Research Proposal

Intelligent Diagnosis Algorithm for Fundus Diseases based on Deep Learning

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1. Research Background

According to the reports of the World Journal of Diabetes and the International Council of Ophthalmology (ICO) [1], it is estimated that by 2030, 440 million people around the world will suffer from diabetes, among which 114 million people in China will suffer from diabetes [2], and one third of them will suffer from diabetic retinopathy [3]. Diabetic retinopathy is one of the most common complications of diabetes mellitus, which has a high rate of blindness, so it is one of the main blindness diseases; Glaucoma is a blinding fundus disease that cannot be reversed [4], and China has the largest number of people in the world suffering from glaucoma, a degenerative disease common in ophthalmology that can cause multiple damage to the eye. For glaucoma patients, when the patients find that the visual amplitude is decreased and it is difficult to see things clearly, it is often the late stage of the disease, and the visual field defect is extremely serious, leading to irrecoverable. Therefore, glaucoma patients must be found as soon as possible, and timely to the hospital for treatment; Age-related macular degeneration (AMD) is also one of the major causes of blindness in elderly patients around the world, including dry macular degeneration and wet macular degeneration, of which wet macular degeneration is more harmful to vision. Wet macular degeneration refers to the choroidal capillaries breaking through the Bruch membrane in the macular region to form choroidal neovascularization (CNV) under the retinal pigment epithelium or the retinal nerve epithelium, which is prone to leakage or bleeding, and damages the vision of patients until blindness [5][6].

The above three common fundus diseases affect a large number of patients with eye diseases in China. However, most patients with ophthalmic diseases are often found to be ill at a later stage, which brings great challenges to the prevention and treatment of ophthalmic diseases. The World Health Organization points out that 80% of blindness can be prevented. Early diagnosis and treatment of eye diseases can slow down the deterioration of the disease and even reverse the progress of eye diseases. However, there were only about 36000 professional ophthalmologists in China, and they were mainly distributed in the cities along the northern route. The lack and uneven distribution of ophthalmologists has brought great trouble to the screening of fundus diseases. Therefore, the development of automatic diagnosis algorithm for fundus diseases can effectively reduce the probability of blindness of patients.

In recent years, with the continuous improvement of AI algorithms such as convolutional neural network, AI assisted diagnosis and treatment decision-making based on medical big data has become increasingly mature, especially in the aspect of medical image recognition. By learning massive imaging data, the machine can acquire the ability to automatically diagnose and analyze images in a short period of time, which is more objective, accurate and efficient than ordinary doctors. In 2017, a joint research team from Stanford University published an AI algorithm for skin cancer in Nature with an accuracy rate of more than 91% [7]. For diabetic retinopathy glucose screening, a variety of AI algorithms also show high accuracy, sensitivity and specificity. Most of these medical AI algorithms adopt deep-learning method to intelligently diagnose medical related diseases. Compared with the "shallow learning" method, which relies on the artificial extraction of sample features in machine learning, deep learning method can automatically extract the required structural features from the training network, and the automatically extracted features can solve the subjective bias factor of manual extraction.

2. Research Objectives

The research goal of this project is to develop an intelligent diagnosis algorithm for fundus diseases based on the existing fundus image data and the advanced intelligent algorithm. Specifically, it is based on the deep learning method to diagnose whether the patient has diabetic retinopathy, glaucoma and age-related macular degeneration, and provide medical interpretable judgment basis.

3. Literature Review

Most lesion detection algorithms for diabetic retinopathy mainly use some basic image features, such as shape, color, brightness, and some specialized knowledge in the retina, such as cup and disc, blood vessels, and macula, to detect the lesion area and to automatically screen for diabetic retinopathy. In order to detect microaneurysms in the early stage, Cree et al. [8][9] segmented the potential lesion area and then performed further processing to generate a list of morphological and intensity features based on each potential lesion area. Niemeijer et al. [10] and Fleming et al. [11] used a variety of local contrast enhancement methods and filtered a channel to estimate the uneven background intensity and generate shadow correction images. On the basis of the above, the potential lesion regions were further extracted, and the candidate regions were classified by K-nearest neighbor clustering.

Glaucoma is mainly detected by optic disc diagnosis. Because it is expensive for doctors to directly evaluate fundus images, some automatic evaluation methods have been proposed. These methods can be roughly divided into two categories: the first is to extract image features and directly classify them into dichotomies [12], while the second is to calculate some clinical indicators of glaucoma, such as cup-to-disc ratio (CDR) [13]. Adam et al. [14] proposed a fuzzy convergence method to automatically locate the optic disc region. Conor et al. [15] used the method of image threshold to locate the optic disc region, and then followed the localization of the optic disc region to study the changes of vascular width and flexion in retinopathy of prematurity. Stefan et al. [16] used LBP feature descriptors [17] to automatically locate the optic disc.

Unlike diabetic retinopathy and glaucoma, where early symptoms can be seen directly with a fundus camera, the lesion area of age-related macular degeneration begins with the internal structure of the retina and therefore needs to be detected with an OCT fundus image. In order to observe the occurrence of fundus lesions, the OCT fundus images need to be stratified first, and then the information between the layers is used to see if there is any abnormality. Mayer et al. [18] proposed to use a series of edge detection algorithms and de-drying algorithms to first obtain the edge of the image, and then to obtain the final retinal layer edge through the method of graph search. Luo et al. [19] proposed a technique involving Canny edge detection and edge flow to find retinal edges to measure the thickness between retinal layers.

4. Research Methodology

For the above three fundus diseases, the candidate wil develop relevent intelligent diagnosis algorithms:

Firstly, a classification algorithm based on expert prior knowledge is proposed to automatically diagnose diabetic retinopathy and locate potential lesions. This algorithm first uses the image annotated by the ophthalmologist to train a sub-network (called Lesion-Net). Then, the lesions output from the Lesion are combined with the original images. Finally, the combination is transmitted to the classification network for the diagnosis of diabetic retinopathy. This algorithm can not only improve the diagnosis performance of diabetic retinopathy, but also locate the potential lesions, providing the medical interpretability for diagnosis.

Secondly, the joint optic disc localization and optic disc & cup segmentation algorithms are proposed to automatically diagnose glaucoma. The multi-task learning based U-Net is adopted to find the optic disc region and output the center coordinates of the optic disc, for boosting the localization accuracy of the optic disc. Then, the segmentation algorithm mainly contains a dense atrous convolution module and the residual multi-scale pooling module to improve the segmentation performance. Finally, the cup-to-disc ratio is calculated to diagnose glaucoma.

Thirdly, an algorithm is proposed to automatically diagnose age-related macular degeneration (AMD), which is consist of the retinal layer segmentation and lesion heatmap generation. The algorithm combines the retinal layer segmentation with retinal edge detection, for boosting the segmentation performance. In addition, this algorithm can directly diagnose age-related macular degeneration and locate the lesions of AMD without any lesion labeling.

5. Expect Outcomes

Through a series of course work and research training, the candidate will accumulate skills in theories, principles, and methods of Intelligent Diagnosis Algorithm of Fundus Diseases based on Deep Learning. To be more specific, he will learn how to design the algorithm which can diagnose whether patients have fundus diseases and can locate the potential lesion area; how to operate models and software to assessment experiment feasibility and analyze the data and results.

During this period, the candidate is expected to prepare manuscripts for publication in professional journals and make a draft of manuscript-based master dissertation.

6. Research Schedule

The specific arrangement is as follow:

	Task	Begin Time	Finish Time	2021				2022												2023					
				9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
1	Literature review and preparation	2021/9/1	2021/10/31																						
2	Take some machine learning courses associated with the project	2021/10/1	2021/11/30																						
3	Design intelligent diagnosis algorithms for fundus diseases	2021/11/1	2022/4/30																						
4	Assess the design feasibility and reasonability by using mathematic models	2022/5/1	2022/6/30																						
5	Participate in academic seminars and deeply comprehend the difficult and important parts of this project	2022/6/1	2022/7/31																						
6	Design experiments based on the algorithms	2022/8/1	2022/10/31																						
7	Adjust the experiemnt scheme and perfect the design	2022/10/1	2022/12/31																						
8	Summarize the result and make discussion	2023/1/1	2023/2/28																						
9	Prepare manuscripts for publication in professional journals	2023/3/1	2023/4/30																						
10	Write academic papers and Master dissertation	2023/5/1	2023/6/30																						

7. Reference

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