Diabetic Retinopathy Fundus Image Grading Using Deep Learning: Research Directions

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Diabetic is a serious health issue caused by high blood sugar level. Nearly one third of diabetic patients suffer from Diabetic Retinopathy (DR) [1], which is an eye disease where the damage occurs in the retina (back side of the eye). Therefore, dark spots will appear in the vision from an affected eye. The vision from the normal eye and diabetic retinopathy are illustrated in Figure 1. DR is the leading cause of vision impairment or blindness. Researchers estimated that the number of people affected by DR worldwide will grow to 191.0 million by 2030 [2]. Even though the early stages of DR are typically asymptomatic, regular eye screening for diabetic individuals is necessary, as quick identification and subsequent care of the problems are critical. Because controlling hyperglycemia, hyperlipidaemia and hypertension is the only preventive therapy, early recognition of DR is even more important [4]. Furthermore, contemporary treatments, like laser photocoagulation can reduce the risk of blindness in proliferative retinopathy and diabetic maculopathy by up to 98%, if the eyes are treated early in the disease [5].

Figure 1: *A vision of a normal eye and of an eye diabetic retinopathy*

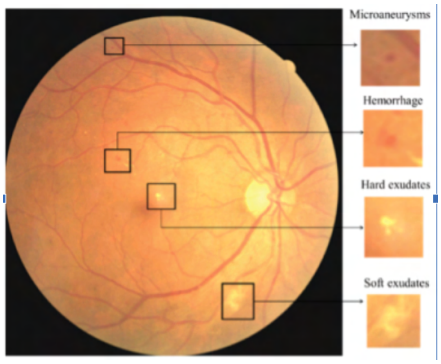


Figure 2: *Different types of DR lesions*

The affected DR contains different lesions (the affected regions of the retina) such as haemorrhage, soft exudates, hard exudates, and microaneurysms, which are illustrated in Figure 3 and this DR image is taken by a colour fundus camera. DR grading by distinguishing the lesions from fundus images is a challenging and fine-grained problem due to the lesions being smaller in size (covers only a few pixels in fundus images) and similar in visual appearance.

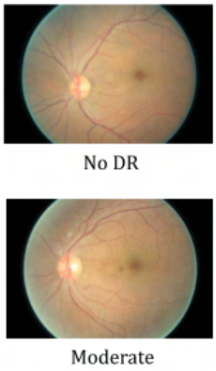


Figure 3: *Normal and Moderate DR images.*

For example, Figure 3 shows the normal and moderate DR images, where it's hard to differentiate them. Based on the type and amount of the lesions appears, the DR images will grade in a severity order which represent the progression of the disease like no DR (healthy), mild, moderate, sever and proliferative DR (complex stage). Here wrong identification of DR images may lead to sever consequences. Therefore, early and proper DR grading is important to decide the appropriate treatment at the correct time, as the treatment depends on the severity

or grade of the DR. Ophthalmologists usually rely on retinal colour fundus camera to examine the retina and detect the presence of lesions to grade the disease. This manual process is time consuming, subjective and prone to human errors. On the other hand, automated computer aided diagnoses systems show good potential to accurately grade the DR and provide objective predictions from colour fundus retinal images [7].

Recently, Deep Learning (DL), especially Convolutional Neural Network (CNN) based automated solutions were proposed, and achieved remarkable success for DR grading with effective prediction in a short time [7]. DL is a machine learning technique, which allows computational models to learn representations of data with multiple levels of abstraction and it has been widely used to solve problems in various domains including computer vision and medical imaging. CNN is a type of DL technique which is designed to automatically classify images and/or to detect regions of interest in images by learning spatial feature hierarchies through multiple levels of building blocks, such as convolution layers, pooling layers, and fully connected layers. Figure 5 illustrates a simple CNN architecture for DR grading. Various CNN based automated approaches have been proposed in DR image analysis including CNN architectures [6], pooling mechanisms [8], attention mechanisms [3], etc. Rather than that, there are various directions to the researchers to improve DR grading performance, including the followings:

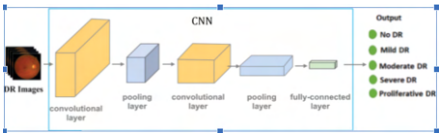
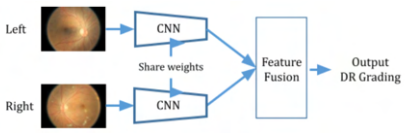


Figure 4: *Simple CNN architecture for DR grading*

Siamese network based feature fusion of both eyes of a patient - Automated DR grading is a fine-grained classification problem as the lesions in DR images are hard to distinguish due to scale, high intra- and low inter-class variations. Usually ophthalmologists determine the DR grading of an eye of a particular patient by examining both eyes of that patient as the DR grading of one eye may give guidance for the diagnosis of the other. Therefore, most of the approaches for DR grading [8] make use of the features from the left and the right eyes of a patient to determine the DR severity level of a particular eye of that patient, and show significantly improved DR grading performance by this information fusion. The kind of CNN architecture used for this purpose is called Siamese network [8]. Siamese networks are types of networks which have two or more identical CNNs each with different inputs, and the weights of these identical networks are shared among them. As the weights are shared, their parameters can be learned with less amount of data compared to training two independent networks. Figure 6 illustrates a sample architecture of Siamese network.



Semi-supervised learning for DR grading - Although CNNs are widely used for image classification and/or segmentation, they are often data-hungry – needs a large amount of annotated data to train as they have millions of parameters to train. However, collecting annotated data in large amounts, is usually a tedious task, particularly it is difficult for medical imaging. Recently semi-supervised learning approaches have been explored, where unannotated data was used in addition to the annotated data to boost the performance of the CNN system. Currently, more researches are focusing on this domain to improve DR grading performance with less amount of annotated data.

Joint classification and segmentation of DR lesions - Just classifying retinal images into one of the predefined classes will not give much valuable information to the ophthalmologists as they will not give any explanation or interpretation on why they are classified into a particular class than other classes. This interpretation may be obtained in terms of segmenting different lesions. Therefore, researchers can focus on a joint framework which will classify images as well as identify lesion regions to give justifications for ophthalmologists on why they are classified into a particular class than the other classes.

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