Eyelash Detection Model for Accurate Iris Segmentation

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Abstract — In this paper, we present a novel eyelash detection model based on three criterions: 1) separable eyelash condition, 2) non-informative condition and 3) connective criterion. The first condition handles separable eyelash and the second condition manages multiple eyelashes. The last criterion avoids misclassification of strong iris texture as a single and separable eyelash. A number of images are selected to evaluate the accuracy and necessity of the eyelash detection model. The results are encouraging.

Keywords: Eyelash Detection, Iris Recognition, Biometrics, Gobar filter

1. Introduction

Automatic personal identification using iris and iris diagnosis (iridology) are two applications that require accuracy segmentation of an iris [1-2]. It is widely accepted that iris is modeled by two circles for pupil and limbus (outer boundary of an iris), and two parabolas for upper and lower eyelids. This model has been used in several areas including iris recognition, eye tracking and animation [1, 4-6]. However, eyelash detection does not been considered. If the eyelashes were considered as part of iris, for automatic personal identification, the accuracy would be reduced. This problem is especially serious for small eye person with dense eyelashes because the percentage of classifying eyelashes as iris is large.

In the present paper, we develop an eyelash detection model, which relies on three criterions: 1) single eyelash condition, 2) non-informative condition and 3) connective criterion. Separable eyelash and multiple eyelashes are handled by the first and second condition respectively. The last criterion avoids misclassification of strong iris texture as a single and separable eyelash.

In this paper, the traditional iris model is reviewed in Section 2 and our eyelash detection model is discussed in Section 3. Experimental results are demonstrated in Section 4. Finally, conclusions are given in Section 5.

1. Traditional Iris Segmentation Model

In general, an eye would be modeled by two circles, pupil and limbus, and two parabolas, upper and lower eyelids. The circles can be defined as

$$(x-x_i)^2+(y-y_i)^2=r_i^2, \qquad (1)$$

where (x_i, y_i) is its center and r_i is its radius ($i = p, l$; p – pupil and l – limbus). The two parabolas have the following general form,

$$(-(x-h_j)\sin q_j+(y-k_j)\cos q_j)^2=a_j((x-h_j)\cos q_j+(y-k_j)\sin q_j), \qquad (2)$$

where a_j (< 0) is imposed to control the curvature of the parabola, (h_j,k_j) is the vertex of the parabola and q_j is the principle angle between x-axis and principle axis of the parabola ($j = m, n$; m – upper eyelids and n – lower eyelids).

Fitting the contours of pupil, limbus, upper and lower eyelids can be divided into two steps. First, an image would be convoluted by a lowpass filter, such as a two-dimensional Gaussian. Then, a gradient operator, $(\nabla \equiv (\partial/\partial x\ \partial/\partial y))$, is imposed to select the edge points. Mathematically, it can be represented by $|\nabla H(x,y) * f(x,y)|$, where $H(x, y)$ is a two-dimensional lowpass filter and $f(x, y)$ is a raw image. If the magnitude of the image intensity gradient in any point is greater than a certain threshold, this point is considered as an edge point. Hough transform can be applied to find out the three parameters, (x_p, y_p, r_p) [3]. Fig. 1 shows an eye which is implemented this traditional segmentation technique. Similar techniques are able to determinate the parameters in the parabolas.

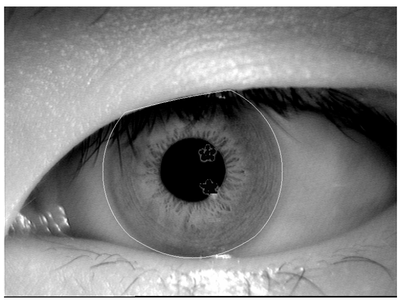


Fig. 1 Illustration of traditional iris segmentation technique

2. Eyelash Detection

There are two types of eyelashes in our eyelash detection model (see Fig. 2). One is a separable eyelash that can be distinguished from other eyelashes. Another type is a multiple eyelash. It is defined that a lot of eyelashes overlap in a small area so they are impossible to separate.

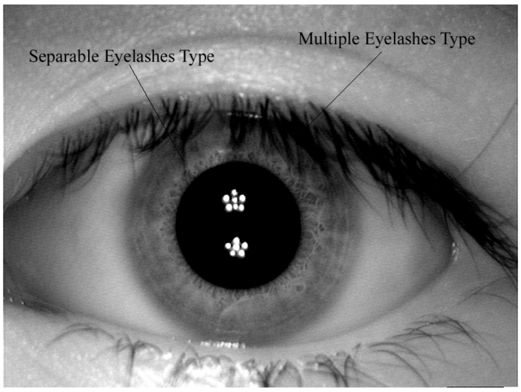


Fig.2 Demonstration the two types of eyelashes

3.1 Separable Eyelash Condition

A real part of a Gobar filter can captures the separable eyelash. In the spatial domain, it has the following general form,

$$G(x,u,s) = \exp\left\{x^2/2s^2\right\}\cos(2pux) \quad , \qquad (3)$$

where u is the frequency of the sinusoidal wave, and s is the standard derivation of the Gaussian envelope. The convolution of a separable eyelash with $G(x,u,s)$ would be very small. Thus, if a resultant point is smaller than a threshold, it is noted that this point belongs to an eyelash. Mathematically, it can be represented by

$$f(x) * G(x,u,s) < K_1 \quad , \qquad (4)$$

where K_1 is a pre-defined threshold and $*$ represents convolution.

3.2. Non-Informative Condition

This condition manages multiple eyelashes. When a lot of eyelashes overlap in a small area, the variance of intensity is very small. Thus, if the variance of intensity in a small window is smaller a threshold, the center of the window is considered as a point in an eyelash. This criterion is described by following equation,

$$\frac{\sum_{i=-N}^{N}\sum_{j=-N}^{N}(f(x+i,y+j)-M)^2}{(2N+1)^2-1} < K_2 \quad , \qquad (5)$$

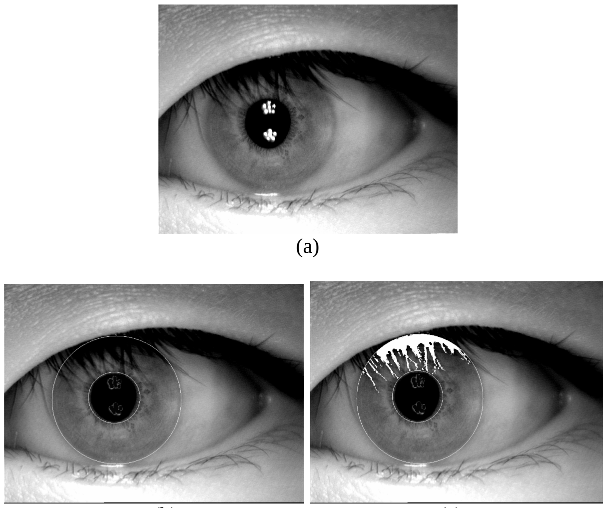
where M is mean of intensity in the small window, *(2N+1)* is the length and width of the window and K_2 is a threshold.

3.3. Connective Criterion

In order to provide more robust and high accuracy detection method, the connective property of our eyelash is used to avoid misclassification from the previous criterions. Each point in an eyelash connects to another point in the eyelash or to an eyelid. If any point fulfills one of the two previous criterions, its neighbor pixels require to check whether they belong to an eyelash or eyelid. If none of the neighbor pixels belongs to eyelid or eyelash, it does not consider as a pixel in an eyelash.

4. Experimental Result

Many different irises have been selected to test the proposed model. Fig 3 is a typical example. Fig. 3(a) shows an original image. Fig. 3(b) and Fig. 3(c) give the segmentation result using traditional model without and with using the proposed eyelash detection model, respectively. The white region in Fig. 3(c) is masked as eyelashes, which are detected by our eyelash detection model. Comparing Fig. 3(b) and Fig. 3(c), a lot of eyelashes remain inside the segmented area in Fig. 3(b) but in Fig. 3(c), almost all the eyelashes are recognized by the proposed model. The result image demonstrates the effective and accuracy of our model.



(a)

(b) (c)

Fig. 3 Different segmentation results from traditional model with and without using proposed model

(a) Original image, (b) Result from traditional model, (c) Result using proposed model

4.1 Detection Error Test

This experiment investigates the accuracy of the proposed model. Seven images are captured from same person with different percentages of eyelashes to cover her iris. The experimental result shows in Table 1. The percentages of eyelashes covering her iris and detection error show in column 2 and 3 respectively. Two images, number 1 and 2, do not have any eyelashes which will be treat as a reference point in the next experiment; other of them have different percentage of eyelashes. The detection errors mentioned in last column. The maximum detection error in the testing images is 4%. In this small database, our model is accuracy.

Table 1: Percentages of eyelashes covering the iris and detection error for all images.

Image no	Percentages of eyelashes covering the iris	Detection error
1	0%	0%
2	0%	0%
3	15%	2%
4	18%	2%
5	21%	2%
6	21%	4%
7	22%	3%

4.2 Identification Test

The purpose of this test is to investigate the effect of proposed model for iris recognition. We have developed an iris recognition system to test our model. It is divided into four parts and briefly described below:

1) Segmentation — Detect and segment the iris.
2) Normalization — Normalize the lighting effect and size of iris.
3) Feature Extraction — Texture information is captured by 12 2-D Gobar filters with different set of parameters. The filtered images are decomposed to a lot of small regions. The mean of texture energy in each small region is considered as feature. It is defined as,

$$E_{kR} = \frac{\sum_{(x,y)\in R} I_k[x,y]^2}{n_R}, \tag{6}$$

where I_k is a filtered image, R is a small region and n_R is number of pixels in a small region.

4) Matching — The matching score of two different images are defined as following equation,

$$S_{ij} = \sum_{R\in A} \left| E_{iR} - E_{jR} \right|, \tag{7}$$

where i, j are represented two irises, A is a set of all small region.

In this experiment, same set of images in the previous experiment is tested. All the images are compared with first image since it does not have any eyelashes.

The traditional iris segmentation technique is applied in step 1 and the matching scores are displayed in Table 2, column 2. The last column of Table 2 are the matching scores which generated by using proposed model in step 1. The matching score S_{12} is a reference point since image number 1 and 2 do not have eyelash. Even though two images do not have any eyelashes, their matching score is not zero.

The matching scores in Table 2 and percentages of eyelash covering iris in Table 1 are imposed to plot Fig. 5. The solid and dash line represent the matching score with and without using the proposed model, respectively. According to Fig. 5, the matching scores without using proposed model increase with respect to the percentages of eyelashes covering the iris. However, for the proposed model, the matching score is stable about 0.06 no matter how to increase the percentages of eyelashes covering the iris. One special case, S_{17} with proposed detection model is less than half of S_{17} which only uses traditional model. The experimental results demonstrate that our detection model is necessary for iris recognition.

Table 2: Summary of recognition score from traditional iris segment model with and without our proposed detection model

Different match up	Matching score based on traditional iris segment model	Matching score with proposed detection model
S_{12}	0.050	0.050
S_{13}	0.076	0.064
S_{14}	0.077	0.060
S_{15}	0.090	0.062
S_{16}	0.098	0.061
S_{17}	0.095	0.043

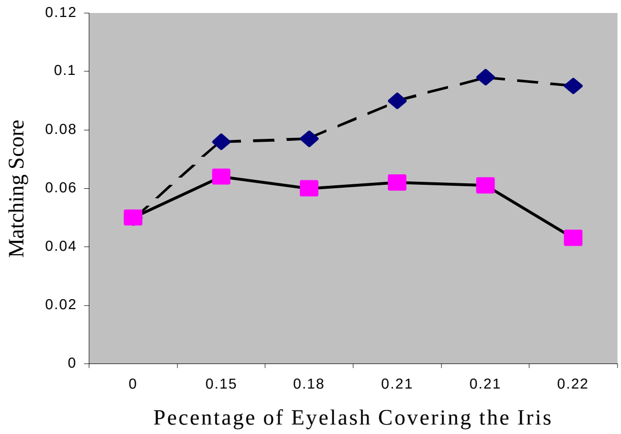


Fig. 4 Comparison of the matching scores with and without using proposed model.
The solid and dash line represents the matching score with and without using the proposed model, respectively.

5. Conclusion

A new eyelash detection model has been developed and reported in this paper. Three conditions, separable eyelash, non-informative condition and connective condition provide accurate iris segmentation. A number of images are selected to evaluate the accuracy and necessity of our eyelash detection model. The results are encouraging.

Acknowledgments

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