AN ALGORITHM FOR MEASURING PTERYGIUM´S PROGRESS IN ALREADY DIAGNOSED EYES

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ABSTRACT

Pterygium is a disease characterized by the growing of the fibrovascular tissue over the cornea, and it is relatively common in equatorial countries, like Brazil. Surgical intervention should be delayed until an optimal time, because this type of disease can manifest itself again in a more aggressive way after the surgery. Nevertheless, the monitoring of the disease is currently held inaccurately by the ophthalmologist, without the help of a specific tool. This work aims to develop a computational method to assist in monitoring the progress of pterygium based on images of eyes already diagnosed.

Index Terms— Pterygium, image segmentation, iris detection

1. INTRODUCTION

Pterygium is a disease of the anterior segment of the eye that is characterized by a fibrovascular tissue with triangular aspect, which grows in the interpalpebral region of the bulbar conjunctiva, with possibilities of reaching the cornea [1]. Usually it occurs on the nasal region of the ocular globe, but it can, more rarely, occur on the temporal region. Pterygium may compromise vision by direct obscuration of the visual axis or through irregular astigmatism, which can be induced by distortion of the cornea or the axial tear film [2]. In addition, it can cause chronic irritation [3]. Fig. 1 shows an image of an eye with pterygium.

It is relevant to mention that the growth rate tends to be more aggressive in cases of the recurrence of the disease after the surgery [4]. Thereby, a premature excision can accelerate the progress of the fibrovascular tissue in recurrence cases, and, on the other hand, the excessive delay of the surgery can cause several damages to the patient, including blindness.

So, this work intends to develop an algorithm based on digital image processing techniques to automatically measure the advancement of the pterygium. The proposed method uses the Circular Hough Transform (CHT) to segment the iris. Then, a region growing algorithm based on Otsu's algorithm is applied on the segmented area of the iris in order to segment the fibrovascular tissue of the pterygium. It is important to mention that this work is an initial propose to the difficult task of segmenting the pterygium's tissue. The main difficulty lies in the fact that it can manifest itself in different ways. Thus, the fibrovascular tissue may have different consistencies and smooth transitions on the iris.

This paper is divided as follows. Section 2 compares two different algorithms for iris segmentation. Section 3 introduces the experimental setup. Section 4 presents the results obtained. Finally, Section 5 concludes the paper.

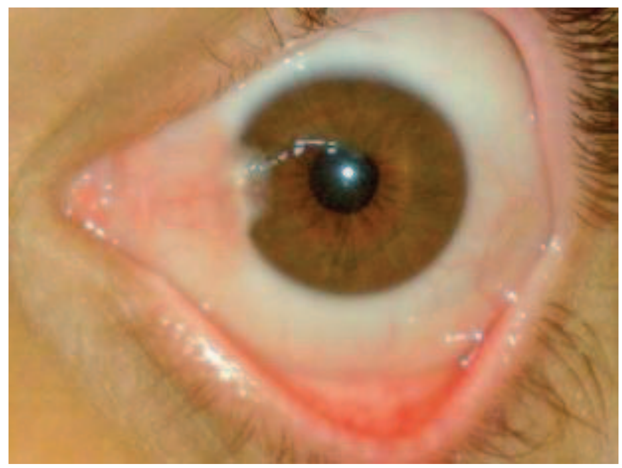

Fig. 1. Eye with pterygium

2. COMPARISSON BETWEEN DAUGMAN AND CIRCULAR HOUGH TRANSFORM ALGORITHMS

In this section, we compare Daugman's [5][6] algorithm and Circular Hough Transform [7] to perform iris segmentation on eyes affected by pterygium. In order to do that, we initially estimate the error rates from both algorithms using Monte Carlo's simulation. Then, we use Wilcoxon's sum rank test to compare the error rates from both algorithms.

Initially, 100 samples of 30 images were created without reposition from a data set of 58 images. Then, both algorithms were executed on each sample. In each execution, the error rates from both algorithms were calculated. The success of the segmentation was defined subjectively. Fig. 2 shows a case of a wrong segmentation, and Fig. 3 shows a successful segmentation.

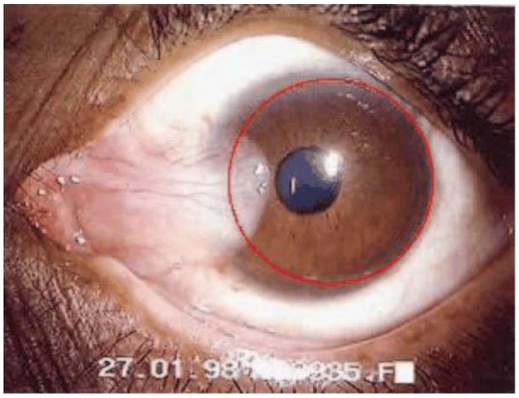

Fig. 2. Wrong segmentation using Daugman's algorithm.

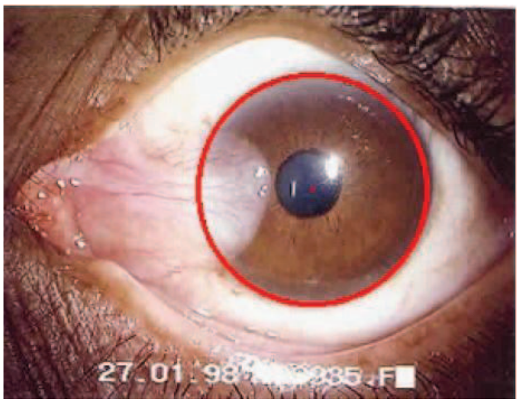

Fig. 3. Correct segmentation using CHT.

Then, the normality of the error rates was investigated. Applying Shapiro-Wilks's test we concluded with 95% of confidence that the error rates do not follow a normal distribution. Because of that, it was necessary to perform a non-parametric test to compare the performance of the algorithms. We used Wilcoxon's sum rank test and with 99% of confidence we concluded that CHT, in comparison with Daugman's algorithm, achieves better results in segmenting iris affected by pterygium.

3. THE PROPOSED METHOD

The proposed system consists of three basic steps: (I) Iris segmentation, (II) pterygium segmentation and (III) evaluation of the advancement of the pterygium. These steps are described below.

3.1. Iris segmentation

Based on the results obtained in Section 2, the CHT was the method used to perform the iris segmentation. As previously related, Fig. 3 illustrates the application of the Circular Hough Transform algorithm on an image of an eye diagnosed with pterygium. In this work, Canny [8] edge detector was used to extract the edges of the grayscale image of the eye before applying the CHT. For the Canny detector, the standard deviation used for the Gaussian filter was 1, the edge detection was performed using a 5x5 Sobel operator, the first threshold was $T_1 = 0.66 * m$ and the second threshold was $T_2 = 1.33 * m$, where m is the median of the histogram of the image.

3.2. Pterygium segmentation

After iris segmentation, it is necessary to segment the pterygium region, and for that no solution was found on the literature. So, this work presents an initial approach to perform the pterygium segmentation. Our proposal is based on a region growing technique and is defined below. Fig. 4 illustrates the basics steps of the proposed algorithm.

1) Transform the iris segmented region to a polar coordinate image $f(\rho, \theta)$.
2) Build a seed image $s(\rho, \theta)$ from $f(\rho, \theta)$ having only pixels that correspond to transition from the iris edge (reconstructed with CHT) to conjunctiva.
3) Build an image $f_q(\rho, \theta)$ based on the binarization of the iris region. In this work, Otsu [9] algorithm was used.
4) Dilate $s(\rho, \theta)$ successively, conditioned to $f_q(\rho, \theta)$. In other words, apply $X_{n+1} = X_n \oplus B \cap f_q(\rho, \theta)$, until $X_{n+1} = X_n$. B is a 3x3 square structuring element, and $X_0 = s(\rho, \theta)$.
5) Extract the connected components of the image. Maintain only the biggest region and discard all the others. The objective of this step is to eliminate spurious elements.
6) Apply simple edge detection. In this work, Sobel [10] method was used.

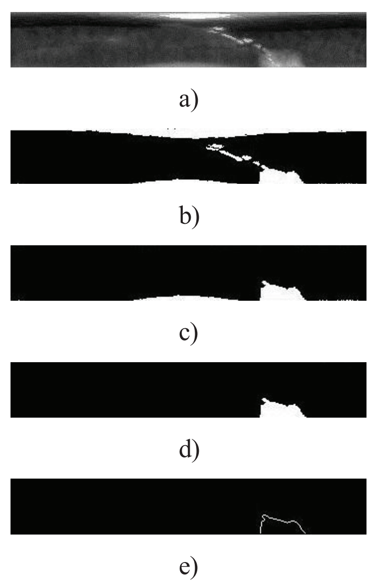

Fig. 4. (a) Iris represented in polar coordinates and (b-e) steps 3 to 6 of the proposed algorithm.

3.3. Evaluation of advancement of the pterygium

After iris and pterygium detection, we can evaluate the advancement of the pterygium over the iris based on the differences of the Euclidean distances between the iris's center to the limb (i.e. the transition between the conjunctiva and the iris) and between the iris's center and the pterygium's tissue. So, we can calculate the percentage of the limb-center distance that has been occupied by pterygium.

4. EXPERIMENTAL SETUP

For the experiments, we used a data set of 58 images of different sizes of eyes with pterygium. In our data set, each image represents a different stage of the progression of the disease.

The experimental setup consisted of performing the following procedures. First, apply the CHT on all images, in order to segment the iris region. The images with good segmentation were used in the next step, while the rest were discarded. Importantly, the criterion used to evaluate the quality of segmentation was subjective and was determined based on the experience of the authors. The next procedure consisted of applying the region growing algorithm described in Section 3 on the selected images in the previous step of the experimental setup. As mentioned in Section 3, this step aims to segment the pterygium. Again, we selected the images with good segmentation subjectively. The rest of images were discarded.

The last stage of the experimental setup consists of estimating the advancement of the pterygium for each image that had a satisfactory segmentation of the pterygium. The calculation of this estimate is given by the percentage of advancement, which is defined as the ratio between the radius of the iris (RI) and the advancement of pterygium (AP). As noted in Section 3, the iris, despite its elliptical shape, was approached by a circle by the Circular Hough Transform. The radius of this circle will be used to define the radius of the iris.

The advancement of the pterygium, in turn, is calculated from the edge map that is obtained in the final stage of the region growing algorithm. The procedure for this calculation is performed as follows. First, we calculate the Euclidean distance from all points of the edge map to the center of the circle of the iris (determined by the Circular Hough Transform). Then we select the smallest of these distances, which is called SD. Thus, the advance of the pterygium (AP) is given by the difference between the radius of the iris and the smallest distance between the points of the edge map and center of the iris, i.e., AP = RI - SD. From the advancement of the pterygium, one can calculate the percentage of advancement of the pterygium (PAP) as the ratio between its advance (AP) and the radius of the iris (RI). The results of the percentage of the advancement of the pterygium are provided and explained in the next section.

5. RESULTS

Some results of the pterygium's segmentation are presented in Fig. 5 and Fig. 6. In these images the circle represents the result of the iris segmentation by Circular Hough Transform. The irregular curve represents the segmentation of the pterygium. As one can see by these images, the segmentation of the pterygium was satisfactory.

The application of the Hough algorithm resulted in a total of 42 correct segmentations of the iris area. Thus, only these images went to the next stage, which is the stage of the segmentation of the pterygium. The step of the segmentation of the pterygium, in turn, resulted in a total of 26 images classified as segmented correctly.

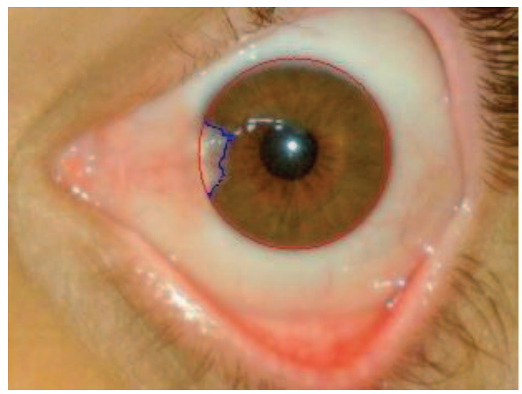

Fig. 5. Segmentation result of the pterygium.

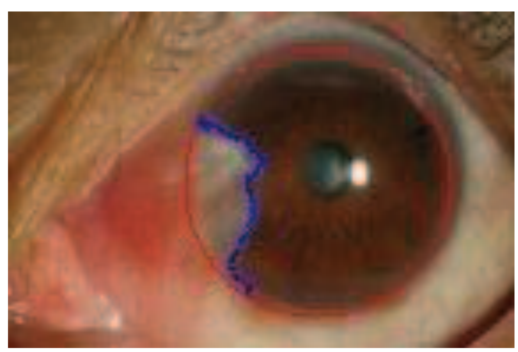

Fig. 6. Segmentation result of the pterygium.

After the segmentation of the pterygium, the rate of advancement of the pterygium was calculated for each of these images. Fig. 7 shows the RI and SD for the image of Fig. 5. Some results for the estimation of the percentage of advancement of pterygium (PAP) by the proposed algorithm and the RI and SD for each of the images that had a satisfactory segmentation of the pterygium are presented in Tab. 1. The percentage of advancement of pterygium in Fig. 7 is referenced in line 1 of Tab. 1, while the results of the application on Fig.3 and Fig.6 are referenced in lines 15 and 19, respectively.

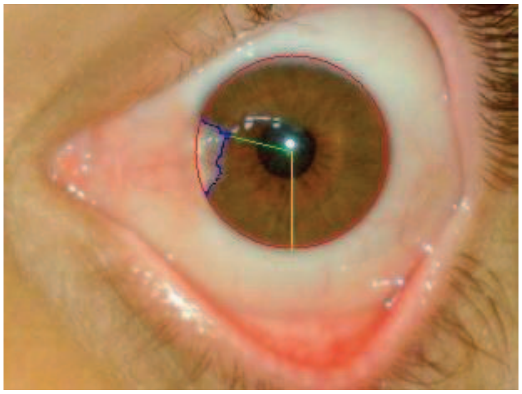

Fig. 7. RI and SD from Fig.5.

Image	DP	RI	PAP
Img 1	37.108	58	36.02068
Img 2	41.1096	64	35.76625
Img 3	9.43398	63	85.02542
Img 4	51.264	141	20.42580
Img 5	49.366	62	44.23076
Img 6	29	52	68.91835
Img 7	28.2843	91	61.08625
Img 8	28.0179	72	61.08625
Img 9	24.1868	52	53.48692
Img 10	3.60555	50	94.7889
Img 11	20.3961	80	74.0487
Img 12	5.38516	56	90.38364
Img 13	89.0225	107	16.80140
Img 14	3	65	95.52238
Img 15	24.0208	67	64.14805
Img 16	34.9285	58	39.77844
Img 17	40.1622	119	66.25025
Img 18	19	58	67.24137
Img 19	16	38	57.48552

Tab. 1. Results of DP, RI and PAP for the test images.

6. CONCLUSION

In this paper, we proposed an original approach to measure the advancement of the pterygium after its segmentation. To detect the advancement of the pterygium we performed two segmentations. The first was the segmentation of the iris in the eye region. For this, we used the Circular Hough Transform (CHT). This algorithm was used because it was more robust, compared to other techniques, in the cases of irises affected by the pterygium. The second segmentation was the detection of the region of the pterygium in the iris. In this segmentation, we used a region growing algorithm based on Otsu's thresholding method. From the last segmentation we can calculate the advancement of the pterygium, as described in Section 4.

The results showed that from the images segmented correctly by the CHT was possible to obtain a hit rate of 63.4% of correct segmentation of the pterygium. Thus, one can consider that the proposed algorithm achieved a reasonable performance with the images from the test set. By the analysis of incorrectly segmented images, it was noticed that the segmentation algorithm failed in the following situations: poor lighting, small advancement of the pterygium over the iris, and in cases where the consistency of the pterygium gradually decreases and it merges with the iris. Thus, the use of a set of standardized test images for application of the algorithm could result in higher hit rates. In addition, the application of other limiarization techniques, instead of Otsu´s algorithm, at the third stage of the pterygium segmentation algorithm could achieve better results. Therefore, we can say that this work reduced the pterygium segmentation problem to a limiarization problem.

Finally, we conclude that this study was successful in demonstrate the feasibility of the estimation of the advancement of the pterygium, based on digital image processing techniques.

7. REFERENCES

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