A New Iris Segmentation Method for Recognition

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Abstract

As the first stage, iris segmentation is very important for an iris recognition system. If the iris regions were not correctly segmented, there would possibly exist four kinds of noises in segmented iris regions: eyelashes, eyelids, reflections and pupil, which will result in poor recognition performance. This paper proposes a new noise-removing approach based on the fusion of edge and region information. The whole procedure includes three steps: 1) rough localization and normalization, 2) edge information extraction based on phase congruency, and 3) the infusion of edge and region information. Experimental results on a set of 2,096 images show that the proposed method has encouraging performance for improving the recognition accuracy.

1. Introduction

Iris patterns are unique to each subject and remain stable throughout life [1][2]. Especially, it is protected by the body's own mechanisms and impossible to be modified without risk. Thus, iris is reputed to be the most accurate and reliable for person identification [3] and has received extensive attentions over the last decade [1][2][4][5][6][8][7][9].

Whereas, iris has some disadvantages for identification. Some parts of the iris are usually occluded by the eyelid and eyelash when it is captured at a distance. The boundary of the pupil is not always a circle. When we approximate the boundary of irises as circles, some parts of pupil will present to the localized iris region. All these factors will influence the subsequent processing because iris pattern represented improperly will inevitably result in poor recognition performance. To solve this problem, a robust method should be proposed to remove the influence of all these noises as much as possible.

However, so far, little work on this problem has been introduced in the public literature. Only Kong [10] present a noise detection model for iris segmentation. Whereas, 1) pupil noises have not been considered in his model, 2) noise regions were directly segmented from original iris images, which is time-consuming, and 3) it has not been tested based on the prevailing recognition algorithm on a large iris dataset. Therefore, it is still a puzzle whether removing four kinds of noises discussed above can improve the recognition performance of a practical iris recognition system. To explore this puzzle, a new model is proposed for iris segmentation in this paper.

The remainder of this paper is organized as follows. Related work is presented in Section 2. Section 3 details the proposed method. Extensive experimental results are presented and discussed in Section 4 prior to conclusions in Section 5.

2. Related Work

Daugman [1][2] proposed an integro-differential operator for localizing iris regions along with removing the possible eyelid noises. From the publications, we cannot judge whether pupil and eyelash noises are considered in his method.

Wildes [4] processed iris segmentation through simple filtering and histogram operations. Eyelid edges were detected when edge detectors were processed with horizontal and then modeled as parabolas. No direction preference leaded to the pupil boundary. Eyelash and pupil noises were not considered in his method.

Boles and Boashah [5], Lim et al. [6] and Noh et al. [7] mainly focused on the iris image representation and feature matching, and did not introduce the information about segmentation.

Tisse et al. [8] proposed a segmentation method based on integro-differential operators with a Hough Transform. This reduced the computation time and excluded potential centers outside of the eye image. Eyelash and pupil noises were also not considered in his method.

Our previous work [9] processed iris segmentation by simple filtering, edge detection and Hough Transform. This made the overall method very efficient and reliable. No

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method was proposed for processing eyelash and pupil noises.

Kong and Zhang [10] presented a method for eyelash detection. Separable eyelashes were detected using 1D Gabor filters. Multiple eyelashes were detected using the variance of intensity. Connective criterion was used in their model. Specular reflection regions in the eye image were detected by setting a threshold.

From the related work discussed above, several interesting points can be concluded as follows:

- All these methods including Kong's [10] detected all possible noise regions directly from original iris images. It would be more time-consuming if one wants to accurately detect all possible noises;
- Although Kong's model has introduced how to accurately detect eyelash and reflection noises, it has not been tested based on the prevailing recognition algorithm on a large iris dataset;
- No method considered how to accurately segment the iris regions and the pupil regions when the shape of the pupil boundary cannot well be approximated as circles;
- No method has been proposed to detect all four kinds of noises, namely eyelashes, eyelids, reflections and pupil.

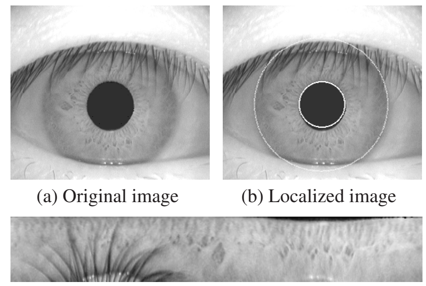
An intuitive observation about noises in the normalized iris images tells us two obvious factors: 1) all kinds of noise regions have visible edge formation and 2) each kind of noise regions has distinct region formation respectively. For example, the pupil and eyelash regions have lower intensity values, and the reflection and eyelid regions have higher intensity values. If the information could be well infused in a model to detect noises, iris segmentation would be successful. Motivated by this idea, we propose a new model for iris segmentation here. Next section will introduce the proposed method in detail.

3. Our approach

An iris image contains not only the region of iris but also eyelash, eyelid, reflection, pupil, etc (One example shown in Figure 1(a),). To facilitate the subsequent processing, the original iris images should be first segmented. It is vital for an iris recognition method to accurately detect noises and segment the iris. However, few efforts to the best of our knowledge have been made to detect all kinds of noises and appropriately segment iris images for recognition. As discussed above, intuitive observations enable us to suppose that infusing edge and region information may be a good strategy for noise detection. The proposed method includes three steps: 1) localization and normalization; 2) edge information extraction based on phase congruency; 3) the infusion of edge and region information.

3.1. Localization and normalization

To speed iris segmentation, the iris is first roughly localized by simple filtering, edge detection, and Hough transform. The localized iris is then normalized to a rectangular block with a fixed size. More detail may be found in [9]. It is an old iris segmentation model that does not consider the pupil, eyelash and reflection noises, as most of previous methods. Figure 1 shows an example.



(a) Original image (b) Localized image

(c) Normalized image

Figure 1. One example

3.2. Edge extraction based on phase congruency

Phase congruency is a dimensionless quantity to describe the significance of image features and invariant to changes in intensity or contrast (Its values range from 0 to 1). Kovesi represented it as follows [11][12]:

$$PC_2(x) = \frac{\sum_n W(x)\lfloor(A_n(x)P_n(x) - T)\rfloor}{\sum_n A_n(x) + \varepsilon} \quad (1)$$

$$P_n(x) = \cos(\phi_n(x) - \bar{\phi}(x)) - \mid \sin(\phi_n(x) - \bar{\phi}(x)) \mid \quad (2)$$

where, $W(x)$ is a factor that weights for frequency spread, ε is incorporated to avoid division by zero, T is a threshold for estimating noises, and the symbol $\lfloor\ \rfloor$ denotes that the enclosed quantity is equal to itself when its value is positive.

Similar to [11][12], we obtain edge information based on phase congruency by a bank of Log-Gabor filters whose kernels are suitable for noise detection.The 2D Log-Gabor filter is specially constructed in the frequency domain. It comprises two components, namely the radial filter component and the angular filter component. The radial filter has the following transfer function:

$$G(\omega) = exp(\frac{-(\log(\frac{\omega}{\omega_0}))^2}{2(\log(\frac{k}{\omega_0}))^2}) \quad (3)$$

where ω_0 represents the center frequency of the filter and k determines the bandwidth of the filter in the radial direction. The angular filter has the Gaussian transfer function:

$$G(\theta) = exp(\frac{-(\theta - \theta_0)^2}{2T(\triangle\theta)^2}) \quad (4)$$

where θ_0 represents the orientation angle of the filter, T is a scaling factor, and $\triangle\theta$ is the orientation spacing between the filters.

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3.3. The infusion of edge and region information

Extensive observations on the CASIA iris dataset show that the pupil and eyelash regions in iris images have lower intensity values and the reflection and eyelid regions have higher intensity values. Intuitively, good segmentation results could be obtained by a simple threshold. However, this result would inevitably be sensitive to the change of illumination and not robust for the subsequent recognition process. For overcoming this problem, the boundary of the probable noise regions is first localized by the edge information based on phase congruency. As discussed above, it is robust to the change of illumination [11].

We set the pupil and eyelash noises to noises of version I. They are detected as follows:

$$N_1(x, y) = PC_2(x, y) + W_1(1 - \frac{f(x, y)}{255}) - T_1 \quad (5)$$

$$N_1(x, y) = \begin{cases} >= 0 & \text{noises of version I} \\ < 0 & other \end{cases} \quad (6)$$

where, $f(x, y)$ represents the normalized intensity image, $PC_2(x, y)$ gives the edge information based on phase congruency, W_1 is used to adjust the relative importance of two constraints, and T_1 is a threshold used to judge the noises of version I. The latter two parameters are adjusted to obtain a tradeoff between accuracy and robustness.

In general, iris imaging cameras use infra-red light for illumination, the reflection regions thus could stably characterized by high intensity values close to 255. Then, a simple threshold can be used to successfully remove the reflection noises.

After the pupil, reflection and eyelash noises were detected, the remaining edge information would be the boundary between the iris and eyelids noises and gives the restricted regions where eyelid noises exist. Hough transform is used in the restricted regions for accurately localizing the eyelid noises, which can speed up the whole process.

As discussed above, noises have distinct edge and region information. Thus, if all neighboring pixels of one possible noise point are not judged as noises, this point should not be classified as a noise point. The connective criterion is used to obtain the final segmentation results.

4. Experimental results

We perform experiments to verify the effectiveness of the proposed algorithm. It is detailed as follows.

4.1. Data acquisition

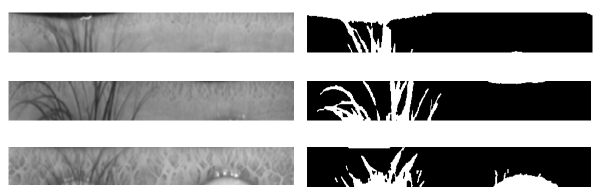
Unlike fingerprint and face, there is currently no common iris database of a reasonable size. A new iris database, called the CASIA iris dataset, is established for our experiments. It includes 2255 iris images from 213 subjects. The total number of iris classes is 306.

4.2. Comparative results

Iris segmentation is only one of the important parts of an iris recognition method, the segmentation results thus should be evaluated by analyzing the performance changes of the recognition algorithm. Daugman's method is the prevailing recognition algorithm now and has best performance on the CASIA iris dataset [9]. Thus, the comparative results are proposed by analyzing the performance changes of Daugman's algorithm with different segmentation models, including our proposed model and the old model that does not consider the pupil, eyelash and reflection noises. For each iris class, we randomly select one sample for training and the the remaining samples are used for testing.

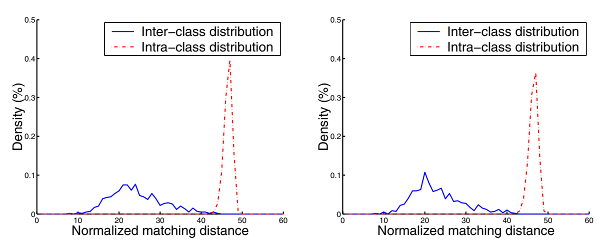
4.2.1 Visual effect

Due to the use of infra-red light for illumination, images in the CASIA iris dataset do not contain specular reflections. Thus, the proposed method has not been tested to remove reflection noises. However, other noises can be accurately detected by the proposed method. Figure 2 shows the segmentation results of some samples in the CASIA iris dataset. The results are impressive. A few gray tails of eyelashes are so similar to the neighboring pixels that they are still not detected. But, this has little influence on the subsequent recognition results. The following recognition results have demonstrated this point.



The normalized images — The result images

Figure 2. Segmentation results



(a) With the old model — (b) With the proposed model

Figure 3. Distance distribution Comparison

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4.2.2 Recognition results

Figure 3 shows the distance distribution comparison. With the proposed model, the mean and the standard deviation of intra-class distribution are reduced. Because iris patterns are represented more properly in the proposed model, the recognition performance is well with the proposed model.

Figure 4 describes the comparison of the verification results. The proposed model seems to be more advantageous than the old model. This also confirms that the proposed model can segment iris images more accurately.

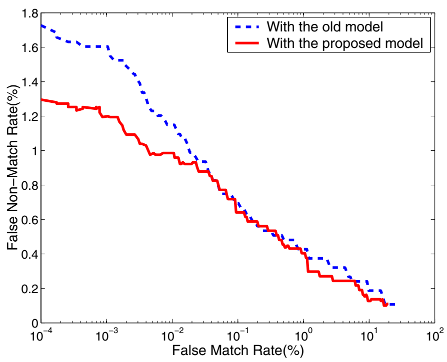

Figure 4. Verification Comparison

4.3. Discussions

All experimental results have demonstrated that the proposed algorithm has an encouraging performance. This also confirm that effective iris segmentation is important for an iris recognition system. However, efforts remain to be taken to further improve its performance.

- The class of iris samples used in our experiments are of a reasonable size. We intend to enlarge our iris database to further evaluate the performance of the proposed algorithm.
- Phase congruency is invariant to changes in intensity or contrast. Region information includes the prior knowledge of noises in iris images. Thus, the infusion of edge and region information is a good strategy for iris segmentation. Experimental results demonstrated this conclusion.
- Noises not only change the features of noise regions, but also influence the features of their neighboring regions. If the influence could be compensated , the recognition performance would be further improved. It will be investigated in our future work.

5. Conclusions

In this paper, we have described an effective approach for iris segmentation, which concentrates on eyelash and pupil noise detection. The proposed algorithm uses a bank of Log-Gabor filters to extract the edge information based on phase congruency. Acquired edge information is then infused with region information to localize the noise regions. Experiment results have shown that the proposed method achieves encouraging performance for improving the recognition accuracy of an iris recognition system.

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