from Color Fundus Images

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Abstract - *Glaucoma is a chronic eye disease that damages the optic nerve, which leads to permanent blindness. Although prognosis of glaucoma is poor, its progression can be slowed down by treatment. Thus, early diagnosis of glaucoma has been shown to significantly reduce the risk of permanent blindness. We present a deep learning-based glaucoma detection system with automatic segmentation of optic disc. In this system YOLO (You Only Look Once) model is trained to automatically segment the optic disc from color fundus images. Using this segmented optic disc, a Deep Learning architecture is developed with CNN working at its core for automating the detection of glaucoma. The experimental results shown that this system predicts the presence of glaucoma around an 85% accuracy.*

Key Words: **Glaucoma, Optic disc, Optic cup, Deep learning, YOLO MODEL, CNN, Fundus image**

1. INTRODUCTION

Glaucoma is a chronic eye disease that damages the optic nerve. It is the leading cause of global irreversible vision loss with a prevalence of population aged 40-80 estimated at 3-4%. The number of people with glaucoma worldwide was estimated at 64.3 million in 2013, increasing to 76.0 million in 2020 and expected to be 111.8 million in 2040. Since glaucoma is an asymptomatic condition until a relatively late stage, the diagnosis is frequently delayed. Population-level surveys suggest that out of total glaucoma affected people, only 10-50% of them are aware that they suffer from this disease. As the symptoms only occur when the disease is quite advanced, glaucoma will always lead to permanent vision loss. So it is called the silent thief of sight. Although prognosis of glaucoma is poor, its progression can be slowed down by treatment. Thus, early diagnosis of glaucoma has been shown to significantly reduce the risk of permanent blindness.
Glaucoma mainly affects the central circular yellowish region of the retina, known as an optic disc. This is the location where millions of retinal nerve fibers that carry visual signals from the eye to the brain converge and exit the retina. The optic disc is devoid of rods and cones which are photoreceptors that are responsible for vision. Hence, the optic disc is often termed as the "blind spot" of the eye. The optic disc has a central portion called the optic cup. The optic cup is a relatively smaller bright cup-like area located at the center of the optic disc. The retinal nerve fibers are typically represented by the annular region between optic disc and the cup boundary, which is known as the neuro retinal rim. The fluid pressure in the inner portion of the eye is called intraocular pressure (IOP). An increase in this IOP leads to blockage of the outflow of aqueous humor. This damages the optic nerve, which is essential to communicate the information from retina to the brain. This deterioration of optic nerve fibers results in the thickening of the retinal nerve fiber layer, which is usually known as 'cupping'. This cupping causes the progression of glaucoma. Therefore, a decrease in the healthy neuro retinal tissues can be easily noticed by measuring cup to disc ratio(CDR) in the eye. These features of the eye can be clearly visualized in fundus images.

The fundus image is an image of the eye obtained through a special fundus camera. It is a non-invasive technique that has proven to be an effective tool for examining the ocular health of an individual. In colored fundus images, the optic disc appears as a bright yellowish region and can be further subdivided into two parts namely the optic cup (inner part) and the neuro-retinal rim (outer boundary). Fundus image of a normal eye is shown fig1(a).In glaucomatous eyes, due to optic nerve cupping, the size of the optic cup increases. This is shown in fig 1(b). As a result, CDR value is also increased. The typical value of CDR for a healthy eye is 0.3. A CDR value greater than 0.65 is classified as an eye with glaucoma as per the clinicians.

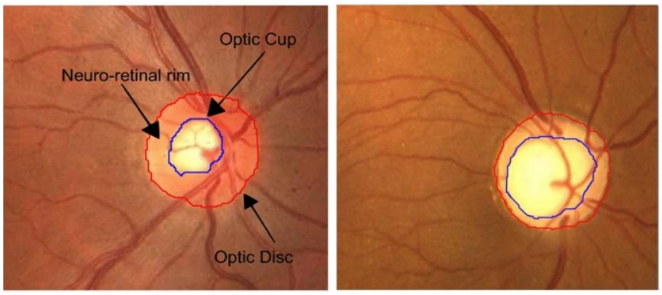

Fig -1: (a) Normal eye (b) Glaucomatous eye

2. EXISTING SYSTEM

The standard care for glaucoma screening consists of routine optometrist visits every 2-3 years, suspicious cases are then referred to an ophthalmologist who performs additional tests and examinations for final confirmation of the diagnosis. A complete glaucoma study usually includes detailed medical history, slit lamp examination, visual field, fundus photography and tonometry[1,2], and since the 90's it also includes some optic nerve imaging test such as scanning laser tomography (HRT)[3], optical coherence tomography (OCT)[4] and scanning laser polarimetry with variable corneal compensation (GDx-VCC)[5]. The subjective interpretation of color fundus images for the identification of glaucomatous signs is a challenging task that requires specific expertise and years of practice. Clinical assessment by manually annotating the cup and disc for each image is labor-intensive, and is also time-consuming.

To overcome the above difficulties a great effort has been made to develop automatic glaucoma detection algorithms based on image processing of color fundus images. These include glaucoma detection based on a probabilistic combination of previously compressed features extracted from the pixel intensity values, the Fourier Transform (FT) and B-splines coefficients[6], or using higher order spectra analysis and texture-based features extracted from preprocessed images and a Support Vector Machines (SVM) classifier[7], or with a feature extraction based on higher-order spectra and discrete wavelet transform and SVM classifier[8,9], or using empirical wavelet transform with a least-squares SVM[10] or with an adaptive histogram equalization convolved with several filter banks processed to create local configuration patterns that feed a k-nearest neighbor (kNN) classifier[11]. These methods apply the approach of identifying features in the image to train a classifier with all the findings extracted directly from the image or from a transformed version of it (using wavelets, FT, high order spectra analysis). In the end, different algorithms explore different aspects and transformations of the optic nerve head to determine patterns that are representative and may identify glaucoma.

All the methods listed above for automatic glaucoma detection are limited by at least one of the following drawbacks.

- The features that are to be extracted by the algorithm should be specified beforehand.
- User involvement is needed to select a region of interest and the method is not completely automatic.
- The segmentation process requires more computational efforts.

3. PROPOSED SYSTEM

The proposed system uses a different approach to the glaucoma detection problem through the use of Convolutional Neural Networks (CNNs). A Deep Learning architecture is developed with CNN working at its core for automatic detection of glaucoma. The advantage of using this architecture is that we don't have to decide the filters but rather just provide the number of kernel filters in each convolution layer. The values of kernel filters are learned automatically by the neural network through the training process. In this architecture, we use a series of combinations of the three basic layers which are: Convolutional layer, Pooling layer, Output layer. The CNN architectures successfully exploit both local and global features present in the images, being a proper tool for the detection of glaucoma.

In addition to that proposed system implements the YOLO(You Only Look Once)[12] algorithm to automatically extract the optic disc, which s the region of interest (ROI). This ROI image is given as input to the proposed Deep Learning architecture. Cropping the images around the optic disc has a clinical reason, that glaucoma disease affects mainly the optic disc and its surroundings. Moreover, cropping the images around the optic disc turned out to be a more efficient way than using the whole image when using CNN for glaucoma assessment as it improves the accuracy.

3.1 YOLO Algorithm

For glaucoma detection, first we need to segment optic disk from the fundus image. For this purpose, a state-of-the art object localization system named "You Only Look Once" (YOLO) has been used. YOLO can draw a bounding box around different objects in an input image given that it was trained with those objects. YOLO uses a deep neural network consisting of 24 convolutional layers followed by 2 fully connected layers for object localization. The architecture of YOLO is depicted in Fig 2. In order to make YOLO capable of localizing optic disc, the deep neural network was required to be trained for that. For the purpose of this training, a dataset containing 1000 fundus images was annotated with the location of optic disc in each image using an annotation tool called LabelImg. The annotation contained object name and bounding box coordinates(Xmin,Ymin,Xmax,Ymax). The trained model could localize the optic disc in a fundus image by drawing a rectangular bounding box around it as shown in Fig 3. Testing is performed using 230 fundus images.

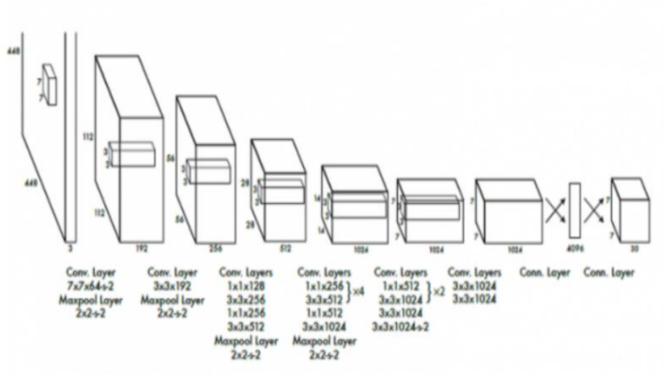

Fig -2: YOLO architecture

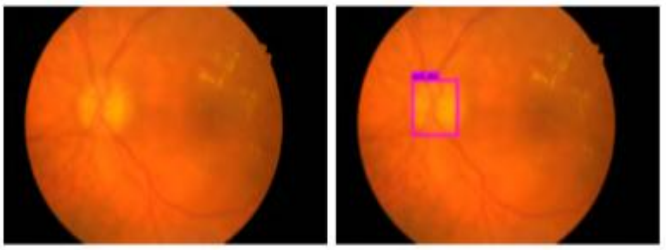

Fig -3: Fundus image and fundus image with bounding box

3.2 CNN Algorithm

CNN (convolution neural network) which is a class of deep learning is used for detection of glaucoma. CNN is most commonly applied to analyzing imagery. A convolutional neural network consists of an input and an output layer, as well as multiple hidden layers. The hidden layers of a CNN typically consist of a series of convolutional layers that convolve with a multiplication or other dot product.

The located portion of optic disc from the YOLO model is given as input to the CNN model. CNN model consists of five convolution +maxpooling layers and two fully connected layers as shown fig 4. CNN layers and number of filters used in each layer is shown in table 1. The training dataset contains 1000 images and testing is performed using 230 fundus images.

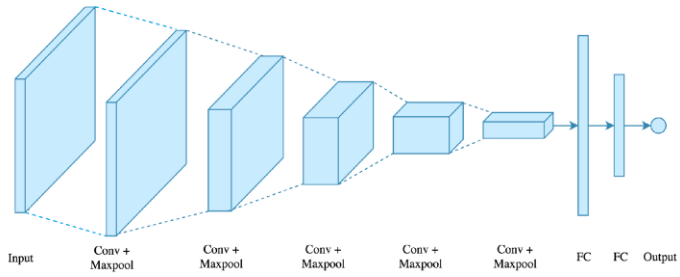

Fig -4: CNN architecture

Table -1: CNN Layers

Layers	No: of filters
Convolution+Maxpooling	32
Convolution+Maxpooling	64
Convolution+Maxpooling	128
Convolution+Maxpooling	64
Convolution+Maxpooling	32
Fully connected	1024
Fully connected	2

4. CONCLUSIONS

Glaucoma is a retinal disease that affects several people globally every year. Early detection is the only way to prevent its progression into permanent blindness. The proposed system uses convolution neural network (CNN) to automatically detect glaucoma. Using digital fundus images of affected patients, we train our system to detect whether a person is affected with or without glaucoma. For this we first locate optic disc from the fundus image using YOLO model and located portion of optic disc is passed to CNN model. We are using CNN due to the high accuracy it offers.

The proposed system provide Increased diagnosis accuracy and safety, Reduces the chance of mistakes in repetitive work, and Guaranteeing consistent and high-quality diagnosis.

If there have been more resources available, the system could be trained more efficiently which could lead to an increased accuracy rate. The proposed system is implemented in such a way that further developments can be made in the future. It can be integrated with a hospital system to provide more facilities like searching for the best doctors, making appointments with them according to the availability, and taking suggestions from them.

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