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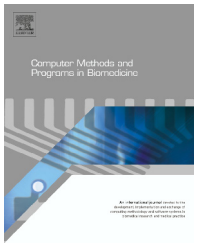

Automated detection of exudates and macula for grading of diabetic macular edema

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ABSTRACT

Medical systems based on state of the art image processing and pattern recognition techniques are very common now a day. These systems are of prime interest to provide basic health care facilities to patients and support to doctors. Diabetic macular edema is one of the retinal abnormalities in which diabetic patient suffers from severe vision loss due to affected macula. It affects the central vision of the person and causes total blindness in severe cases. In this article, we propose an intelligent system for detection and grading of macular edema to assist the ophthalmologists in early and automated detection of the disease. The proposed system consists of a novel method for accurate detection of macula using a detailed feature set and Gaussian mixtures model based classifier. We also present a new hybrid classifier as an ensemble of Gaussian mixture model and support vector machine for improved exudate detection even in the presence of other bright lesions which eventually leads to reliable classification of input retinal image in different stages of macular edema. The statistical analysis and comparative evaluation of proposed system with existing methods are performed on publicly available standard retinal image databases. The proposed system has achieved average value of 97.3%, 95.9% and 96.8% for sensitivity, specificity and accuracy respectively on both databases.

1. Introduction

The research in medical image analysis is of great significance in this modern era. The study in this field will greatly benefit the health care systems and society. One of the common diseases all over the world is diabetes in which the lack of insulin causes high blood sugar in humans. The long term diabetes also affects the human retina resulting in a condition known as diabetic retinopathy (DR) [1]. This condition damages the retinal blood vessels causing them to leak which ultimately leads to blindness. The patients of different types of diabetes develop some form of retinopathy after the twenty years of this chronic disease. DR of any stage develops in nearly all of the patients having diabetes of type 1 and about 60% of the patients with diabetes of type 2 [1].

DR is normally categorized in different stages such as background or non proliferative DR (NPDR) and proliferative DR (PDR) [2]. NPDR contains initial signs of DR whereas PDR is categorized as advance and severe stage of this retinal disease. In NPDR, different lesions such as microaneurysms, hemorrhages and exudates appear on the retina and based on their count and location NPDR is classified as mild, moderate or severe NPDR [3]. The central portion of retina which is usually darkest in digital fundus image and rich in cones is called macula (Fig. 1). The macula is accountable for the clear, sharp and detailed vision [3]. The center of macula is called fovea which is responsible for very fine details in the image. When

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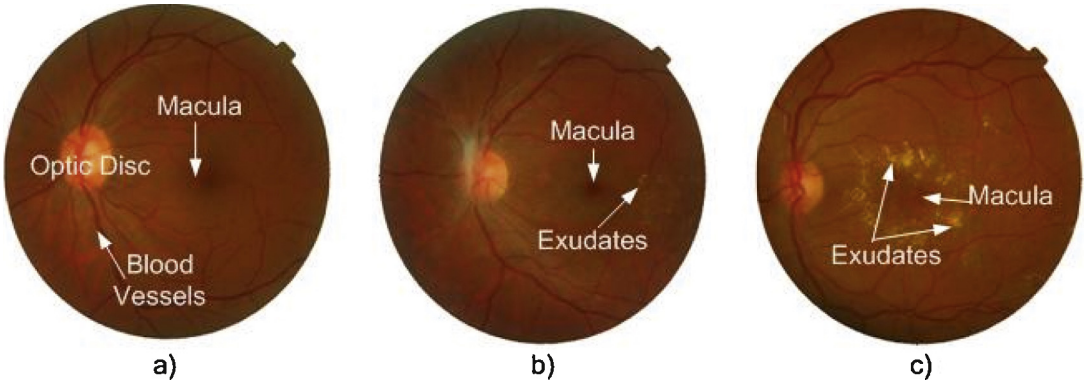

Fig. 1 – Digital image of human retina and different stages of macular edema: (a) healthy retinal image with its main components, (b) non-CSME retinal image with exudates and macula, (c) CSME retinal image with exudates and macula.

the macula is affected in diabetic patients, it leads to diabetic maculopathy or diabetic macular edema (DME) which is some times also considered as advanced stage of DR.

DME is one of the common sight threatening conditions among diabetic patients in which the fluid rich in fat leaks out of damaged blood vessels and get deposited near macula and leads to distorted central vision. The human visual loss can be prevented by early detection and diagnosis of DME. The two types of macular edema are, non clinically significant macular edema (non-CSME) and clinically significant macular edema (CSME) [3]. Non-CSME is a mild form of edema in which there are no symptoms of the disease because the locations of exudates are at a distance from fovea and the central vision is not affected. CSME is the severe form of edema in which the exudates leak out and get deposited very close to or on the fovea affecting central vision of the eye [4]. Irrespective of diabetic retinopathy, long term diabetic patients have chances of developing DME. Fig. 1 shows digital retinal images with different stages of edema.

The remaining article consists of four sections. Section 2 explains the related work with respect to macular edema and briefly explains the main novelty of proposed system. The detailed proposed system and its complete methodology are given in Section 3. Section 4 represents the standard retinal image databases which we have used to evaluate proposed system. The experimental and comparative results of proposed system using different evaluation parameters are also elaborated in this section. The discussion and conclusion are given in last section.

2. Related work

Automated and reliable detection of edema is vital for early cure of the disease. Edema occurs when exudates appear near or on the macula, so automated detection of macula and exudates are important to construct a computer aided diagnostic system for DME. There are various computerized methods in the literature which are proposed for the detection of macula, exudates and edema.

Exudates are the basic sign of DME and first step in automated diagnosis of DME is reliable detection of exudates. Niemeijer et al. [5] proposed a machine learning based supervised algorithm for automated detection of exudates. K nearest neighbor classifier was used for the training and testing of feature set of exudates. The sensitivity and specificity of 95% and 86% were found respectively for 300 images from different patients. In [6], the top down and bottom up strategies for the detection of lesions are proposed. The improved fuzzy C-means along with support vector machines (SVM) classifier were utilized for the detection of exudates. Automatic extraction of exudates was done using marker controlled watershed transformation be Reza et al. [7]. The proposed algorithm used average filtering and contrast adjustment followed by gradient modification using marker controlled watershed transformation. The algorithm was tested on DRIVE and STARE databases and shows 95% sensitivity. Nayak et al. [8] proposed a texture analysis based feature extraction and ANN based automatic classification for the detection of exudates. The algorithm was tested on 140 subjects and the average sensitivity and specificity were found to be 90% and 100% respectively. Acharya et al. [9] proposed a higher order spectra (HOS) based method for the identification of exudates. Features were extracted through HOS which are then fed to SVM classifier. The method was tested on 300 subjects and the sensitivity and specificity were found to be 82% and 88%. Akram et al. [10] proposed a hybrid fuzzy neural network based method for the detection of exudates along with dark lesions. They used only a few number of features to form a feature set to classify the lesions into two categories. Another method for detection of exudates using Gaussian mixture model based classifier and different descriptors has been used in [11].

The next step in automated grading of DME is to identify the location of macula in retinal image to check the severity of disease. Sagar et al. [12] proposed a macula detection technique by using segmented blood vessels and the darkest region property in the image of retina. The segmentation of retinal blood vessels is done by morphological operations followed by thresholding. This method for macula detection achieved an average accuracy of 96% on DRIVE and STARE databases. In [13], the authors have proposed a method for fovea detection based on matching correlation together with typical fovea characteristics. This technique was tested on some local dataset and the sensitivity and specificity were found to be 80.4% and 99.1% respectively. Tan et al. [14] proposed a macula detection technique by detecting a region in