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Complex wavelet based quality assessment for AS-OCT images with application to Angle Closure Glaucoma diagnosis

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ABSTRACT

Background and objectives: Angle closure disease in the eye can be detected using time-domain Anterior Segment Optical Coherence Tomography (AS-OCT). The Anterior Chamber (AC) characteristics can be quantified from AS-OCT image, which is dependent on the image quality at the image acquisition stage. To date, to the best of our knowledge there are no objective or automated subjective measurements to assess the quality of AS-OCT images.
Methods: To address AS-OCT image quality assessment issue, we define a method for objective assessment of AS-OCT images using complex wavelet based local binary pattern features. These features are pooled using the Naïve Bayes classifier to obtain the final quality parameter. To evaluate the proposed method, a subjective assessment has been performed by clinical AS-OCT experts, who graded the quality of AS-OCT images on a scale of good, fair, and poor. This was done based on the ability to identify the AC structures including the position of the scleral spur.
Results: We compared the results of the proposed objective assessment with the subjective assessments. From this comparison, it is validated that the proposed objective assessment has the ability of differentiating the good and fair quality AS-OCT images for glaucoma diagnosis from the poor quality AS-OCT images.
Conclusions: This proposed algorithm is an automated approach to evaluate the AS-OCT images with the intention for collecting of high quality data for further medical diagnosis. Our proposed quality index has the ability of automatic objective and quantitative assessment of AS-OCT image quality and this quality index is similar to glaucoma specialist.

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1. Introduction

Glaucoma causes irreversible optic nerve damage and is associated with raised Intra-Ocular Pressure (IOP) [1]. Glaucoma can be broadly classified into two types: angle-closure and open-angle depending on the anterior chamber angle status. Angle-closure disease is characterized by a narrow Anterior Chamber (AC) angle with subsequent blockage of the trabecular meshwork. This reduces the aqueous outflow resulting in raised IOP. The AC angle can be imaged and measured by an anterior segment optical coherence tomography (AS-OCT) imaging technique [2]. AS-OCT is a non-contact, fast, and highly reproducible imaging device which provides cross sectional views of the AC and angle structures of the eye [3]. AS-OCT has helped to demonstrate the multifactorial mechanisms of Angle Closure Glaucoma (ACG) disease which includes pupil block, plateau iris configuration, thick peripheral iris roll, and increased anterior lens vault mechanisms [4].

Noise and blur are two fundamental degradation processes that occur in AS-OCT images. Image Quality Assessment (IQA) techniques can predict the quality of a natural image which matches with the human vision [5]. IQA of the AS-OCT images is a significant issue because multiple images usually have to be made until one is sufficient for ACG mechanism detection and analysis by glaucoma experts. Many IQA algorithms are explored for natural images [6–8] and these algorithms can be broadly classified into three categories, viz. full-reference (FR) IQA algorithms which require both original and distorted images [6]; reduced reference (RR) IQA algorithms that require distorted image and some information about the original image [7] and no-reference or blind IQA algorithms which do not require any additional information except distorted images [8].

In general, FR-IQA and RR-IQA algorithms perform better than the blind IQA algorithms since no information about the original (or reference) signal is available in the blind IQA algorithms. Some learning techniques have been used in [8,9] for blind IQA algorithms for natural images. Fang et al. [10] proposed a new blind IQA algorithm using the characteristics of natural images. These algorithms are proposed for natural images and cannot be directly applied to medical images, particularly AS-OCT images, as characteristics of natural and AS-OCT images are quite different. Moreover, the criteria to assess the quality of natural and AS-OCT image are different. For example, a natural image with consistent edges is assumed to be a good image [11]. While in the AS-OCT images, the criteria used for a good image as follows: visible anterior segment characteristics (such as identification of the anterior chamber structures, position of the scleral spur, angle opening distance, trabecular-iris space area and angle recess area), the smallest amount of artefacts resulting from movement of eyelids and corneal scars in the image. From these requirements, we can realize the need for designing a new IQA method for the AS-OCT images. Very few IQA algorithms are proposed in the literature for posterior segment OCT images [12–14]; but not for the anterior segment (AS) OCT images. All these studies for posterior segment OCT image quality assessments require additional information for the objective assessments parameters such as signal to noise ratio (SNR), signal strength (SS), and signal deviation (SD) with application to glaucoma diagnosis.

The researchers have also used SNR to assess the quality of the posterior segment OCT images [12], although study about the IQA [15] matrices and use of IQA matrices [16] suggested that SNR is a poor indicator of the image quality since it does not count the distribution of the scan image. Another image quality parameter such as signal strength (SS) is used in the posterior segment OCT imaging device which combines SNR and the uniformity of the signal within a scan. The value of SS parameter ranges from 1 to 10, where the increment of the SS parameter suggests the better image quality [12]. Signal deviation is also used to characterize OCT images [14] which are based on signal pixels in the total number of A-scans within one B scan. These three existing objective parameters SNR, SS and SD require the signal pixels and noisy pixels values which are given by the customized OCT software. All these above mentioned algorithms [12–14] can be classified into reduced reference IQA techniques. However, there is no blind IQA algorithm exists in the literature, which can assess the quality of OCT images. Therefore, this work proposes a blind IQA algorithm for AS-OCT images. The algorithm is designed to match the suggestions of the OCT experts which does not require any additional information.

This study aims to develop a new technique to evaluate the quality of AS-OCT images in a quantitative and objective way which matches with the subjective evaluation done by the OCT experts. This can enable the OCT users to obtain good quality images for efficient diagnosis of ACG. To the best of our knowledge there is no existing technique for AS-OCT image quality assessment. The proposed method is compared with subjective assessments from the experts of OCT images to verify its reliability.

2. Proposed methodology

Overview of the proposed method for image quality assessment of AS-OCT images is shown in Fig. 1. This includes the acquisition of raw AS-OCT images followed by the extraction of a large number of morphological features based on complex wavelet based LBP representation. A small set of discriminative and inter-dependent features are then selected and fed into a Naïve Bayes Classifier. Performance is then evaluated using the selected features. Then the selected features are used for the quality index parameter calculation and for grading the images.

2.1. *ACG database*

The data used in this work consists of AS-OCT eye images of 194 patients affected with the angle-closure disease. These images were provided by the Department of Ophthalmology in the National University Hospital, Singapore (NUHS). Ethics approval was obtained from the review board of NUHS and written consent was also obtained from all subjects prior to AS-OCT imaging. A skilled technician obtained the clinical images through a horizontal scan, including sections of the nasal and temporal quadrants, of all subjects using AS-OCT