A Fast and Accurate Eyelids and Eyelashes Detection Approach for Iris Segmentation

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ABSTRACT: *Iris segmentation step is an essential process in iris recognition system. This step becomes much more difficult due to the presence of eyelids and eyelashes. This paper contributes to fast and robust eyelids and eyelash detection algorithm. The main contributions are: (1) Proposition of robust eyelids detection algorithm based on the Radon transform and polynomial curve fitting, using Least Squares Fitting method. (2) Eyelashes detection using diagonal gradient and thresholding process. The proposed method was evaluated on the CASIA V3 database and compared to the previous work. As the experimental results show that the proposed algorithm provides an encouraging performance in terms of accuracy and computational complexity. Moreover our method is very useful for iris recognition system which requires excluding the bits generated from eyelashes regions during iris matching stage.*

Keywords: Iris, Segmentation, Eyelids, Eyelashes, Radon

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1. Introduction

The iris recognition system is composed of essentially four modules. The first one is the acquisition process. The second one is the limbic boundary localization. This step includes the detection of the limbic and pupillary boundary, followed by the top and lower eyelids and eyelashes localization process. The third is the normalization, and the last is the feature extraction. Generally iris regions are covered by eyelids and eyelashes. These artifacts decrease the accuracy of iris recognition system. To overcome this problem, many methods are proposed in litterature. Masek [1] estimate the eyelids by two horizontal lines. This method is not very accurate because it would isolate too much the iris region, which makes the recognition process less accurate [1]. The new iris segmentation methods tried to follow the eyelids shape irregularity. Zhaofeng [2] proposed an algorithm which used the 1D rank filter to remove the eyelashes and edge detection followed by a curve fitting to address the eyelids shape irregularity. Kallel [3] used the radial segmentation approach and circle model to estimate the contour eyelids. Young [4] used masks for detection eyelid candidate points and the rotatable parabolic Hough transform to locate the eyelids boundaries. Yi [5] proposed an algorithm that used the Daubechies wavelets in the vertical direction and the modified Canny edge detector in the horizontal direction to minimize the eyelashes effects. Finally the longest connected pixels are selected and fit with a second order parabolic curve.

In this paper we start by giving a description of two eyelids and eyelashes detection methods then, we propose our new method aiming to an accurate and fast eyelids and eyelashes detection. Then in section four a comparative study of two existing methods is evaluated using CASIA iris image database V3.0 [6]. Finally, we present the conclusion.

2. Description of Standard Eyelids and Eyelashes Detection Methods

2.1 Zhaofeng Algorithm

To undertake the shape irregularity of eyelids, Zhaofeng [2] propose to use six models, statistically established, of the upper and lower eyelids as shown in Figure 2. The pupil center is taken as reference to draw the eyelids models.

These models are determined manually using a training set. After that the model with the highest similarity is considered as the first guess of the eyelid.

The algorithm is achieved in five steps as described by the following flowchart as shown in Figure 3.

• The first step in this algorithm is performed using 1D horizontal rank filter. This type of filter is an image processing algorithm that replaces the value of each pixel by the *pth* value of the neighborhood of this pixel. A rank filter is controlled by two parameters named generally by *L* and *p*, where *L* controls the smoothness of the output image and *p* define the rank filter. After this step, most eyelashes are weakened as shown in Figure 1.

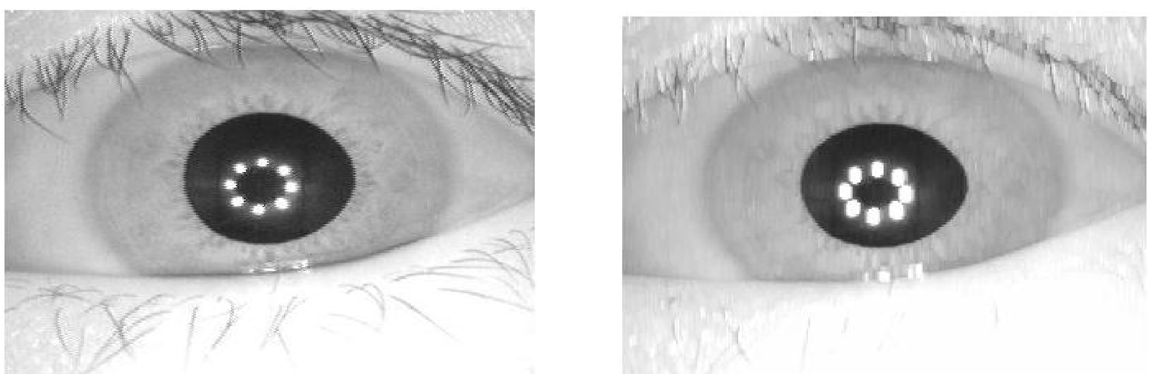


Figure 1. Results of the application of the 1D rank filtering. (a) Input image (b) Result of 1D horizontal rank filtering

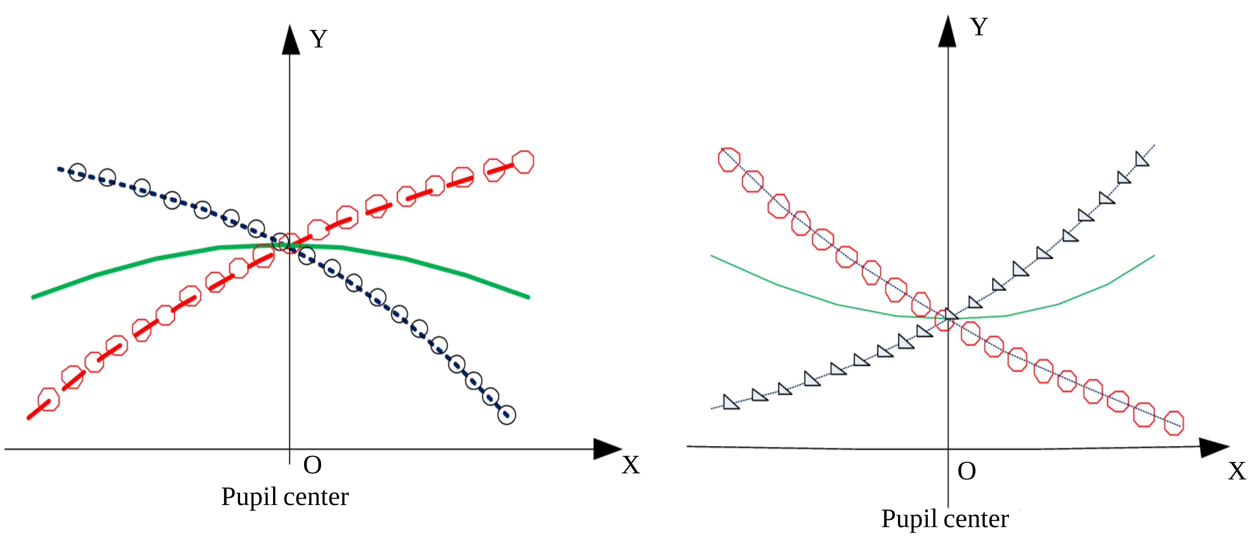


Figure 2. Six models of the upper and lower eyelids. (a) Three models of the upper eyelid. (b) Three models of the lower eyelid

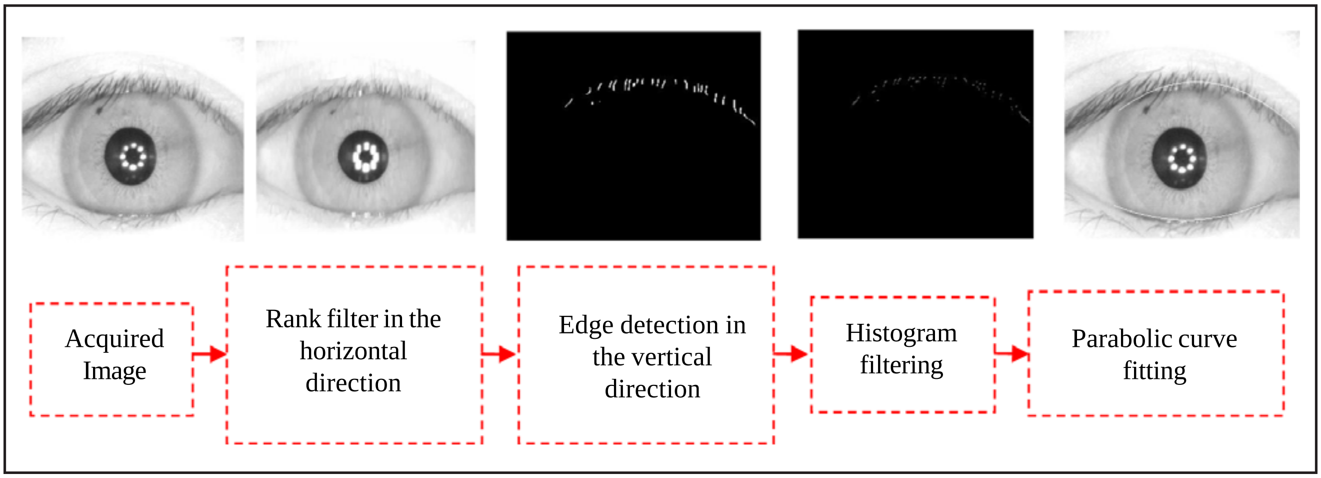


Figure 3. The flowchart of top eyelid localization algorithm. (a) Input image. (b) Application of the 1D rank filter in the horizontal direction. (c) Compute the edge detection map in the vertical direction. (d) Result of histogram filtering. (e) Estimate the top eyelid by parabolic curve fitting

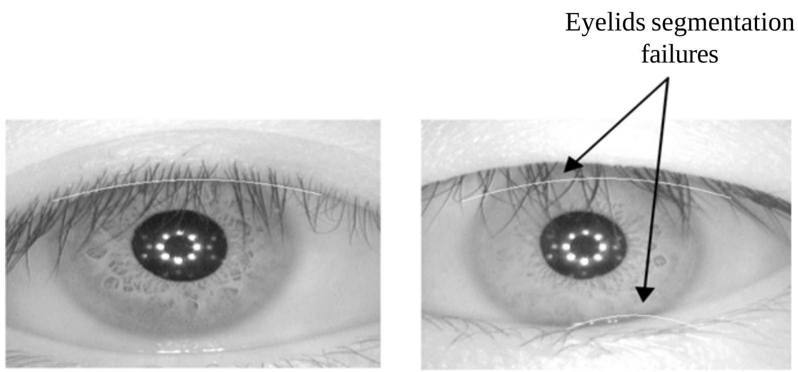


Figure 4. Examples of top and lower eyelids detected by Zhaofeng method

• The second step is the edge detection map in the vertical direction when we using one of the edge detection operators. This operator is applied on the upper region of the filtered image as illustrated by Figure 3 (c).

• The third step (Figure 3 (d)) is used to eliminate noisy edge points via shape similarity. This process computes the difference between the model and the edge map of the previous step. The most suitable model (which has the highest similarity with the edge) is taken. The points of the edge map in accordance with the selected model are reserved as genuine eyelid points.

• The fourth step is the parabolic curve fitting. The genuine eyelid points are estimated by a parabolic curve as shown in Figure 3 (e) and Figure 4. Although the Zhaofeng method gives a good result but it suffers from some problems. First, this method is a semiautomatic algorithm because it always needs models for any iris database. These models are manually developed using a training set. So, the accuracy of the eyelids is related to these models.

Second, in the 1D horizontal rank filter step, the eyelashes are not totally vertical. There are two categories of eyelashes named separable and multiple [7] with random directions. So the 1D horizontal rank filter is not good enough to weaken or eliminate the eyelashes for many images.

2.2 Radial Segmentation Aapproach Methods

In this method [3, 8] the upper and lower eyelids are approximated by two non concentric arches with different radius. They are drawn from six points in the directions (35°, 90°,120°, 230°, 270°,310°) as shown in Figure 5. The pupil center is taken as a starting point to compute the gradient vectors in each direction.

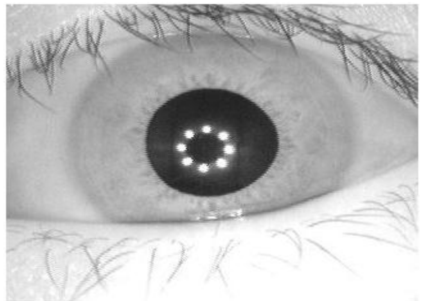


Figure 5. The six directions used to compute the intensity gradient vector

Each point is computed through a study of intensity gradient vector in the corresponding direction. The local extrema of this vector corresponds to the desired points. Using these points and the circle equation (1), we define the arches parameters of the top and lower eyelids respectively by

$$(r_{upper}, x_{upper}, y_{upper}) \text{ and } (r_{lower}, x_{lower}, y_{lower})$$

$$(x_k - x)^2 + (y_k - y)^2 = r^2,\ k = [1, 3] \qquad (1)$$

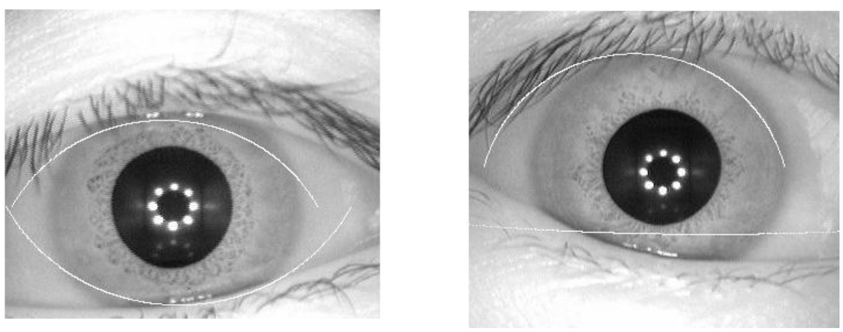


Figure 6. Examples of top and lower eyelids detected by radial segmentation approach

The radial segmentation approach has also some problems. The first point to notice is the circular shape used to model the eyelids which have generally a parabolic shape [9]. The second point is related to the accuracy of the lower and upper arches. We know that the eyelids are usually occluded by eyelashes. So this method is efficient for the no occluded eyelids. Figure 6 shows the segmentation results of the upper and lower eyelids using radial segmentation approach.

In order to solve the problems related to the eyelids shape and the process automation of detection we have developed a new method for removing eyelashes and detecting eyelids as much as possible. In the following section we will describe the proposed method.

3. Proposed Method

One of the most commonly encountered problems in iris recognition system is eyelids and eyelashes occlusion. They are two major challenges which can degrade iris image quality. These artifacts must be detected in order to get a clean iris image. For that reason we sought to develop a new method based on the Radon transform and the polynomial curve fitting to detect eyelids. To detect eyelashes we use the diagonal gradient and a simple thresholding process.

3.1 Eyelids Detection

The proposed method is described in the flowchart of Figure 8. In this flowchart we describe the detection process of the upper eyelid as an example.

• **Crop the ROI**. The region of interest (ROI) is estimated by a rectangular form with surface S defined by (2). This surface corresponds to the region between the two upper horizontal tangents of the outer and inner iris boundaries, as illustrated in Figure 7.

$$S = (Y_{Imax} - Y_{Pmax}) * m \tag{2}$$

Where,

$$Y_{Pmax} = \max\{Y_{Pi}, i = 1, .. k\} \tag{3}$$

$$Y_{Imax} = \max\{Y_{Ii}, i = 1, .. k\} \tag{4}$$

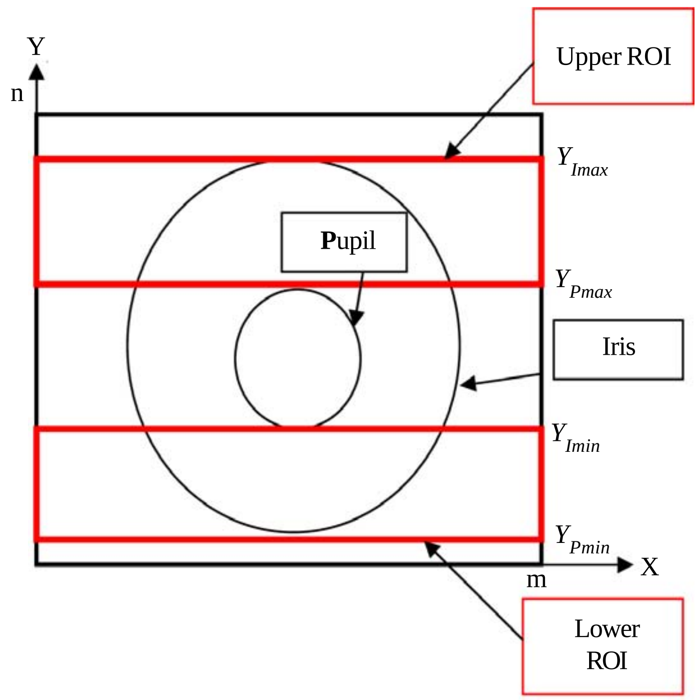


Figure 7. The process of detection of the region of interest

In the equation above k is the angular resolution and y_{Pi}, y_{Ii} are defined respectively the coordinates of the circle boundary points constituting the circle of the pupil and the iris. The (n, m) is the size of the original image.

• Share the rectangle in two equal regions.

• Applying the Radon transform on the edge map of each part. The edge map is created using modified Canny edge detection operator in the vertical direction. The modified Canny algorithm is consisting of: image size reduction, Image blurring, compute gradient magnitude and direction, gamma correction, non maximum suppression and Hysteresis thresholding as described in our paper [10].

• The detected lines are then approximated by polynomial curve fitting using Least Squares Fitting method. The third-degree polynomial model of the data is defined by (5):

$$f(x) = a_3 x^3 + a_2 x^2 + a_1 x + a_0 \tag{5}$$

Figure 9 shows some of a challenging iris images whose eyelids boundaries are significantly occluded by eyelashes.

3.2 Eyelash Detection

The detection eyelashes process is achieved in two steps. The first step consists of computing the diagonal gradient using the matrix $D + 45°$ because eyelashes have generally tilted directions.

This matrix is defined by the difference between the shifted input image in the downshift and left directions and the upshift and right directions. The magnitude of the gradient vector as shown in Figure 10 (b) is characterized by the presence of the eyelashes as the pronounced edges. So in the second step and in order to preserve these edges a simple threshold process is efficient to isolate these regions.

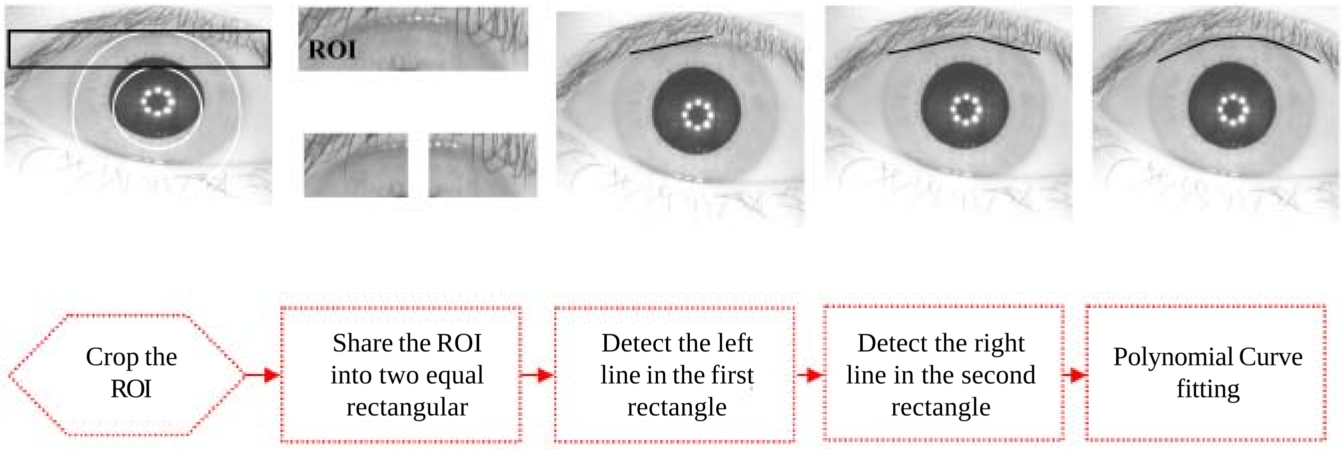


Figure 8. The flowchart of the top eyelid localization. (a) Region of Interest (ROI). (b) Share the ROI. (c) Detect the left line in the first rectangle (d) Detect the right line in the second rectangle (e) Polynomial Curve fitting

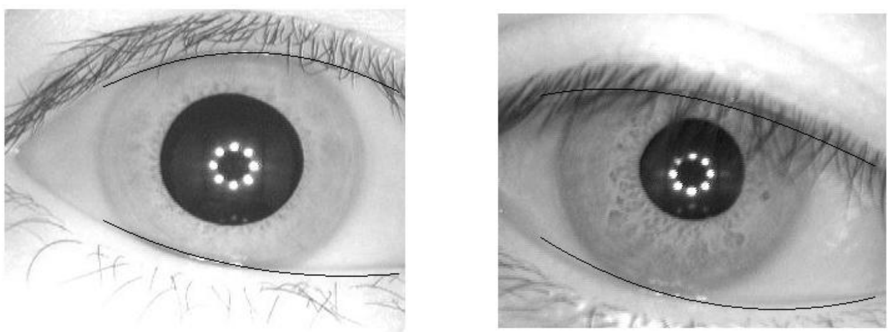
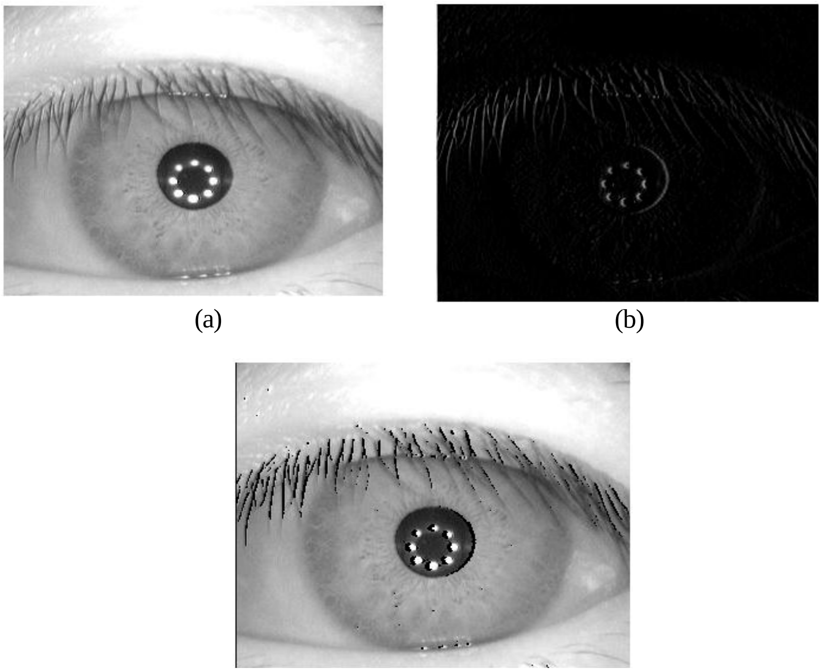


Figure 9. Examples of top and lower eyelids detected by our method

$$D+45° = \begin{vmatrix} I_m(1,1) & I_m(1,2) & .. & I_m(1,\ j) & .. & I_m(1,m-1) & 0 \\ I_m(2,1) & I_m(2,2)-I_m(0,0) & .. & I_m(2,j)-I_m(0,j-2) & .. & I_m(2,m-1)-I_m(0,m-2) & -I_m(0,m-2) \\ . & . & .. & . & .. & . & . \\ . & . & .. & . & .. & . & . \\ I_m(i,1) & I_m(i,2)-I_m(i-2,0) & .. & I_m(i,j)-I_m(i-2,j-2) & .. & I_m(i,m-1)-I_m(i-2,m-3) & -I_m(i,m-2) \\ . & . & .. & . & .. & . & . \\ . & . & .. & . & .. & . & . \\ I_m(n-1,1) & I_m(n-1,2)-I_m(n-3,0) & .. & I_m(n-1,j)-I_m(n-3,j-2) & .. & I_m(n-1,m-1)-I_m(n-3,m-3) & -I_m(n-1,m-2) \\ 0 & -I_m(n-2,0) & .. & -I_m(n-2,j) & .. & -I_m(n-2,m-3) & -I_m(n-2,m-3) \end{vmatrix}$$

4. Experimental Results

In this paper, we evaluated the performance of the proposed method by using the CASIA iris image database V3- interval [6]. This database is composed of 2655 images from 249 persons. It was taken with a Self-developed sensor in an indoor environment. It contains many images with a poor quality, heavy occlusion… Each image is an 8-bit gray level value with a pixel resolution of 320 * 280.



(a) (b) (c)

Figure 10. The eyelashes detection process. (a) Input image (b) The modulus of the diagonal gradient vector. (c) Eyelash regions denoted as black

In order to evaluate the proposed method it's necessary to implement some convention methods from literature, Zhaofeng method and radial segmentation approach. In the experiment, we used Matlab 7.9 with a computer Duo CPU 2 GHz and 2.99Go of RAM.

First we evaluate the accuracy of the upper and lower eyelids of the proposed method and the illustrated methods above. From table 1 we can deduce that the accuracy of the lower eyelid is better than the upper eyelid for the three methods. This is because lower eyelid is not occluded by eyelashes. We can deduce also that the proposed method outperforms the radial segmentation approach and Zhaofeng method.

Second, let us come to compare the speed of the proposed method. From table 1 we deduce that our method is the fastest compared with Zhaofeng method with a factor up to 8 and 264 compared with radial segmentation approach.

The radial segmentation approach is the slowest because the study of the gray level gradient vector in six directions is very time consuming as shown in table 1.

	Upper Eyelid Accuracy (%)	**Lower Eyelid Accuracy (%)**	**Speed (s)**
Zhaofeng Method	86.25	88.13	1.058
Radial Segmentation Approach	77.17	83.6 3	3.036
Our Approach	87.23	94.5	0.125

Table 1. The Time and Accuracy Values With Our Method and the Proposed Methods

5. Conclusion

This paper presented a good detection algorithm that can be used to detect eyelids and eyelashes for iris recognition system. Especially for methods which want to exclude eyelashes from iris code bits during matching template stage.

To detect eyelids we proposed a method based on the Radon transform and the polynomial curve fitting. Eyelashes are then detected using the diagonal gradient. This is very efficient method because eyelashes have generally a tiled direction. As a future work we want to include our method in iris recognition system in order to see the influence on the accuracy of the iris recognition system.

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