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Automatic methods for diagnosis of glaucoma using texture descriptors based on phylogenetic diversity

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ABSTRACT

Glaucoma, a multifactorial optic neuropathy causing numerous ocular conditions in retinal and optic nerve cells, is an asymptomatic and chronic pathology; hence, early detection is essential for treatment. This study presents two automatic methods for performing optic disc delineation and glaucoma quantification. These proposed methods are based on the Otsu and k-means algorithms, which were incorporated for delimiting the optic disc region. The methods were exhaustively tested using red, green, and blue channel images extracted from the image of a retina. After segmentation, we performed characterization using texture properties based on phylogenetic diversity indices. The classification was then performed using multiple classifiers. The methodology obtained promising results. In the best case, the results obtained using the Otsu algorithm reached 100% sensitivity, 99.3% specificity, 99.6% accuracy, and a ROC curve of 0.996.

1. Introduction

With increasing population aging, a greater number of people are affected by eye diseases that impair vision. Glaucoma is the second leading cause of blindness worldwide after cataracts, and approximately 60 million cases were diagnosed in 2010. Therefore, early detection is essential as the first step in treating the condition. Changes in the shape, color, or depth of the optic disc (OD) constitute some of the indicators used to determine the presence of various visual pathologies. According to [1] globally more than 80% of vision deficiencies can be avoided through early diagnosis of pathology.

Glaucoma is an optic neuropathy characterized by progressive loss of retinal ganglion cells and their axons, potentially leading to irreversible loss of vision [2]. In addition to intraocular pressure (IOP), other factors, such as age, central corneal thickness, disc bleeding, and abnormal structural and functional measures of the optic nerve status, have been identified as being associated with the risk of developing glaucoma [2]. The location of the OD in the images of the fundus of the retinal residue is important, as it greatly facilitates diagnosis of diseases of the retina, such as glaucoma, occlusion, cancer of the hypophysis, and papilloma.

Because of these difficulties, in the study described in this paper we developed a computer-aided diagnosis (CAD) system for the

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Table 1
Summary of related works.

Work	Descriptors, techniques and classifier
[4]	He developed a study for automatic detection of glaucoma. Initially the manipulation of the illumination variations of the images is made, and then the segmentation is performed.
[5]	Uses correntropic features based on empirical wavelet transformations are applied to extract the texture characteristics.
[6]	Initially, the images were cut to reduce processing, then the segmentation for OD detection. Later, another segmentation was used to find the OC to evaluate the progression of glaucoma.
[7]	Used the Asghari and Jalali algorithms to detect an OD.
[8]	He objective of that study was to measure the ratio of OD to OC to diagnose which images were healthy and which were glaucomatous.
[9]	In the study the automatic detection of glaucoma was proposed by utilizing the ratio between the segmentation of the OD to the OC.
[10]	The terrestrial truth was obtained through manual segmentation which was performed by five specialists. A local binary pattern with various density functions were proposed to segment the OD boundary.
[11]	Uses the Circular Hough (CHT) transformation to improve the OD limit. Based on the location of the OD, the region of interest was extracted by applying the polar transformation.
[12]	It uses the Otsu algorithm with four thresholds to segment OD and OC. To exclude false positives, the CHT was used.
[13]	Features based on discrete wavelets were extracted from the optical disc image. The extraction was followed by a selection of optimized genetic characteristics combined.
[14]	Study aimed to detect the optical disc and optic cup limits to aid in the automatic diagnosis of glaucoma. The region classification model and adaptive edge smoothing update techniques are used for feature extraction.
[15]	The study performed an automatic process to locate the OD and retinal image optical glass.
[16]	Uses the digital image processing applying mathematical morphology in a support vector machine (SVM). The resulting vector is classified by an SVM as positive or negative for the drusen.

automatic detection of glaucoma. In this system, digital image processing techniques using the Otsu and k-means algorithms are applied for the segmentation of the OD in retinal images. In addition, characterization is performed by means of descriptors of textures based on the indices of phylogenetic diversity.

This paper presents contributions in two research areas. For the first area, the medical field, we offer a fully automatic system to assist the diagnosis of glaucoma that uses two distinct approaches. These approaches fulfill the role of a second opinion in addition to that of a specialist. For the computing area, we propose new techniques that are capable of discriminating textures based on phylogenetic diversity and the use of Otsu and k-means algorithms applied to OD segmentation.

The remaining sections of this article are organized as follows. In Section 2, we present related studies. In Section 3, we show the proposed methods for automatic quantification of optic nerve alterations that cause glaucoma. The experimental results, discussions, and comparisons with other methods are presented in Section 4. Finally, we present the conclusions of this study in Section 5.

2. Related studies

Image processing is applied in many disciplines, from remote sensing, which involves the processing of hyperspectral images (HSI) [3], to the processing of medical images. In the literature, there are several related studies that addressed image processing techniques for the early diagnosis of glaucoma. Table 1 we present the summaries of related works.

The presented studies attained impressive results for the automatic detection of glaucoma. However, some of the studies demonstrate difficulties in the execution of the method. These difficulties are as follows. 1) It can be observed that a large number of the studies were focused only on OD and OC segmentation with the objective of discovering the relationship between the OD and the OC through the calculation of their diameter. Therefore, to reach a diagnosis some of the methods require the direct intervention of a specialist to assign markings. 2) Some papers, such as [5], do not clearly describe some of the steps used in the methodology, which makes it difficult to perform a detailed analysis and subsequently identify elements that can be improved. 3) Few studies explored the texture properties contained in the OD region.

The Otsu and k-means algorithms are used to identify the ROI to extract the texture characteristics by applying descriptors based on the phylogenetic diversity indexes (PDI). This allows accurate classification in the task of determining in which images the retina is healthy and in which it is glaucomatous; it does not require segmentation of the OC to calculate the relation between it and the OD or the intervention of a specialist.

Therefore, to keep human intervention at a minimum, we chose to use texture analysis for characterizing the ROI of the OD. We selected this method because the amount of information that can be obtained from this analysis is substantial. In other words, this type of analysis allows the extraction of properties that cannot be perceived by the human eye.

3. Method

In this section, we present the proposed methodology for diagnosing glaucoma in retinal images. The purpose of this study is to segment the OD region, then extract the characteristics using texture descriptors, and then classify the images with multiple classifiers to validate the method developed for automatic detection of glaucoma. The flowchart presented in Fig. 1 shows the five steps followed to implement the proposed methodology.