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Investigation of the severity level of diabetic retinopathy using supervised classifier algorithms ☆

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ABSTRACT

Diabetic retinopathy is a condition that occurs in individuals with several years of diabetes mellitus and causes a characteristic group of lesions in the retina and progressively damages it. Detecting retinal fundus diseases in advance helps ophthalmologists to apply proper treatments that may cure the disease or decrease its severity and thus protect patients from vision loss. Diabetic retinopathy is usually diagnosed by ophthalmologists using dilated images that are captured by pouring a chemical solution into the patient's eye, which causes inconvenience and irritation to the patient. In this paper, we propose a method to detect lesion exudates automatically with the aid of a non-dilated retinal fundus image to help ophthalmologists diagnose the disease. The exudates from the low contrast images are detected and localised using a neighbourhood based segmentation technique. A support vector machine (SVM) and probabilistic neural network (PNN) classifiers are proposed to assess the severity of the disease, and the results are compared with the same segmentation technique. The average classification accuracy for the SVM and PNN classifiers are determined to be 97.89% and 94.76%, respectively.

1. Introduction

Diabetic retinopathy (DR) is reported to be the most frequent cause of blindness worldwide in individuals aged 20–74 years. The occurrence of retinopathy is strongly related to the duration of diabetes. During the first two decades of diabetes, nearly all patients with type 1 diabetes and over 60% of patients with type 2 diabetes have retinopathy [1]. Diabetic retinopathy starts with mild non-proliferative abnormalities, which are distinguished by improved vascular permeability, severe non-proliferative diabetic retinopathy (NPDR), and vascular closure, and ends with proliferative diabetic retinopathy (PDR), which is characterised by the growth of new blood vessels on the retina and the posterior surface of the vitreous. Approximately 21% of diabetes patients have retinopathy at the time of first diagnosis of diabetes, and the percentage increases with time [1].

Diabetic retinopathy occurs under conditions of high blood glucose or sugar over a long period of time. The major symptoms of this disease are microaneurysms (MAs), haemorrhages and exudates. Microaneurysms, the primary abnormalities occurring in the eye of the disease, are focal dilatations of the retinal capillaries, which are identified as tiny and dark red spots appearing either alone or in groups. Haemorrhages occur in the deeper layers of the retina, when blood leaks from the retinal vessels. These haemorrhages are often called 'blot' haemorrhages because of their round shape. Some of the

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diabetic retinopathy patient's blood vessels may swell and leak fluid, while for other patients, abnormal new blood vessels grow on the surface of the retina. The signals sent by the retina for nourishment triggers the growth of new irregular and brittle blood vessels. These blood vessels develop along the retina and the surface of the clear and vitreous gel, which fills the inner recesses of the eye; however, they have thin and brittle walls. If these blood vessels leak blood or watery fluid, severe vision loss and even blindness can occur. The leakage of watery fluid from the fragile or abnormal blood vessels is called an exudate. These exudates are classified as hard and soft exudates. The preliminary stage of the exudates involves hard exudates, which have a yellowish colour, while the severe stage of the exudates involves soft exudates, which appear as cotton wool. Earlier detection of this disease helps ophthalmologists to provide the appropriate treatment and thus protects the patient from vision loss.

Diabetic retinopathy exhibits few visual or ophthalmic symptoms until the visual loss increases. Currently, laser photocoagulation is regarded as an effective treatment technique against diabetic retinopathy because laser photocoagulation hinders the progression of retinopathy, thereby controlling the loss of vision; however, it does not restore the lost vision. Moreover, the chemicals used for laser photocoagulation may cause blindness. To detect the diabetic retinopathy at an earlier stage, patients with diabetes should be evaluated using an automatic detection technique. The use of digital non-mydriatic images is the preferred automated technique towards the examination and detection of diabetic retinopathy.

The algorithm proposed in this paper improves the performance and the classification accuracy. The method consists of the following steps: preprocessing, ROI extraction, exudates detection, feature extraction and severity measurement by using SVM and PNN classifiers. Based on the preprocessing and ROI extraction, the exudates were detected. After the detection of exudates, the features of the exudate-detected images were determined and the severity level of the disease is measured by using both SVM and PNN classifiers.

Generally, the classifier consists of two types: supervised and unsupervised. The supervised classifier requires training data for each time testing to provide good results. The unsupervised classifier does not require training data each time testing is performed. Once the data are trained, the classification can be performed at any time; however, the result may or may not be good. The classification algorithm used for recognising the disease must provide accurate results because the proposed work deals with the health condition of a diabetic patient. To enable accurate classification, the supervised type of SVM and PNN classifiers are used. These classifiers are flexible regarding the choice of a similarity function and are also able to handle large feature spaces. Both of the classifiers considered have two working modes, viz. the training and testing modes. The severity of the disease is identified in the testing mode based on the features extracted for the particular image. Before the feature extraction, the features of all of the normal and abnormal images are trained. Finally, the performances of the classifiers are compared.

1.1. Literature review

Tang et al. [2] detected haemorrhages during splat feature classification by extracting features, such as colour, spatial location, interactions with neighbouring splats, texture information and shape. Splat feature classification can be obtained by dividing the image into a number of splats. The wrapper approach was used to choose the best possible subset of splat features. Deepak and Sivaswamy [3] suggested the use of a motion pattern technique for the detection of macular edema. Two single-class classifiers, such as Gaussian and Principal Component Analysis Data Description classifiers were used to locate the lesions in the eye. The rigorousness was assessed by the Symmetry measure. Agurto et al. [4] developed instantaneous amplitude and frequency characteristics of a retinal image for lesion detection.

Lazar and Hajdu [5] identified retinal microaneurysms with the help of directional cross-section profiles, where each profile was analysed by extracting the features, such as size, height and shape. Naive Bayes classification was also used to eliminate false candidates by evaluating the statistical measures of those feature sets. Ram et al. [6] proposed two clutter rejection methods to discriminate the MAs from the non-MAs by using similarity computation. Goatman et al. [7] proposed a vessel detection approach on the optic disc (OD) based on watershed lines and ridge strength measurement and also used the SVM classifier to distinguish normal and abnormal vessels on the OD. Antal and Hajdu [8] proposed a method for detecting lesions formed due to diabetic retinopathy. The output of multiple classifiers was obtained after performing pre-processed methods and candidate extractors.

Giancardo et al. [9] used a new method to detect macula swelling by analysing multiple view retinal fundus images. The method had three stages, viz. a preprocessing technique, registering multiple retinal fundus views and dense pyramidal optical flow. The dense pyramidal optical flow was calculated to build a naive height map of the macula. Osare et al. [10] used computational intelligence and pattern recognition to analyse the diabetic retinal fundus image along with machine learning techniques.

Sopharak et al. [11] used the Fuzzy *C*-Means (FCM) clustering technique for detecting pixels of the exudates in the fundus image. Giancardo et al. [12] introduced a methodology for diagnosing macular edema by using a new set of features based on colour. Wavelet decomposition was mainly used for automatic lesion segmentation, which was used to automatically train a classifier to diagnose the disease.

Sopharak et al. [13] adopted the FCM clustering technique for the segmentation of exudates, in which morphological operators were used for the reconstruction of the original image. Ali et al. [14] proposed a novel statistical-atlas based method for the segmentation of exudates. The test fundus image was first warped onto the atlas co-ordinate to obtain a distance map that has a mean atlas image showing the candidate lesions. Post-processing techniques were introduced for the