Research on iris location based on improved particle swarm algorithm and sub-regional noise reduction

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Abstract. Iris localization is the basis of iris recognition, iris medical diagnosis and other technical fields. In view of image of Asian iris, according to the characteristics of the human eye pupil, the combination method of image back-complement enhancement and improved particle swarm optimization is firstly adopted to fit and locate the inner circle of iris. Then, combined with the characteristics of the outer iris boundary, the outer iris circle is located by using the method of sub-regional noise reduction and improved particle swarm optimization. Meanwhile, coordinate transformation approach is introduced for normalization of image. Finally, the feasibility of the method is verified by using iris library of Chinese Academy of Sciences and the self-built iris library sample. This study successfully overcomes the interference of the spot in library and can efficiently complete the segmentation of the iris region.

1. Introduction
Due to the influence of many factors such as the change of the distance from the human eye to the lens, the stimulation of the pupil and the individual differences during the image acquisition process, the recognition rate is low and the feature extraction error occurs later. The Daugman iris segmentation method first proposed by Daugman from University of Cambridge, England segmented images by the method of circular detection matcher according to the phenomenon of iris shape similar to ring[1]. Akind of Hough Transformation proposed by Wildes located the iris and combined the maximum parameters obtained by the accumulator array as the inside and outside circle parameters of the iris[2]. Basit and Javed proposed an iris location method based on luminance value analysis to calculate the iris inner edge data with two methods while the outer edge of the iris was then obtained by finding the maximum gradient points in various directions [3]. Particle swarm algorithm, an optimization algorithm based on swarm intelligence proposed by Dr. Kennedy and Eberhart, is characterized by high-speed convergence in the early stage of the algorithm, but it is easy to fall into local optimum in the later stage of the algorithm to reduce the convergence accuracy and speed[4]. This article mainly includes two aspects: First, in order to improve the accuracy and speed of iris location, an improved particle swarm optimization algorithm for iris location is proposed in this paper. This algorithm expands the search space of the algorithm reasonably, avoids the local optimization of the algorithm effectively, and greatly improves the convergence speed of the algorithm. Moreover, it also gradually improves the quality of the candidate solution in the middle and later stages of the search, with final converge to the global optimal solution. Second, to locate the outer edge of iris, canny operator is first called to
detect the edge of iris image but the detected image contains complex image information. In order to better remove noise interference, a sub-regional noise reduction is put forward and four noise areas are identified in this paper. It is proved by experiments that most of the noise can be eliminated, and it is easy to find the contour of the outer circle of the iris, that is, sclera boundary profile.

2. Laboratory materials and equipment
Iris image data sources used in this paper are divided into two aspects, one is iris gallery CASIA V4.0 of the Chinese Academy of Sciences, and the other is the self-built iris gallery. Since dark brown Asian iris is not visible in visible light, equipment used to build the gallery 3.9 mm camera with infrared 850nm narrowband of KS2A17 model, as shown in Figure 1.

![Figure 1. Infrared 850 nm Narrowband Camera](image)

The experimental environment is as follows: CPU is Intel(R) Core(TM) i5-5300U, 8G memory, with Win7 professional edition 64 bits operating system and used software is MATLAB2018b.

3. Location of iris image
As an independent organ of the human body, human’s eyes consist a variety of structural tissues. In addition to iris information, there are other information on other structures in collected human eye images that will undoubtedly interfere with feature extraction. In order to reduce the complexity and facilitate the extraction of later feature textures, the iris image should be located first. The overall process includes image grayscale, noise reduction, image enhancement, iris localization, normalization [5]. Figure 2 is the overall flow chart of iris localization.
3.1. Iris image grayscale
The image collected by iris image acquisition instrument is often color image but no color features are involved in this study so that color information of iris image does not affect the extraction of feature texture in this study. However, complex color information increases the complexity of image processing and information processing capacity. In this paper, grayscale processing is first carried out to improve the efficiency.

Color information is represented by RGB three channels in digital images. The values of the three channels in color images are various. The process of grayscale transformation is the transformation of three-channel color image to one-channel gray image. When three channel components have the same value (R=G=B), it represents a gray color called a gray image [6]. The weighted average method is adopted to realize the gray processing of iris image. Depending on the importance of the RGB component and other specific conditions, each of the three channels is given different weights for weighted average. Its expression is as shown in formula (1).

\[ \text{Gray} = 0.299 \times R + 0.587 \times G + 0.144 \times B \] (1)

In the formula, Gray represents the gray value of the iris image. RGB three components are assigned value as Gray, to transform the color image into a gray image.

3.2. In-Iris edge localization of noise reduction and enhancement
In the process of image acquisition, affected by uneven illumination, lens distance, eyelash or eyelid occlusion, there is great difference in collected image quality of iris. For block of spot light or eyelashes, eyelids and others, it is not easy to read useful information from the image, which affects the extraction of iris features [7].

By observing the iris image in the self-made iris library, it is found that its noise is mostly light spots and eyelashes. In this paper, the open and closed operations in mathematical morphology are used to reduce noise for image. It is to create an ellipse with radius of 5 and a height of 1 as structural element SE, conducting corrosion, open operation, closed operation treatment for original figure 3(a). The final noise reduction results are shown in Figure 3(b). The result shows that the spot in the pupil
has been removed in original figure, and the eyelashes above the right are also removed in original figure. The interference is removed and the original information in the iris is blurred in this operation. However, it highlights the edge of the inner and outer circles of the iris, which is easy to locate and does not affect the later feature extraction.

After image enhancement for the image of the de-noised iris, contrast of enhanced image to highlight the pupil in the image, and results are shown in figure 3(c).

![Original](image1.png) ![After noise reduction](image2.png) ![Enhanced image](image3.png)

Figure 3. Comparison before and after pretreatment

### 3.3. Location of Internal circle of iris

The feature texture studied in this paper is concentrated in the iris region in the iris image. To facilitate the extraction of feature texture, the location of the iris in the iris image shall be determined. In this paper, we first find out the rough region of inner circle and outer circle and then adopt an improved particle swarm optimization algorithm for fitting the inner and outer circles of iris to achieve accurate and fast location of the iris.

In terms of traditional particle swarm optimization (PSO) algorithm, it is characterized by high convergence speed in the early stage of the algorithm, but it is easy to fall into local optimization in the later stage of the algorithm so that the convergence accuracy and speed are reduced [8]. In order to improve the convergence speed of the algorithm in the later stage, velocity updating formula of traditional particle swarm optimization is improved in traditional particle swarm optimization in this paper:

\[
\begin{align*}
    v_{ik}^{k+1} &= \begin{cases} 
        v_{ik}^k + c_1 r_1 (p_{ik} - x_{ik}^k), & A(i) = 1 \\
        v_{ik}^k + c_2 r_2 (g - x_{ik}^k), & A(i) = 0
    \end{cases}
\end{align*}
\]

In the formula, velocity update for i particle is marked by A(i). A (i) is initialized to 1, and the algorithm defaults to the first speed update for the i particle, that is to consider the individual optimal particle only. To update the velocity based on the individual’s best position is helpful for particle swarm algorithm to perform local search. When the i particle continues to stagnate during the stagnation period, the algorithm replaces the A (i) value with 0. And in this case, the i particle uses a second mode of speed update, considering global optimal particles, only. Based on the global optimal position of the particle, the speed update method is helpful to improve the global search capability of PSO. Similarly, if the i particle marked A (i)=0 remains stagnant during the stagnation period, the A (i) value is changed to be marked as 1. Using these two speed updating formulas, the global optimal particle or individual optimal particle is selected according to the actual situation to carry on the speed updating. Although it may affect the search optimal solution in the early stage of the algorithm, it can effectively expand the search space of the algorithm and avoid the algorithm falling into the local optimum, which greatly improves the convergence speed of the algorithm, and gradually improves the quality of the candidate optimal solution in the middle and later stages of the search, with final converge to the global optimal solution.

The edge function is used to detect the boundary while the canny operator is called to detect the iris edge of the image with enhanced contrast. The detection result is shown in figure 4(a). As shown in Figure 4(b),12 points with equal distance between any adjacent two points are selected on the iris
inner boundary. Every five points are connected at two points, and the intersection of all lines is the center point.

![Image](a) canny Operator Edge Detection  (b)  Points Selection of Iris Inner Boundary

Figure 4. Rough positioning of inner edge

Using PSO to find the circle center coordinate O (x, y) and radius r, of the inner boundary of iris, algorithm running process is shown in Figure 5(a). And then, the iris inner boundary is fitted to complete for fitting localization of iris inner boundary, as shown in figure 5(b). In this paper, the object function of particle swarm optimization algorithm are shown in formula (3):

$$f = \min_{x,y,r} \sum_{i=1}^{n} |(x - x_i)^2 + (y - y_i)^2 - r^2|$$  (3)

![Image](a)Algorithm Process of Particle Swarm in Iris     (b) Results of fitting iris inner circle

Figure 5. Fitting and locating of inner edge of iris

3.4 Noise reduction and enhancement of iris outer edge location

As the inner edge of iris, eyelash, eye face, iris texture, etc are determined to be the noise region when locating the outer edge of iris, in order to reduce the influence of the noise region on the location of the outer iris boundary, four noise regions are determined according to the center coordinates and radius of the inner iris boundary in this paper. They are the upper and lower eyelashes of the pupil, the lower half of the eyeball, the upper part of the eyeball and the pupil part of the inner boundary of the iris.

The upper and lower eyelashes of the pupil:

$$\{ (x, y) \mid y_0 - \Delta y \leq y \leq y_0 + \Delta y \}$$  (4)

The upper half of the iris includes lines above the pupil, eyelashes, and palpebra superior. The value of the variation $\Delta y$ in this region is determined by the range of the $r$ values. When value of $r$ is in range of $r_{min} + \frac{2}{3}(r_{max} - r_{min})$, $\Delta y$ is valued 15 while the value of the $\Delta y$ is set to 25 if the $r$ value exceeds this range. To eliminate the noise in the upper part of the iris, the gray value here is set to 0.

The lower part of the eyeball:

$$\{ (x, y) \mid (x - (x_0 - 2r))^2 + (y - y_0)^2 > (2r + \Delta r)^2 \}$$  (5)
The part of the eye is mainly the lines of the lower eyelashes and palpebra inferior where the value of variance $\Delta r_1$ in this region is determined by the change in the range of values of the $r$. When the value of $r$ changes in the range of $[r_{\text{min}} + \frac{2}{3}(r_{\text{max}} - r_{\text{min}}), r_{\text{max}}]$, the value of $\Delta r_1$ is 75. Otherwise, if this range is exceeded, the value of $\Delta r_1$ becomes 95. To eliminate the noise in the lower part of the iris, the gray value is set to 0 here.

The upper part of the eyeball:

$$\left\{(x, y) \mid \left|x - (x_0 + 2r)\right|^2 + \left|y - (y_0)\right|^2 > (2r + \Delta r_2)^2\right\}$$

(6)

The part of the eye is mainly the lines of the upper eyelashes and palpebra superior where the value of variance $\Delta r_2$ in this region is determined by the change in the range of values of the $r$. When the value of the $r$ changes in the range of $[r_{\text{min}} + \frac{2}{3}(r_{\text{max}} - r_{\text{min}}), r_{\text{max}}]$, the value of $\Delta r_2$ is 60. Otherwise, if this range is exceeded, the value of $\Delta r_2$ becomes 80. To eliminate the eyelash noise on your eyes, the gray value is set to 0 here.

Parts of pupils and iris:

$$\left\{(x, y) \mid \left|x - x_0\right|^2 + \left|y - y_0\right|^2 \leq r_{\text{min}}^2\right\}$$

(7)

This area mainly includes noise of inner circle line and outer circle of iris. To eliminate the noise in this part, the gray value here is set to 0.

It is easy to obtain the contour of the outer edge of the iris after removing the above four parts of the noise area and the obtained images are shown in figure 6.

![Canny edge detection](image1)
![After removing the noise area](image2)

(a) canny edge detection   (b) After removing the noise area

Figure 6. Noise Reduction Results

3.5. Location of iris outer circle

Particle swarm algorithm is adopted to find the circle center coordinate $O (x, y)$ and radius $r$ of the inner boundary of iris and iris outer boundary points are shown in figure 7(a). Then, the iris inner boundary is fitted to complete the fitting localization of the iris outer boundary as shown in Figure 7(b). The object function of particle swarm optimization algorithm in this paper is shown as formula (8):

$$f = \min_{x, y, r} \sum_{i=1}^{12} \left|\left(x - x_i\right)^2 + \left(y - y_i\right)^2 - r^2\right|$$

(8)

![Outer edge points of iris](image3)
![Out-circle fitting results](image4)

(a) Outer edge points of iris   (b) Out-circle fitting results

Figure 7. Location of outer circle of iris
3.6 Iris image normalization

In this paper, in order to facilitate later iris feature extraction, the coordinate transformation approach is adopted to normalize the iris image after positioning, to make the iris image after positioning be a standard image and to remain the original image information [9].

An iris image with a ring is normalized to a rectangular image of 600*150 as shown in Figure 8. The process is to cut a circular iris image from somewhere to pull each side into a rectangular shape but the image was slightly distorted so that the deformed part is replaced by nearby pixel points, and the coordinate formula is shown in formula (9).

\[
\begin{align*}
    x(r, \theta) &= (1 - r) \cdot x_a(\theta) + r \cdot x_s(\theta) \\
    y(r, \theta) &= (1 - r) \cdot y_a(\theta) + r \cdot y_s(\theta)
\end{align*}
\]  

(9)

Figure 8. Normalization

4. Experimental results and analysis

A total of 352 samples of the CASIA V4.0 from self-built iris gallery and Chinese Academy of Sciences are tested in this paper. The experimental results are shown in Table 1.

| Location position          | Number of tests | Correct results | Success rate |
|----------------------------|-----------------|-----------------|--------------|
| Internal circle positioning| 352             | 345             | 98.01%       |
| Outer circle positioning   | 352             | 302             | 93.78%       |

The improved particle swarm algorithm and sub-regional noise reduction for iris localization presented in this paper overcome the interference of the spot in the gallery and realize iris location and ensure the integrity of iris feature extraction information. Moreover, the algorithm can accelerate the efficiency of iris feature extraction in the later stage, and it also has certain popularization value for the research of iris location, iris feature extraction and iris auxiliary diagnosis application.

Acknowledgments

The work was supported by the School of Mechanical and Control Engineering, Shengli College, China University of Petroleum with experimental equipment and funding.

In addition, thanks to open source of iris gallery from Institute of Automation, Chinese Academy of Sciences.

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