Decision Support Systems 59 (2014) 341–350

Contents lists available at ScienceDirect

Decision Support Systems

journal homepage: www.elsevier.com/locate/dss

An intelligent mobile based decision support system for retinal disease diagnosis

A. Bourouis [a], M. Feham [a], M.A. Hossain [b], L. Zhang [b,*]

[a] STIC Laboratory, Abou-bekr Belkaid University of Tlemcen, Algeria
[b] Computational Intelligence Group, Department of Computer Science and Digital Technology, Faculty of Engineering and Environment, University of Northumbria at Newcastle, UK

ARTICLE INFO

Article history:
Received 4 February 2013
Received in revised form 24 November 2013
Accepted 8 January 2014
Available online 20 January 2014

Keywords:
Retinal disease
Neural Networks
Mobile applications for Android environments
Retinal image analysis
Rooted method

ABSTRACT

Diabetes and Cataract are the key causes of retinal blindness for millions of people. Current detection of diabetes and Cataract from retinal images using Fundus camera is expensive and inconvenient since such detection is not portable and requires specialists to perform an operation. This paper presents an innovative development of a low cost Smartphone based intelligent system integrated with microscopic lens that allows patients in remote and isolated areas for regular eye examinations and disease diagnosis. This mobile diagnosis system uses an artificial Neural Network algorithm to analyze the retinal images captured by the microscopic lens to identify retinal disease conditions. The algorithm is first of all trained with infected and normal retinal images using a personal computer and then further developed into a mobile-based diagnosis application for Android environments. The application is optimized by using the rooted method in order to increase battery lifetime and processing capacity. A duty cycle method is also proposed to greatly improve the energy efficiency of this retinal scan and diagnosis system in Smartphone environments. The proposed mobile-based system is tested and verified using two well-known medical ophthalmology databases to demonstrate its merits and capabilities. The evaluation results indicate that the system shows competitive retinal disease detection accuracy rates (>87%). It also offers early detection of retinal diseases and shows great potential to be further developed to identify skin cancer.

1. Introduction

The increasing popularity of Smartphones with sensing capability is giving researchers the opportunity to design and develop mobile applications. Particularly, mobile technologies are creating new values in healthcare domains. For instance, handheld devices and Smartphones have been regarded as promising platforms to provide affordable solutions and scalable approaches to widespread care, and ultimately better patient health outcomes due to their mobility. With the new generation of mobile operating systems, e.g. Windows Phone 7, iOS, and Android, there have been substantial increasing developments and adoptions of mobile applications [1]. To date, more than 10,000 medical and healthcare applications are dedicated to Smartphones and hundreds of other handheld devices [2]. Since mobile technology has enabled the practice of care anywhere possible in medical fields, such as for patient monitoring, it is becoming a reality that it is no longer the case that a doctor must be physically present to monitor patients, or obtain their biological data.

However, comparing with other mobile-based intelligent health monitoring systems, there are limited developments focusing on retinal disease related detection. Moreover, research showed that diabetes and Cataract are the key retinal diseases that cause retinal blindness. Especially, the number of diabetic patients aged 64 + will be over 82 million in developing countries by 2022 and nearly 40 million people mostly living in remote areas in developed countries will become blind due to Cataract (http://www.who.int/blindness/en/). Fig. 1 also shows some examples of healthy and infected retinal images respectively for diabetes and Cataract conditions.

Therefore, this paper is motivated by the above medical research and focuses on the development of an intelligent mobile-based automatic diagnosis facility to identify retinal diseases. It employs a feed forward Neural Network (NN) to analyze patients' retinal images and perform disease diagnosis. The Neural Network is initially trained with healthy and infected retinal images on a personal computer and then embedded in an Android environment. An energy efficient algorithm based on the duty cycle technique is also proposed to optimize the power consumption of this retinal disease diagnosis system in Smartphone environments. After retinal images are captured by the microscopic lens attached with the Smartphone, a series of Android's image processing APIs are also employed to analyze the raw images. The selection of an optimal number of hidden neurons for the Neural Network implementation is also carried out. We also

* Corresponding author at: Department of Computer Science and Digital Technologies, Faculty of Engineering and Environment, University of Northumbria, Newcastle NE1 8ST, UK. Tel.: +44 191 243 7089.
E-mail addresses: a_bourouis@mail.univ-tlemcen.dz (A. Bourouis), m_feham@mail.univ-tlemcen.dz (M. Feham), alamgir.hossain@northumbria.ac.uk (M.A. Hossain), li.zhang@northumbria.ac.uk (L. Zhang).

0167-9236/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.dss.2014.01.005

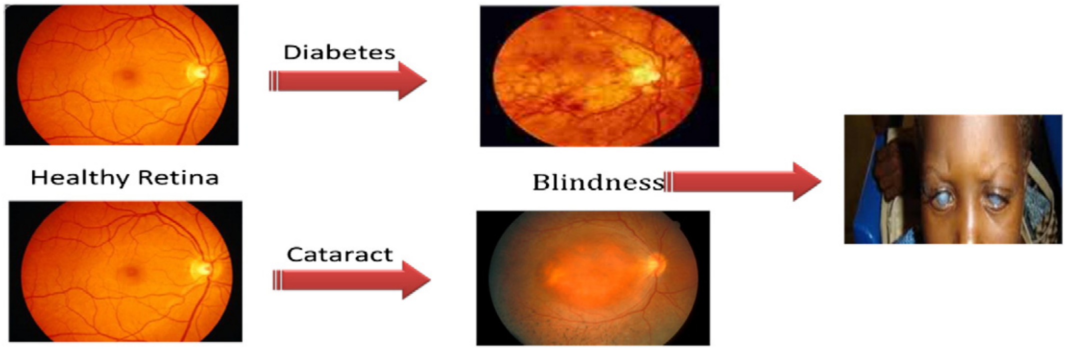

Fig. 1. Healthy and infected retinal images that cause blindness.

present experiments using 260 retinal images extracted from two well-known medical retinal image databases (DIARETDB0 and STARE databases) to evaluate the system's efficiency. The DIARETDB0 image database is especially built to support the development of benchmark diabetic retinopathy detection methods. The STARE database includes healthy and infectious retinal images with various medical causes e.g. diabetes, Cataract and Drusen. In our application, we especially focus on the detection of retinal problems caused solely by diabetes and Cataract. The algorithm is implemented, tested and verified for both rooted and unrooted operating environments of the Smartphone to demonstrate its merits and capabilities for optimal solutions.

Finally, the proposed intelligent mobile-based scheme allows Smartphone users to get access to low cost regular eye examination and disease diagnosis without the need of any specialists at anytime and anywhere.

The paper is organized in the following way. Section 2 discusses related work. The mobile-based retinal disease diagnosis system is presented in Section 3 including discussions of the methodology and the implementation of the core functionality of the system. Details of the evaluation of the system are presented in Section 4. Finally, Section 5 summarizes and concludes the contribution of our research.

2. Related work

In this section, we discuss related decision support systems for healthcare and medical computer-aided diagnosis based on PCs and Smartphones. Since optimization plays a crucial role for mobile-based applications, various optimization strategies are also explored and discussed.

2.1. Desktop-based diagnosis applications

Several computing techniques have been proposed in the literature for the detection of eye abnormalities and retinal diseases. Wang et al. [3] applied a Bayesian classifier based on color features to detect eye diseases. They used a complex algorithm that combined a brightness adjustment method with both statistical classification and a local-window-based verification strategy. Their system achieved reasonable accuracy rates but it needed a high processing capacity. Region growing techniques on gray level images were described in [4] for the diagnosis of eye abnormalities. The idea was based on a supervised method for blood vessel detection in retinal images. It used a Neural Network scheme for pixel classification and computed a 7-D vector composed of gray-level and moment invariants-based features for pixel representation. As compared with other existing solutions in literature, this method was simple and easy to implement but it required comparatively more complex tools and resources.

Data mining techniques and decision support systems have been also employed for the detection of eye abnormality. For example, Jegelevicius and Lukosevicius [5] used a decision support algorithm for the differential diagnosis of intraocular tumors using parameters from eye images. Dua et al. [6] have also proposed a retinal blood vessel monitoring algorithm which was able to provide information on retinal vessel that can be calibrated to normal expected blood vessel diameters. It was also used to detect microvascular anomalies to aid the early detection of diabetic retinopathy. Another integrated analyzer has been presented by Cree et al. [7]. The system described, quantified and monitored the presence of microaneurysms in retinal fluorescein angiograms. Moreover, a multi-layer Neural Network for the detection of lesions in gray scale retinal images was discussed in [8]. However, this Neural Network based system had not been properly evaluated using a larger dimension of input vectors. Abnormality classifications using perception learning have also been proposed in [9]. This work also described the use of a multi-layer Neural Network to distinguish eye diseases. The analysis was based on the selection of an optimal number of hidden neurons and it explored principal component analysis for feature optimization.

2.2. Mobile-based diagnosis systems

The development of intelligent mobile-based healthcare systems (i.e. mHealth) has become a rising research topic recently, since mHealth applications with the advancements in mobile technologies are able to provide efficient solutions for health monitoring. Especially, some systems also included pervasive wearable monitoring devices [10]. For example, a mobile health monitoring system including a ring sensor for blood oxygen saturation level monitoring was described in [11,12]. A Smartphone based health data acquisition system was also discussed in [13]. Their work generally proposed a low cost mobile-based solution and used a mobile device's Bluetooth to transfer patients' physiological data collected using medical devices to a temporary storage. Remote heart monitoring for elderly people using cellular wireless networks is discussed in [14]. Their system monitored elderly people's health condition through a network of wireless sensors and used this information to recommend personalized treatment plans to doctors. Another approach for ECG data compression for a mobile tele-cardiology model is described in [15]. This system employed a significant compression ratio and showed reduction in transmission time over GSM network.

Moreover, there has been substantial development of mobile technologies on a number of medical fronts. For example, the development of modern Smartphone hardware technologies has provided impetus on mobile adaptation to many health services. For instance, Zhu et al. [16] proposed a prototype system that used a mobile device with a built-in camera, wireless network connectivity and intelligent image analysis algorithms to estimate the calorie intake.