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Referral system for hard exudates in eye fundus

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ABSTRACT

Hard exudates are one of the most common anomalies/artifacts found in the eye fundus of patients suffering from diabetic retinopathy. These exudates are the major cause of loss of sight or blindness in people having diabetic retinopathy. Diagnosis of hard exudates requires considerable time and effort of an ophthalmologist. The ophthalmologists have become overloaded, so that there is a need for an automated diagnostic/referral system. In this paper a referral system for the hard exudates in the eye-fundus images has been presented. The proposed referral system works by combining different techniques like Scale Invariant Feature Transform (SIFT), K-means Clustering, Visual Dictionaries and Support Vector Machine (SVM). The system was also tested with Back Propagation Neural Network as a classifier. To test the performance of the system four fundus image databases were used. One publicly available image database was used to compare the performance of the system to the existing systems. To test the general performance of the system when the images are taken under different conditions and come from different sources, three other fundus image databases were mixed. The evaluation of the system was also performed on different sizes of the visual dictionaries. When using only one fundus image database the area under the curve (AUC) of maximum 0.9702 (97.02%) was achieved with accuracy of 95.02%. In case of mixed image databases an AUC of 0.9349 (93.49%) was recorded having accuracy of 87.23%. The results were compared to the existing systems and were found better/comparable.

1. Introduction

Diabetes is becoming one of the rapidly increasing health threats in the recent years [1,2]. WHO has suggested that around 347 million diabetes affected people are present in the world today. Among them a large number of people are undiagnosed and untreated [3]. It has been estimated that 80% of these people belong to middle or low income countries which cannot afford expensive treatments. Between 2005 to 2030 the death rate of diabetes affected people will double according to statistics of WHO [3]. The Diabetics' Institute of Pakistan has estimated that in Pakistan there are 12.9 million people suffering from this disease. It makes up about 10% of the total population. Around 3.5 million such patients remain undiagnosed due to poor medical conditions [4]. These figures are alarming.

Hard exudates are among the most common artifacts found in the eye fundus image in people suffering from Diabetic Retinopathy. In most of the cases the presence of hard exudates suggests that the patient requires immediate referral to an ophthalmologist or medical expert for proper treatment of the disease. Usually the presence of hard exudates in the eye fundus also indicates the existence of other vision threatening anomalies. Manifestation of hard exudates can be exploited for diagnosis of Diabetic Retinopathy or alternatively Diabetes. If left untreated, the disease can seriously affect the patient, causing blurred vision and in the worst case scenario, blindness. The above mentioned statistics provided by WHO elucidates the rapid increase of the disease in the world, especially third world countries. The ophthalmologists are becoming more engaged and overloaded due to increasing number of patients. This problem establishes the need for an automated system for diagnosis/referral. This system will reduce the load on the ophthalmologists and medical experts resulting in more effective utilization of their energies. Digital imaging medical diagnostic tools have proven to be very effective when it comes to providing better medical facilities to low income or poor countries. The digital imaging diagnostic procedures are non-invasive, painless and patient-friendly. Such diagnostic/referral systems have already been launched in The Netherlands [5], United kingdom [6] and Australia [7]. A study conducted in United Kingdom suggests that using automated systems, for screening fundus images, at clinics reduces 36.6% load from the medical experts [8].

In this paper a referral system for the condition of hard exudates in diabetic retinopathy has been proposed. The proposed referral system uses SIFT [9] to extract features/descriptors from the images, K-means clustering [10] for making Visual Dictionaries

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(VD) [11–14] and a simple binary class support vector machine (SVM) [15] for classification. Section 2 gives a brief introduction about hard exudates. In Section 3 the proposed technique consisting of training and testing phases has been discussed. Section 4 explains how the dataset is constructed and experiments are designed. Section 5 gives the details of obtained results. In Section 6 conclusions have been drawn.

2. Hard exudates

The hard exudates visible in the eye fundus images are usually of yellow color but may also be found in white color [16]. Hard exudates are formed due to the lipid break down materials which are usually left behind when the localized edema resolves. Usually they have sharp margins, as seen in Fig. 1(a)–(d). Often they appear as waxy and shiny structures [17]. Few important works for the detection of hard exudates have been very briefly discussed.

Sopharak et al. [18] tried to develop a system using basic image processing algorithms like filtering and contrast enhancement. In the work it has been assumed that the pixels close to exudates can be separated from the normal pixels by using only their intensities. Garcia et al. [19] introduced a extrude detection system by using classifiers and machine learning. In this system the candidate regions for hard exudates were separated. Properties like average and standard deviation of RGB values of candidate regions and normal regions were taken as features. The classifiers were used to find the hard exudates based on these features. In another work by Sopharak et al. [20] a new approach using fuzzy clustering and data analysis algorithms for the detection of hard exudates was suggested. The features used in the system like pixel intensities, standard deviation of pixel intensities and hue etc. were carefully chosen by the medical experts. Another pixel based approach was introduced by Dupas et al. [21]. Sanchez et al. [22] addressed the same problem by using dynamic thresholding and mixture of statistical methods. In addition various algorithms for pre-processing and post-processing were also used. Another system for the detection of hard exudates was introduced by Welfer et al. [23]. This system uses morphological operations and watershed transforms in LUV color space for the detection process. Sanchez et al. [24] introduced another hard exudates detection system by exploiting the patient's contextual information. Chen et al. [25] proposed an algorithm which used a combination of histogram operations and morphological operations. The classification was done by using SVM. Garcia et al. [26] made use of logistic regression in combination with multilayer perceptron classifier and radial basis function classifier for the detection of hard exudates from fundus images. His method required proper pre-processing. Kayal et al. [27] employed various basic images basic techniques for the purpose of hard exudates detection. The summary of the stated works and their performance has been given in Table 1.

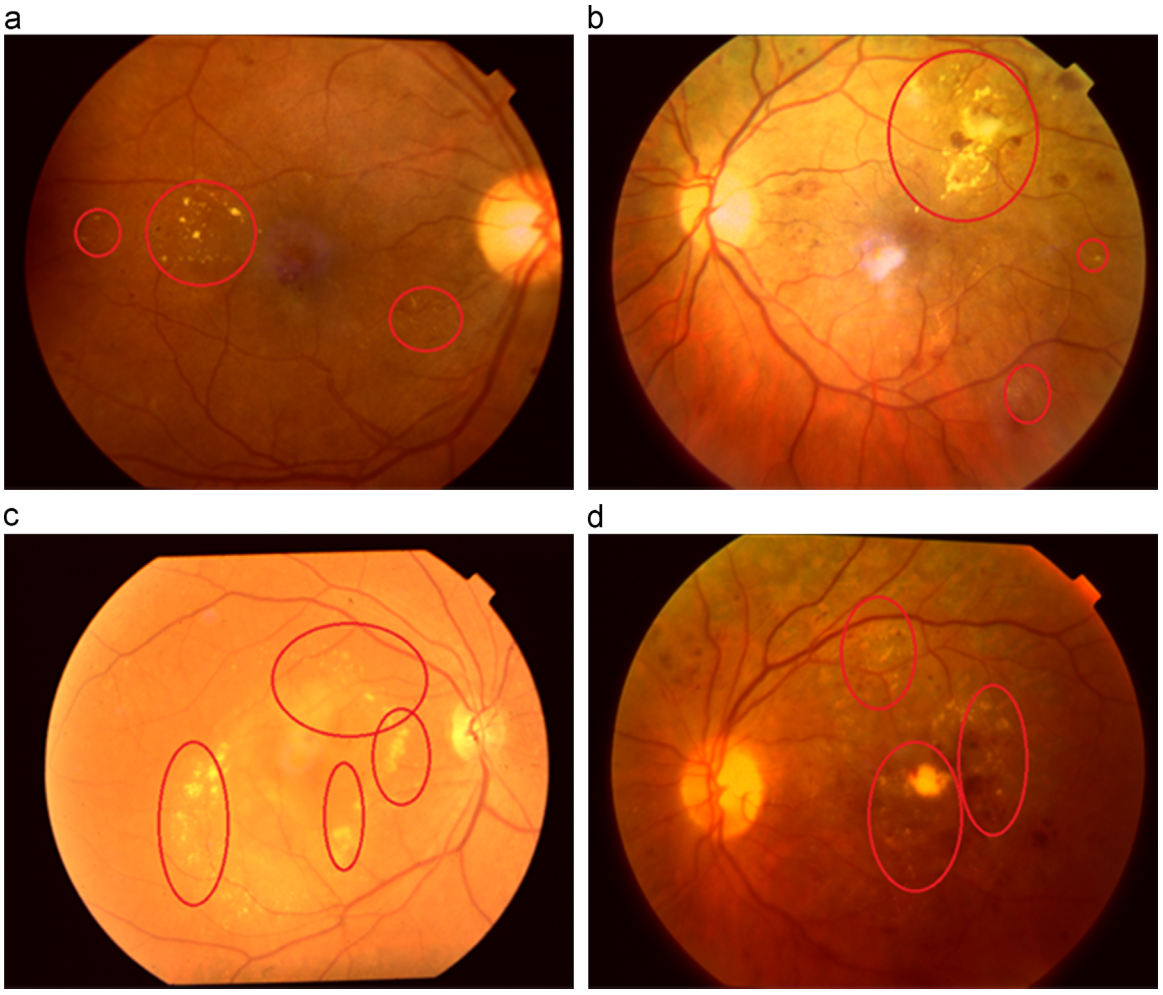

Fig. 1. (a–d) Examples of digital fundus images containing hard exudates.