Computers in Industry 69 (2015) 72–80

Contents lists available at ScienceDirect

Computers in Industry

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

A computer-aided healthcare system for cataract classification and grading based on fundus image analysis

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ARTICLE INFO

Article history:
Received 29 January 2014
Received in revised form 27 June 2014
Accepted 26 September 2014
Available online 11 November 2014

Keywords:
Fundus image classification
Cataract detection
Ophthalmic disease
Healthcare improvement
Healthcare system

ABSTRACT

This paper presents a fundus image analysis based computer aided system for automatic classification and grading of cataract, which provides great potentials to reduce the burden of well-experienced ophthalmologists (the scarce resources) and help cataract patients in under-developed areas to know timely their cataract conditions and obtain treatment suggestions from doctors. The system is composed of fundus image pre-processing, image feature extraction, and automatic cataract classification and grading. The wavelet transform and the sketch based methods are investigated to extract from fundus image the features suitable for cataract classification and grading. After feature extraction, a multiclass discriminant analysis algorithm is used for cataract classification, including two-class (cataract or non-cataract) classification and cataract grading in mild, moderate, and severe. A real-world dataset, including fundus image samples with mild, moderate, and severe cataract, is used for training and testing. The preliminary results show that, for the wavelet transform based method, the correct classification rates of two-class classification and cataract grading are 90.9% and 77.1%, respectively. The correct classification rates of two-class classification and cataract grading are 86.1% and 74.0% for the sketch based method, which is comparable to the wavelet transform based method. The pilot study demonstrates that our research on fundus image analysis for cataract classification and grading is very helpful for improving the efficiency of fundus image review and ophthalmic healthcare quality. We believe that this work can serve as an important reference for the development of similar health information system to solve other medical diagnosis problems.

1. Introduction

Along with the development of information technology, computer-aided healthcare by integrating medical devices and healthcare information systems to improve healthcare quality and productivity is getting more and more attention. In particular, computer-aided healthcare system may provide a solution in the developing areas where medical resources are scarce. An example is about the diagnosis and treatment of eye cataract. The WHO's report in 2004 shows that there are 53.8 million people globally suffering moderate to severe disability caused by cataract, 52.2 million of whom are in low and middle income countries [1]. Although early and correct diagnosis will help patients reduce the suffering, millions of them, especially in under-developed area, can hardly get a chance to receive treatment in hospital, because of the limited healthcare resources, lacking healthcare information and economic consideration. It has long been a desire to develop a convenient and cost-effective computer-aided auxiliary diagnosis system, which is able to help cataract patients in under-developed areas to know timely their cataract conditions and obtain treatment suggestions from doctors. In this paper, we demonstrated a possible solution of a computer-aided healthcare system for cataract classification and grading based on fundus image analysis.

Retina consists of several light-sensitive neuron layers, lining the inner surface of the eye, in which many diseases manifest themselves, such as macular degeneration, glaucoma and diabetic retinopathy [2]. Ophthalmologists and scientists have been

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http://dx.doi.org/10.1016/j.compind.2014.09.005
0166-3615/

seeking the approach to examining the retina for a long time. Jan Evangelista Purkinje invented the ophthalmoscope in 1823 and Charles Babbage improved it in 1845 [3,4]. In 1851, von Helmholtz reinvented the ophthalmoscope, regarded as the revolution of ophthalmology. In 1910, Allvar Gullstrand developed the first fundus camera [5] and received the Nobel Prize in Physiology or Medicine in 1911. Nowadays, the fundus imaging has been widely used as primary retinal imaging, routine physical examination and population screening programs, because of its safety and cost-effectiveness.

The cataract is a clouding or dulling of the lens inside the eye, which leads to a decrease in vision and is considered as the most common cause of blindness. The cataract brings many difficulties to the patients' life, such as appreciating colors and changes in contract, driving, reading, recognizing faces and coping with glare from the bright lights [6]. The longer with cataract, the lower vision the patients will have. The cataract can be diagnosed by ophthalmologists or optometrists with a slit lamp, and then be classified with lens opacities classification system (LOCS) [7]. Cataract removal surgery is the most effective treatment, which is usually conducted when the cataract influences badly on patients' daily life and work. Although the cataract is not in the retina, the clouding in crystalline lens will reduce the light that focused on the retina, leading to the degradation of fundus image quality. By judging the difference between non-cataract fundus image and the cataract one, well-experienced ophthalmologists can decide whether to conduct a surgery.

The present cataract examination equipment and methods, such as lens opacities classification system (LOCS) [4], are intricate for most patients and can only be operated by well-experienced ophthalmologists. To make them applicable to perform a diagnosis based on fundus image, the well-experienced ophthalmologist has to be physically close to the patients. This fact makes the ophthalmologist becoming a scarce resource and a bottleneck that causes the large scale screening of the cataract disease in the early stage impossible. The fundus image can be more easily obtained only with the help of nurses from community service even the patients themselves. This paper focuses on fundus image analysis and fully automatic cataract classification. Its goal is to reduce the burden of scarce resources and improve the effectiveness and efficiency of fundus image review, through which to enable active and enhanced healthcare services.

Studies on fundus image analysis have been made for years. Segmentation and location of retinal structures, such as retinal lesions [8–10], vessels [11–17], optic disc [18–21] and fovea [22,23], have been widely studied. Based on these techniques, researchers are also trying to develop diagnose systems for specific retina-related diseases includes microaneurysms [10], diabetic retinopathy [24–29], age-related macular degeneration [30], glaucoma [31–34], cardiovascular diseases [35]. Li et al. has made an effort to classify and diagnose specific cataract automatically by split image and retro-illumination image, including nuclear cataract [36–39], cortical cataract [40] and posterior sub-capsular cataract [41,42]. However, there is little work reported on cataract classification and grading by using fundus images.

Fig. 1 shows the fundus image of non-cataract and cataract in different gradings. In the image (a) without cataract, the blood vessels can be shown very clearly, even the capillary ones. The more severe cataract the patients have, the more cloud will be in the lens, resulting in that less vessels can be observed from the fundus image. There are less vessels details in mild cataract patients' eye fundus image, while only the trunk vessel and little details in the moderate cataract ones'. Furthermore, there is hardly anything in the severe cataract ones'. By selecting appropriate features such as detecting the vessel details in fundus images, it is possible to find a method to recognize the cataract and classify its grading automatically.

The motivation of the paper is to develop a fundus image analysis based automatic classification and grading system for cataract so that cataract patients can receive preliminary classification and get suggestions from ophthalmologists timely, conveniently and even remotely, meanwhile hospitals can manage their un-sufficient medical resources more efficiently and take more capacity and ability for cataract treatment instead of preliminary cataract screening.

The contribution of this paper can be summarized as follows: (1) a computer-aided healthcare system for cataract classification and grading based on fundus image analysis is proposed. Since it provides great potential to reduce the burden of the well-experienced ophthalmologists (the scarce resources) and enable the large scale cataract screening, which is helpful and worthwhile for other medical diagnosis problems by using similar approaches. (2) An experimental study on exploiting fundus image for cataract classification and grading is described, where two feature extraction methods, based respectively on the wavelet transformation and the sketch with discrete cosine transformation, are investigated. The empirical experiments on the real-world datasets are reported, which illustrates that, for the wavelet transform based method, the correct classification rates of two-class classification and cataract grading are 90.9% and 77.1%, respectively. For the sketch based method, the correct classification rates of two-class classification and cataract grading are respectively 86.1% and 74.0%, which are comparable to the wavelet transform based method. (3) A pilot study is described for the application of the proposed approach in a real-world usage scenario. It demonstrates that our research on fundus image analysis for cataract classification and grading is very helpful for improving the efficiency of fundus image review and ophthalmic healthcare quality. We believe that our pilot study can serve as an important reference for the development of similar health information system for enhanced medical care.

The paper is organized as follows. Section 2 introduces the framework of our automatic classification and grading system for

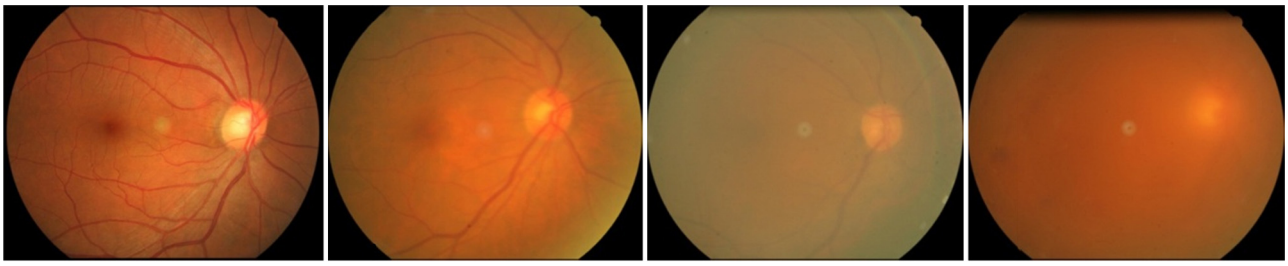

Fig. 1. Fundus images of non-cataract and cataract in different gradings. (a) Non-cataract; (b) mild; (c) moderate; (d) severe.