# NOISE REMOVAL AND IMPAINTING MODEL FOR IRIS IMAGE

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**ABSTRACT**

Noise removal is an important problem for iris recognition. If the iris regions were not correctly segmented in iris images, segmented iris regions possibly include noises, namely eyelashes, eyelids, reflections and pupil. Noises influence the features of both noise regions and their neighboring regions, which will result in poor recognition performance. To solve this problem, this paper proposes a method for removing noises and impainting iris images. The whole procedure includes three steps: 1) localization and normalization, 2) noise removal based on phase congruency, and 3) iris image impainting. A series of experiments show that the proposed method has encouraging performance for improving the recognition accuracy.

## 1. INTRODUCTION

The human iris is reputed to be the most accurate and reliable for person identification [1-2] and has received extensive attentions over the last decade [3-11].

Nevertheless, there are some disadvantages for iris recognition. 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 [3-11], some parts of pupil as noises will present to the localized iris region. All these factors will lead iris patterns to be represented improperly both in noise regions and in the neighboring regions of noises, and thus inevitably result in poor recognition performance.

So far, little work has discussed this kind of influences on iris recognition in the public literature. Therefore, it is still a puzzle whether removing the blight discussed above can improve the recognition performance in a practical iris recognition system. To explore this puzzle, a new approach is proposed in this paper for alleviating the blight that exists both in noise regions and the neighboring regions.

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 is the inventor of the most successful commercial iris recognition system now and published his wonderful results in 1993 [3]. He proposed an integro-differential operator for localizing iris regions along with removing the possible eyelid noises [4].

Wildes [5] 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.

Boles and Boashah [6], Lim et al. [7], Noh et al. [8] and Tisse et al. [9] mainly focused on the iris image representation and feature matching, and did not introduce the information about noise removing.

Our previous work [10] processed iris segmentation by simple filtering, edge detection and Hough Transform. This made the overall method very efficient and reliable.

Kong and Zhang presented a noise detection model in [11]. As all other methods, noise regions were segmented from original iris images, which was time-consuming.

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

1) All these methods detected all possible noise regions directly from original iris images, which would be more time-consuming;
2) Although Kong has introduced a noise detection model, it has not been tested based on the prevailing recognition algorithm on a large iris dataset;
3) None of methods 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;

4) All methods only simply removed the noises from iris images and did not consider how to remove the blight of noises in their neighboring regions.

Because there are good works on eyelid and reflection noise detection [3][5][10] and little work has paid attention to eyelash and pupil noise, this paper will mainly focus on the latter.

## 3. OUR APPROACH

Extensive observations about noises in the normalized iris images tell us two obvious factors: 1) visible edge formation and 2) distinct region formation. For example, the pupil and eyelash regions have lower intensity values. If the information could be well infused in a model to detect noises, noise detection would be successful. If the intensity values of the occluded iris regions can be correctly inferred by image impainting technique, iris patterns would be represented more properly both in noise regions and in the neighboring regions of noises. Accordingly, the recognition performance would be improved. Motivated by this idea, we propose a new model for noise removing and image impainting here. The following diagram illustrates its main steps.

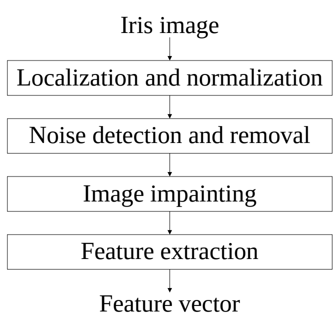
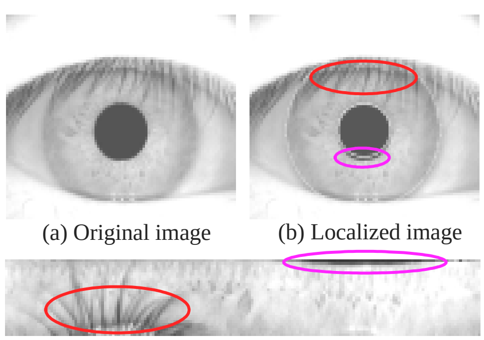



**Figure 1.** *Diagram of our method*

### 3.1. Localization and normalization



(a) Original image (b) Localized image

(c) Normalized image

**Figure 2.** *One example*

An iris image contains not only the region of iris but also eyelash, eyelid, reflection, pupil, etc. Thus, the original iris images should be first segmented. 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 [10]. It is an old iris segmentation model that does not remove the pupil and eyelash noises as most of previous methods. One example is shown in Figure 2.

### 3.2. Noise detection and removal

In general, iris image cameras use infra-red light for illumination. The pupil and eyelash regions have lower intensity values. Intuitively, good segmentation results could be obtained with a simple threshold. However, this result would inevitably be sensitive to the change of illumination. For overcoming this problem, the boundary of the probable noise regions can be first localized by the edge information based on phase congruency, which is a dimensionless quantity and invariant to the change of illumination [12-13]. It is represented as follows:

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

$$P_n(x) = \cos(\phi_n(x) - \bar{\phi}(x)) - \left|\sin(\phi_n(x) - \bar{\phi}(x))\right| \qquad (2)$$

where, $W(x)$ is a factor that weights for frequency spread, $\varepsilon$ 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 [12-13], we obtain phase congruency by a bank of 2D Log-Gabor filters whose kernels are suitable for noise detection. Then, noises are detected as follows:

$$N(x,y) = PC_2(x,y) + W_1\left(1 - \frac{f(x,y)}{255}\right) - T \qquad (3)$$

$$N(x,y) \geq 0 \qquad (x,y) \in Noise \qquad (4)$$

where, $f(x, y)$ represents the normalized intensity image, $PC_2(x, y)$ gives phase congruency, $W_1$ adjusts the relative importance of two constraints, and $T$ is a threshold used to judge the noises. The latter two parameters are adjusted to obtain a tradeoff between accuracy and robustness. The connective criterion is finally used to obtain the noise detection results.

### 3.3. Iris image impainting

As discussed above, noises not only change the features of noise regions, but also influence the features of their neighboring regions. Intuitively, impainting technique can further remove the noise influence and thus further improve the recognition performance. An impainting technique has been proposed to estimate occluded pixels from their neighboring regions [14-15]. It was adopted in our algorithm because it is simple, fast and effective.

Suppose that, $X_k$ is the $k^{th}$ block of the detected noise regions in the normalized iris image. Every pixel in $X_k$ is reconstructed by spatially averaging the values of its four closest intact neighbors. Let $X_k(i, j)$ denote the impainting value of the sample at the $i^{th}$ row and $j^{th}$ column of $X_k$. It can be computed as follows:

$$X_k(i, j) = \alpha X_k^{left,right} + (1-\alpha) X_k^{up,down} \tag{5}$$

$$X_k^{left,right} = w_1 X_k^{left} + (1-w_2) X_k^{right} \tag{6}$$

$$X_k^{up,down} = (1-w_1) X_k^{up} + w_2 X_k^{down}) \tag{7}$$

where, $X_k^{left}$ is the closest element in the block to the left of $X_k$; $X_k^{right}$ is the closest element in the block to the right of $X_k$; $X_k^{up}$ is the closest element in the block above $X_k^{left}$; $X_k^{down}$ is the closest element in the block below $X_k$ . $w_1$ and $1$-$w_1$ are used to weigh the contributions from the pixels on either side of the noise pixel; $w2$ and $1$-$w2$ are used to weigh the contributions from those above and below the lost pixel. The contributions from the blocks on either side are weighted by $\alpha$ , and those from the ones above and below are weighted by 1-$\alpha$ .

## 4. EXPERIMENTAL RESULTS

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

### 4.1. Testing data

In our experiment, the CASIA iris dataset [16] is used as the testing data. It includes 2255 iris images from 213 subjects. The total number of iris classes is 306. Some samples from it are shown in Figure3.

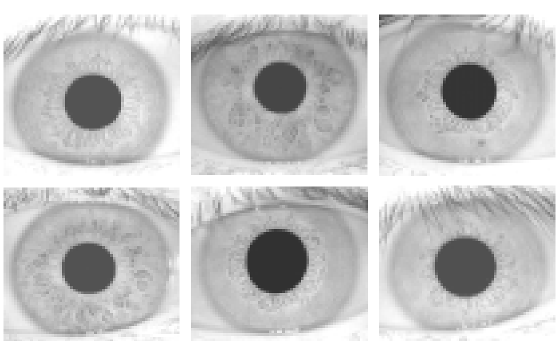


**Figure 3.** *Iris samples from the CASIA Iris Dataset*

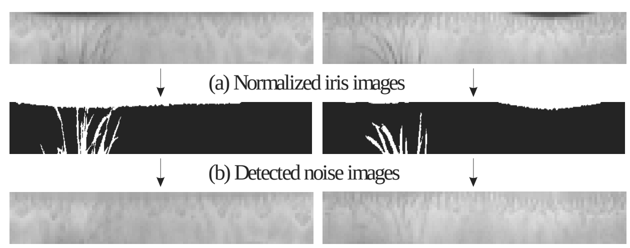
Noise removal is only a step of an iris recognition method. Thus, the proposed method can be evaluated by analyzing the recognition performance changes of Daugman's algorithm with different models, including the proposed model and the previous model that does not consider the pupil and eyelash noises. Note that Daugman's algorithm was implemented according to the open literature [3-4] and has best performance on the CASIA iris dataset [10].

### 4.2. Comparative results

For each iris class, we randomly select one sample for training and the remaining samples are used for testing.

#### *4.2.1. Visual effect*

Figure 4 shows the noise removal and image impainting results of two 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. Thus, a few regions still exist noises in the result images. However, this has little influence on the subsequent recognition results. The following recognition results have demonstrated this point.




(c) Images after noise removal and impainting

**Figure 4.** *Visual effect*

**Table1.** *Comparison of correct recognition rate (CRR)*

| Comparison | CRR |
|---|---|
| Previous | 100% |
| Noise removal | 100% |
| Noise removal + Image impainting | 100% |

#### *4.2.2. Recognition results*

Because iris patterns are represented more properly in the proposed model, the mean and the standard deviation of intra-class distribution would be reduced, which could result in good recognition performance. With the proposed method and the previous approach, Daugman's algorithm respectively obtains 100% correct recognition rate. Table 1 gives the comparison of correct recognition rate. Figure 5 describes the comparison of the verification results. The proposed model seems to be more advantageous than the old model. This also confirms that the design of noise removal and image impainting is successful for an iris recognition system.

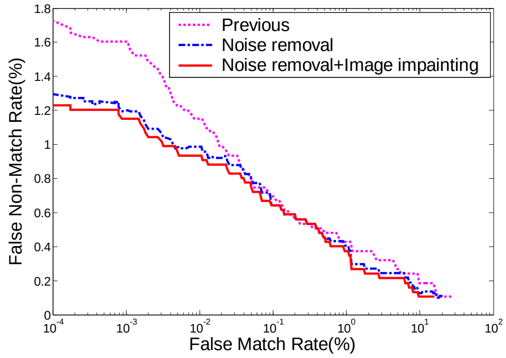



**Figure 5.** *Verification Comparison*

### 4.3. Discussions

All experimental results have demonstrated that the proposed algorithm has encouraging performance. However, efforts remain to be taken to further improve its performance.

1) Phase congruency is invariant to changes in intensity or contrast. Region information includes the prior knowledge of noises in iris images. Thus, infusing them is a good strategy for noise detection. Experimental results demonstrated this conclusion;
2) Noises not only change the features of noise regions, but also influence the features of their neighboring regions. Because impainting technique can compensate the latter influence to some extent, noise removal and image impainting can improve recognition performance of an iris recognition system. Experiment results demonstrated it;
3) In this paper, the qualities of the testing iris images are relatively good and the impainting technique is simple, the advantages of impainting are thus not obvious. We intend to enlarge our iris database and try different impainting methods in our future work.

## 5. CONCLUSIONS

In this paper, we have introduced an effective noise removal and image impainting approach for iris recognition. 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. Then, impainting technique is used in normalized iris images. Experiment results have shown that the proposed method achieves encouraging performance for improving the recognition accuracy of an iris recognition system.

## 6. ACKNOWLEDGEMENTS

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