PAPER • OPEN ACCESS

Research on image preprocessing for iris recognition

To cite this article: XiuYing Mo and Tan Chen 2021 *J. Phys.: Conf. Ser.* **2031** 012024

View the article online for updates and enhancements.

Research on image preprocessing for iris recognition

XiuYing Mo[1], Tan Chen[2]

[1]Guangzhou Huashang Vocational College, Guangzhou, Guangdong, 511300, China

[2]Guangzhou Zhiyuan Electronics Co., Ltd, Guangzhou, Guangdong, 511300, China

[*]Corresponding author's e-mail: zsb@gzhsvc.com

Abstract. With the development of social economy, identity identification has penetrated into every aspect of people's life. As the bottom technology of identity authentication, biometric technology is getting more and more attention in recent years. At present, iris based identification technology is a research hotspot with rapid development at home and abroad. Iris, as an important identification feature, has the advantages of uniqueness, stability, collectability and non-invasive. In this paper, the iris recognition algorithm is deeply studied, focusing on the image preprocessing in the iris recognition algorithm. In the aspect of positioning, the coarse to fine algorithm is used to ensure the accuracy and improve the positioning speed. The pupil location is divided into three steps. Based on the accurate pupil location, the iris is located in one step, and the effectiveness of the location is tested.

1. Introduction

With the rapid economic growth and the rapid change of science and technology, living in such a highly information-based modern society, identity identification has penetrated into every aspect of people's life[1]. The traditional identification methods such as password have the disadvantages of easy forgetting and easy counterfeiting, which do not meet the needs of modern digital society. According to relevant data, the losses caused by the loss of certificates or passwords every year are very alarming. Iris, as an important identification feature, has the advantages of uniqueness, stability, collectability and non-invasive. Non invasive (or non-contact) biometric recognition is the inevitable trend of identity recognition research and application development. Compared with non-contact identification methods such as face image and voice, iris has higher accuracy. According to statistics, the false recognition rate of iris recognition is the lowest among all kinds of biometrics[2-3]. Iris based identification technology has been paid more and more attention by academia and enterprises. Iris contains a lot of texture information. Its tissue structure has been finalized at the stage of embryonic development. It is unique and unchanged for life. Iris is isolated from the external environment and cannot be modified by surgery. Theoretically, these characteristics of iris can become the best biometric means of anti-counterfeiting performance.

2. Introduction to iris recognition system

The iris recognition system in this paper is mainly composed of seven modules: image acquisition, image preprocessing, iris location, normalization, iris coding, iris matching and iris database. Among them, the iris database stores the iris code registered by iris coding[4-5]. The whole recognition process is shown in Figure 1. This paper mainly studies the image preprocessing of iris technology. Generally, the images collected in iris recognition system can not be encoded directly and need preprocessing. The result of preprocessing is related to the success or failure of the whole recognition

process. Iris image preprocessing includes iris image smoothing, iris location, iris image normalization and iris image enhancement.
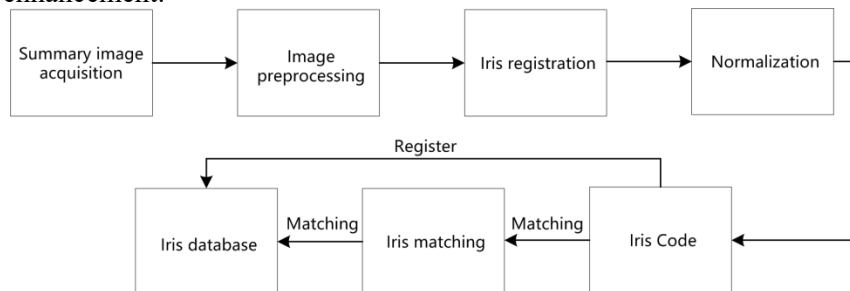

Figure 1. Iris recognition system recognition process.

3. Iris image smoothing

The iris images collected by the iris acquisition system generally have noise[6-7]. In this paper, the median filter method is used to remove the image noise. Median filtering is to sort the gray values of pixels in a sliding window, and replace the original gray value of the central pixel of the window with the median value. It is a nonlinear image smoothing method. It sorts the values of all pixels in the field from small to large, and takes the median value as the output value of the central pixel. After median operation, the sliding window traverses each pixel of the whole image, The final image is the image after median filtering. In this paper, 3 iris images superimposed with noise are smoothed by domain average method and median filter method respectively. It is found that median filter method can remove noise well and ensure that image details are not lost, while domain average method will make the image more blurred. The signal-to-noise ratio of the smoothed image is calculated. The average signal-to-noise ratio of the image smoothed by the neighborhood filtering method is 26.1dB, while the average signal-to-noise ratio of the image smoothed by the median filtering method is 29.1dB. From the signal-to-noise ratio, it can be seen that the median filtering method is better than the domain average method, as shown in Figure 2.
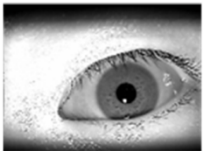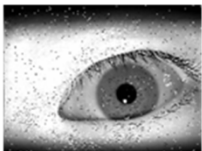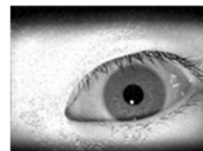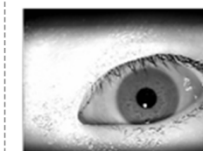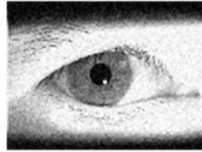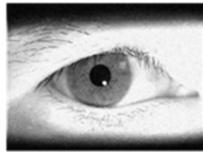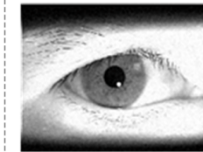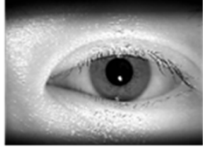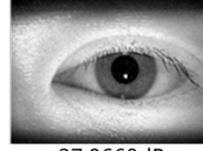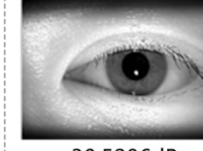

Figure 2. Comparison of signal-to-noise ratio between neighborhood filtering smoothing and median filtering smoothing.

4. Iris image location

Based on Daugman algorithm, this paper proposes an improved and simpler algorithm. This algorithm has good execution and good practical value. The improved localization algorithm mainly consists of several steps: binarization of iris image, coarse localization of any point in pupil, accurate localization of pupil, accurate localization of outer edge of iris and removal of upper and lower eyelids. After binarizing the image, we can quickly find any point in the pupil with the line integral function, then use the position information of this point as the initial search position, and use the original Daugman location algorithm to accurately locate the center and radius of the pupil. Finally, taking the position and size of the pupil as the initial search information, the original Daugman location algorithm is used to accurately locate the center and radius of the iris outer circle. This process is highly efficient and accurate because it has undergone rapid rough positioning and then precise positioning. The removal of upper and lower eyelids uses the arc integral template, and takes the iris center and inner radius as the starting search position. The speed is also very fast. This algorithm is described in detail below.

4.1. Binarization of iris image

In order to quickly locate any point in the pupil with line integration, it is necessary to highlight the pupil part in the image and weaken other parts in the image. The best way is to binarize the image. In this way, the image will become a binary image, and the contrast between the pupil part and the non pupil part will be very high, which is very conducive to rough positioning. The key of binarization is to find an appropriate threshold, and the gray of pixels less than the threshold will become 0; All pixels above the threshold become 1, which is the binarization of the image. In order to find out the threshold, we first observe the gray histogram of iris image.
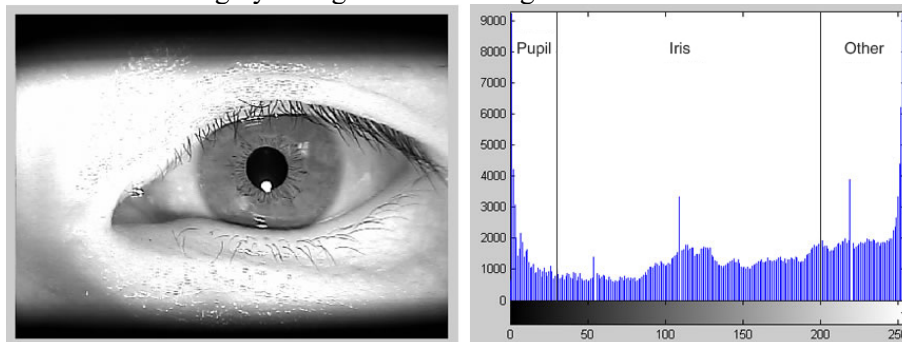

Figure 3. Gray histogram distribution of iris.

From the figure, we can see that the gray level of the pupil is much smaller than that of other parts of the eye, and the pixel distribution of the approximate gray level in the pupil area is concentrated; The gray value distribution of iris is relatively wide, and the gray value is slightly larger than that of pupil; The largest gray value is the other parts of the eye, including eye white and skin. According to this characteristic of pupil, the threshold of pupil can be found from gray histogram. The specific steps are: 1) calculate the gray histogram of the whole image; 2) In the gray histogram, the area adjacent to the peak with the smallest gray value is the gray distribution of the pupil area, as shown in the right figure of Figure 3. According to experience, if the gray value 20 is taken as the threshold, the pupil area is less than the domain value. Then, binarize the image with equation (1).

$$IN(x,y) = \begin{cases} 0 & I(x,y) < TH \\ 1 & I(x,y) \geq TH \end{cases}$$

(1)

Where in (x, y) is the gray value after binarization in the image, I (x, y) is the gray value in the original image, and th is the threshold. After all pixels in the image are converted by the above formula, the binarization of the image is completed. In this way, the pupil is roughly separated, as shown in Figure 4.
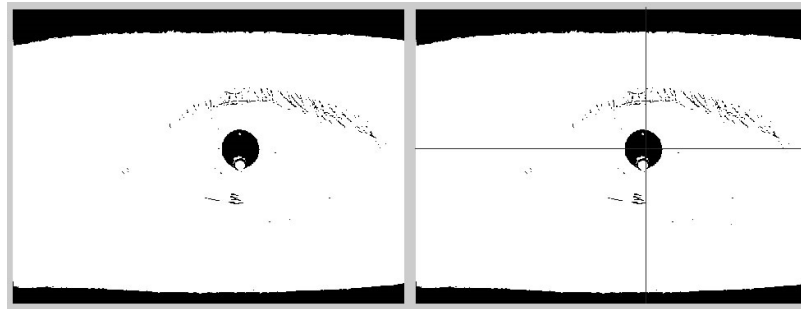
Figure 4. Binarized iris image (L), coarse positioning pupil (R).

4.2. Coarse positioning of pupil

After binarizing the iris image, we can quickly locate a point in the pupil with line integral. Through observation, Through observation, it can be seen that a pair of cross lines can be drawn at the center of the pupil circle, one is a horizontal line and the other is a vertical line, represented by LH and LV respectively. If we move LH up and down, or LV left and right, we can find that only at the center of the pupil, the number of black pixels passed by LH and LV is the largest. So, we can use the line integral to find the center of the circle. The coarse positioning algorithm is as follows.

$$IT(x, y) =\sim IN(x, y) \tag{2}$$

$$Xi = \int_{y1}^{y2} IT(i, y)dy \tag{3}$$

$$Yi = \int_{x1}^{x2} IT(x, i)dx \tag{4}$$

$$x_0 = \max i(X1, X2, ...) \tag{5}$$

$$y_0 = \max i(Y1, Y2, ...) \tag{6}$$

$$r_0 = \frac{\max(X1, X2, ...) + \max(Y1, Y2, ...)}{4} \tag{7}$$

Let the coordinates of the upper left corner of the image rectangle be (X_1, Y_1) and the coordinates of the lower right corner be (X_2, Y_2). Let the grayscale of the pupil part in the binary image in (X, Y) become 1 and the other parts become 0, which is conducive to the next operation. xi is the integral of the gray value of the point on the vertical line of $X = I$, that is, the sum. Y_i is the same. X_0 is the X coordinate of the center of the circle after rough positioning, taking the subscript of the maximum value in $X_1, X_2,...$, and Y_0 is the same. R_0 is a rough estimate of the pupil radius.

After obtaining the roughly located pupil center and radius, the Daugman location algorithm can not be directly used for accurate location. Because after the above rough positioning, only a certain point in the pupil is obtained, and it is not sure whether this point is close to the center of the circle. This will still bring unnecessary computation to Daugman's positioning. Therefore, we need to further coarse positioning. This coarse positioning is based on the first coarse positioning, using the template search method. The size of the template is $r_0 \times 4$, which is a square template.

$$
\begin{array}{ccccc}
I(x - 2r0, y - 2r0) & ... & I(x, y - 2r0) & ... & I(x + 2r0, y - 2r0) \\
... & ... & ... & ... & ... \\
I(x - 2r0, y) & ... & I(x, y) & ... & I(x + 2r0, y) \\
... & ... & ... & ... & ... \\
I(x - 2r0, y + 2r0) & ... & I(x, y + 2r0) & ... & I(x + 2r0, y + 2r0)
\end{array}
$$

Figure 5. Positioning template.

This is a summation template. The operation rules are as follows.

$$\max_{x0,y0} \iint_{x0,y0} I(x,y)dxdy \quad \begin{cases} x \in (x0 - 2r0, x0 + 2r0) \\ y \in (y0 - 2r0, y0 + 2r0) \end{cases} \tag{8}$$

Take (x_0, y_0) as the starting point, move the summation template up, down, left and right, and find out the maximum value. At that time (x_0, y_0) is the pupil circle center after positioning, and then calculate the pupil radius on this basis. The method is the same as (7). Because the pupil is a circular surface and the pixel gray in the pupil is 1, the summation value is the largest when the summation template completely covers the pupil. At this time, the center of the template falls near the pupil circle center. Through further positioning, it can well eliminate the influence of insufficient eyelashes or white light.
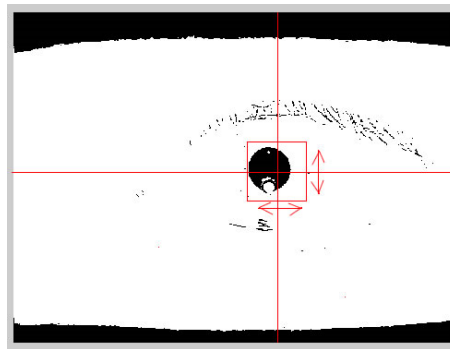

Figure 6.   Summation template positioning demonstration.

4.3. Accurate positioning of iris

Now, we have further roughly located the circle center and radius (x0, y0, r0) of the pupil, which can be accurately located by Daugman. From Figure 5, we can see that there is often a spot in the pupil. The gray value of the light spot is larger than that of other normal pixels in the pupil. There is a large gray difference compared with the normal points in the pupil. Therefore, before accurately positioning the pupil, the spot must be removed to avoid wrong positioning. In the roughly located pupil area, the light spot is removed according to the gray value, and its gray is set to zero.After removing the light shift, use the following equation (9) to accurately locate the pupil.

$$\max_{(r,x0,y0)} \left| \frac{\partial}{\partial r} \oint_{(r,x0,y0)} \frac{I(x,y)}{2\pi r} ds \right| \tag{9}$$

Equation (9) is the simplified Daugman positioning formula, I (x, y) is the smoothed iris image, and the smoothing operator is removed (because the image has been median filtered earlier). To explain this equation in popular language is to determine a specific circle whose center is (x0,y0) and radius is (R), and accumulate the gray values of all pixel points on the circumference of the circle, Then subtract one pixel smaller than the radius r of the circle, and the gray values of all pixel points on the circumference of the circle with the same center are accumulated. This is the actual operation of integral and differential. Then traverse (x0, y0, r0) and finally find the circle with the largest difference. Its function is to find the boundary of a circle.

The amount of integral and differential operations to traverse the whole image is very huge. If the Daugman localization algorithm is directly used to traverse the iris image, even a 100 × A small area of 100 also takes 30 seconds, which is unbearable in practical application. Therefore, a fast positioning algorithm is proposed. Using the rough positioning results calculated above, the traversal range can be greatly reduced. Three iris image samples are located with an accuracy of 100% and a very fast speed. The average positioning time is within 1s, which is more than 20 times faster than that of Daugman positioning algorithm, as shown in Figure 8.The data were measured on a computer with a CPU of 1.6GHz and a memory of 256M.
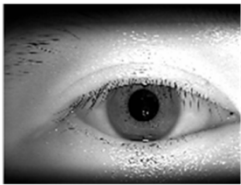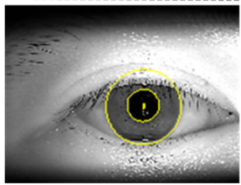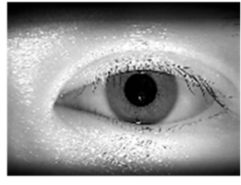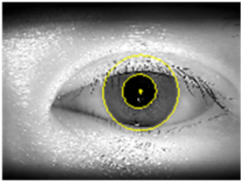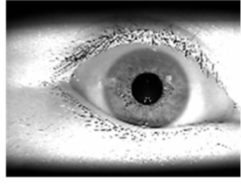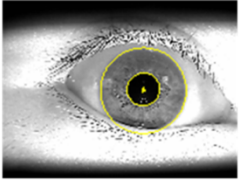
Figure 7. Iris positioning effect.

5. Image quality evaluation after positioning

After iris positioning, not every iris image can be encoded, and not every positioning is so accurate. This is an image affected by many objective factors, which requires us to evaluate the quality of iris image. If we pass the evaluation, we can go to the next step of normalization. Otherwise, it is considered that this image does not meet the requirements. You should continue to collect or return error information to the user. In this paper, the iris image quality evaluation is mainly divided into the following four aspects.

- Overall quality evaluation, judge whether the image is well focused, clear and whether the brightness is too strong or too weak.
- Judge whether the iris exists in the image center. At the moment of acquisition, if it is in the closed state, the iris is not in the image. If the eyes deviate suddenly, the iris will deviate from the center of the field of view seriously, resulting in serious deformation of the iris in the collected image.
- Judge whether the iris part in the image is clear and judge the size of the iris area in the image. On the one hand, the eyelid generally covers part of the iris. If the eyelid covers too much, it will seriously affect the accuracy of iris recognition.
- For the judgment of effective points in iris, due to the existence of various interferences, there are some invalid points in iris, which will change with the change of environment, so they must be removed to improve the accuracy of recognition:

6. Normalization and enhancement of iris

Based on the iris fine positioning results, a dual dimensionless projection polar coordinate system is established, which can maintain the reference positioning of the same area in the iris tissue without paying attention to the expansion and contraction of the pupil and the size of the iris image. The relationship between dimensionless polar coordinates and rectangular coordinates is:

$$x(\rho,\theta) = (1-\rho)x_i(\theta) + \rho x_0(\theta) \qquad (10)$$

$$y(\rho,\theta) = (1-\rho)y_i(\theta) + \rho x_0(\theta) \qquad (11)$$

In practical application, 64 points in direction ρ and 512 points in direction θ are taken. For the normalized iris image, because its texture is not clear enough, we need to enhance it to make its texture more prominent for the later coding work. Here, the local histogram equalization method is used to enhance the iris image. The gray level dynamic range of the iris image is relatively large, and it is disturbed by illumination and eyelashes. The global histogram equalization is not ideal for iris image enhancement. In order to eliminate these defects, local histogram equalization is used here. Divide the rectangular image(64pixels×512pixels) into small pieces(32pixels×32pixels). After local histogram equalization, it will produce serious block effect. At the same time, in human iris image, there will be rich texture near the inner circle of iris, while the dynamic range of image gray near the outer circle of iris is very small. A transition zone is set in the middle of adjacent blocks, and the linear interpolation method is used to eliminate the block effect.

7. Conclusion

Based on the image preprocessing of the improved Daugman iris recognition algorithm, the preprocessing program in iris recognition is successfully simulated with MATLAB. The algorithm has been tested with 20 test samples provided by Guilin iris information technology Co., Ltd., and the accuracy rate has reached 100%. The fast image processing method is adopted to make the running speed of the algorithm meet the practical requirements. From the current test results, the iris recognition algorithm in this paper has a very good recognition effect. It is hoped that an effective in vivo detection method can be developed in the future. Infrared biological detection technology can be used to detect the blood vessels in the white eye.

References
[1]   Nguyen K, Fookes C, Ross A, et al. Iris recognition with off-the-shelf CNN features: A deep learning perspective[J]. IEEE Access, 2017, 6: 18848-18855.
[2]   Zhao Z, Kumar A. Towards more accurate iris recognition using deeply learned spatially corresponding features[C].Proceedings of the IEEE international conference on computer vision. 2017: 3809-3818.
[3]   Wang C, Muhammad J, Wang Y, et al. Towards complete and accurate iris segmentation using deep multi-task attention network for non-cooperative iris recognition[J]. IEEE Transactions on information forensics and security, 2020, 15: 2944-2959. Chen Y, Wu C, Wang Y. T-center: a novel feature extraction approach towards large-scale iris recognition[J]. IEEE Access, 2020, 8: 32365-32375.
[4]   Qin Yuanyuan, Zhao Yuanyuan, Xu Jiheng. Application of iris recognition technology in access control system [J]. Hubei agricultural mechanization, 2019 (23): 92-93.
[5]   Wang Chaonan, Guo Huijie, Han Yiliang, Yang Fan. Design of intelligent information management platform based on iris recognition [J]. Digital communication world, 2019 (12): 92-93.
[6]   Tian Zilin. Research on some key algorithms in iris recognition [D]. Henan University of science and technology, 2019.
[7]   Hokchhay Tann,Heng Zhao,Sherief Reda. A Resource-Efficient Embedded Iris Recognition System Using Fully Convolutional Networks[J]. ACM Journal on Emerging Technologies in Computing Systems (JETC),2019,16(1).
[8]   S. Janardhanarao,V.Jyothi. A Multi Biometric IRIS Recognition System based on a Profound Learning Method[J]. International Journal of Recent Technology and Engineering (IJRTE),2019,8(3s).
[9]   Xu Yuntao, Xu Wujun, Zhai Menglin. High concurrency iris recognition system based on B / S architecture [J]. Computer Engineering, 2019,45 (08): 102-106.
[10]   Ma Xiaofeng, Gao Weiwei. Improved iris recognition algorithm based on Gabor filtering [J]. Software, 2019,40 (07): 57-61.