Research on Iris Recognition Algorithm Based on Hough Transform

Zeng Yiming, Wu Jun

School of Electronic & Engineering, SEU, Nanjing City, Jiangsu Prov., China
wyxzj@just.edu.cn

Abstract. This paper proposes an iris recognition algorithm based on Hough transform. Firstly, the iris image is preprocessed, and the iris boundary is detected by Hough transform combined with Canny edge detection algorithm. Then, the annular iris region is normalized into a rectangular region by using the Rubber sheet algorithm; then the 1D Log-Gabor filter pair is used. The texture features of the normalized iris image are extracted, and the recognition algorithm based on the Hamming distance classifier is used for the final pattern matching according to actual needs. In this paper, the CASIA Iris Image Database V1.0 iris image database is used as the experimental object, and the simulation is performed on the MATLAB platform to verify the effectiveness of the iris recognition algorithm. Experiments show that the iris recognition method is feasible and effective.

1. Overview

In today's era, with the increasing level of global information technology, the demand for information security has become stronger. Biometric identification technology is based on personal biometrics, and identity authentication through pattern recognition is accurate and convenient, which has become a hot research direction today. Among them, the emerging iris-based recognition technology has broad application prospects.

The iris has a complex structure and rich texture. It is an organ inside the human eye, and the difference between different irises is very obvious [1]. Therefore, compared with other branches in biometrics, iris recognition is more accurate and difficult to forge due to its stable and unique characteristics. Despite the development of iris recognition over the years, it not only has significant progress in imaging devices, but also been fully developed in the recognition algorithm, but its application value remains to be discovered.

2. System overall framework

As a kind of biometric technology, the iris recognition system mainly consists of two parts:

- Registration function - add an iris feature template to the database;
- Recognition function - combines the currently collected iris features with the iris feature template in the database.

The iris image is collected by the camera and transmitted to the host computer for processing. During the iris image processing, boundary detection and noise filtering are performed on the collected iris image, thereby extracting the iris region in the image. The iris area is extended to a rectangular area represented by radial and angular directions to facilitate subsequent image processing. In the iris feature extraction process, the iris feature is extracted by appropriate algorithms and corresponding feature templates are formed. The registration function adds the obtained feature
template to the iris feature database; the recognition part compares the obtained feature template with the template in the database, and determines the matching result.

3. Iris image detection

The detection of the iris image is the detection of the inner and outer edges of the iris. According to the gray shape characteristics of the iris image, the edge detection of the iris is performed by Hough transform combined with Canny edge detection.

3.1. Classic algorithm for iris detection

Traditional iris detection algorithm includes the Daugman algorithm and the Wildes iris based on the combination of edge information and circular Hough transform. Detection algorithm [2].

The advantage of the calculus operator proposed by John Dougman is that it achieves high precision. However, it needs searching on the entire image that makes the calculation amount quite large.

The algorithm of edge detection combined with Hough transform proposed by Wilder is a very good solution for detecting the iris boundary. However, for iris images with blurred images and inconspicuous boundaries, it is difficult to obtain effective boundary points by selecting thresholds.

3.2. Canny detection

The basic idea of Canny edge detection is to first select the Gauss filter to smooth the image, then use the non-extreme suppression technique to obtain the edge image, select the sensitivity threshold parameter as the default value, and generate the Gaussian filter standard deviation for smoothing. The default value [3].

The specific process of the Canny edge detection algorithm can be divided into the following five steps:

1. Apply a Gaussian filter to smooth the image to eliminate noise

Due to the interference of image noise, the result of edge detection is highly prone to error, so a Gaussian filter can be used to convolve with the image to smooth the image to reduce the influence of noise on the edge detector and reduce the probability of false detection.

The Gaussian filter of size (2k+1)×(2k+1) is given by:

\[ H_{i,j} = \frac{1}{2\pi \sigma^2} \exp \left( -\frac{(i-(k+1))^2+(j-(k+1))^2}{2\sigma^2} \right); 1 \leq i,j \leq (2k+1) \]  

2. Find the intensity gradient of the image

The Canny algorithm uses four gradient detection operators to detect edges in the horizontal, vertical, and diagonal directions in the blurred image, and returns horizontal (Gx) and vertical (Gy) The first derivative value of ). The gradient and direction of the edge thus determine:

\[ G = \sqrt{G_x^2 + G_y^2} \]  

\[ \theta = \tan^{-1}(G_y, G_x) \]

In the formula, G can be calculated using the hypot function, and \( \tan^{-1}(-1) \) is an arctangent function containing two parameters. The edge direction angle can be represented by one of four angles of horizontal (0°), vertical (90°), and two diagonals (45° and 135°). The edge direction will be set to map from \( \theta \) in a particular angle to a specific angle value of 0°.

3. Applying non-maximal values to suppress false responses to edge detection

Suppressing non-maximum values as an edge refinement technique, indicating the position where the intensity value changes the most, and all gradient values other than the local maximum (normally set to 0) will be suppressed.

4. Applying double thresholds to determine potential edges

These spurious responses can be eliminated by selecting high and low double thresholds to preserve edge pixels with higher gradient values and filtering out edge pixels with weaker gradient values.
(5) Tracking edges by lag
   Edge detection is accomplished by suppressing all other weak edges and connecting strong edges.

3.3. Hough transform
The basic principle of Hough transform is to express the given curve of the original image space as a point of the parameter space by the duality of points and lines. At this time, the problem of detecting the given curve (the overall characteristic) in the original image is transformed to find the problem of peak (local characteristics) in the parameter space [4]. The circular Hough transform derives the radius and center coordinates of the pupil and iris regions for iris image detection [5].

In the WILDES iris detection algorithm system, a circular Hough transform method is adopted. First, the first derivative of the pixel intensity in the initial image is calculated, and then the result is processed by the threshold to generate an edge point. The boundary parameter of the iris passes the boundary in the edge point. The parameters are determined by voting.

Hough is defined as:

$$H(x_c, y_c, r) = \sum_{j=1}^{n} h(x_j, y_j, x_c, y_c, r)$$  \hspace{1cm} (3-4)

Here,

$$h(x_j, y_j, x_c, y_c, r) = \begin{cases} 1, & \text{if } g(x_j, y_j, x_c, y_c, r) \\ 0, & \text{other} \end{cases}$$

among them:

$$g(x_j, y_j, x_c, y_c, r) = (x_j - x_c)^2 + (y_j - y_c)^2 - r^2$$

$$(x_j, y_j), (j=1, \cdots, n)$$ is the entire boundary point on the image after edge extraction. For each boundary point $(x_j, y_j)$, if any $g(x_j, y_j, x_c, y_c, r)$, can be confirmed by the parameters $(x_c, y_c, r)$. The determined boundary circle passes through the boundary point $(x_j, y_j)$. Therefore, when the circle passing through has the most boundary points, it is indicated that $H$ corresponding to the maximum value is most likely to represent the circumferential boundary to be tested.

4. Extraction and identification of iris features
Iris recognition is based on the texture feature of iris recognition. The effective feature extraction algorithm is used to transform the texture features in the normalized iris image into unique feature points that can be compared, and then calculated according to the algorithm of pattern matching. The similarity size is used for identification [6].

4.1. Normalization of the iris area
Since the size of the iris is not fixed, and the displacement of the iris image will also cause misjudgment of iris recognition, the effective iris region obtained after noise detection and iris detection processing needs to map the annular iris region to a fixed size by normalization. A rectangular area that eliminates the adverse effects of image displacement on iris recognition [7].

Remap each point in the iris region to a pair of polar coordinates using equations (4-1), (4-2), (4-3)\((r, \theta)\)Where $r$ is in the interval $[0, 1]$, the angular range of $\theta$ is $[0, 2\pi]$. Wherein, the vertical dimension of the normalized representation is defined by the radial resolution, and the horizontal dimension of the normalized representation is defined by the angular resolution.

$$I(x(r, \theta), y(r, \theta)) \rightarrow I(r, \theta)$$  \hspace{1cm} (4-1)

$$x(r, \theta) = (1 - r)x_p(\theta) + rx_i(\theta)$$  \hspace{1cm} (4-2)

$$y(r, \theta) = (1 - r)y_p(\theta) + ry_i(\theta)$$  \hspace{1cm} (4-3)

In the middle $I(x, y)$ Represents an image of the iris area, $(x, y)$ Is the initial Cartesian coordinates, $(r, \theta)$Is the corresponding normalized polar coordinates. All the weighting coefficients ($r$ ranges from 0 to 1) the same points correspond to points on the same circumference, and all points of the same angle correspond to points on different circumferences in the radial direction.
4.2. Iris feature extraction

Since 2D-Gabor filtering can capture local structural information corresponding to spatial position, spatial frequency and direction selectivity, the extraction of iris texture features generally adopts 2D-Gabor filtering method. The formula for the 2D-Gabor filter in image space is:

\[
G(x, y) = \exp\left(-\pi \left[\frac{(x-x_0)^2}{\alpha^2} + \frac{(y-y_0)^2}{\beta^2}\right]\right) \times \exp(-2\pi i (u_0(x-x_0) + v_0(y-y_0)))
\]

\[(4-4)\]

\[\exp(-\pi\left[\frac{(x-x_0)^2}{\alpha^2} + \frac{(y-y_0)^2}{\beta^2}\right])\] indicates a Gaussian function that determines the size of the filter after windowing; \((x, y)\) Represents the coordinate position of the filter in the spatial domain; \((x-x_0)\) Represents the center position of the filter in the spatial domain; \(\alpha, \beta\) Determine the size of the window, which respectively represent the width and length of the effective Gaussian window; \(u_0, v_0\) indicates the coordinates of the filter in the spatial frequency; \(\omega\) = \((u_0^2 + v_0^2)^{1/2}\) Represents the filter spatial frequency; \(\theta = \arctan(\frac{v_0}{u_0})\) indicates the filter direction angle, similar to the spatial frequency.

By selecting different \(\omega\), values can be obtained with Gabor filters of different scales, and thus can extract features of iris images at different scales; \(\theta\) The value of the Gabor filter can be obtained in different directions, and the texture features of the iris image in different directions can be obtained [9].

Field's Log-Gabor proposed in 1987 has the advantages of multi-channel and multi-resolution of Gabor filtering, and has no DC component. The feature extraction can be achieved well with the 1D Log-Gabor filter, and its frequency response is given by equation (4-5) [8]:

\[
G(f) = \exp\left(-\frac{(\log(f/f_0))^2}{2(\log(\sigma/f_0))^2}\right)
\]

\[(4-5)\]

\(f_0\) Indicates the center frequency, \(\sigma\) The filter bandwidth is given. In order to make the filter shape constant, \(\sigma/f_0\) Should be a constant. The Log-Gabor filter can describe the signal based on the local frequency response.

At this stage, the iris image is divided \(m \times n\) Piece. The local phase information is encoded in each iris sub-block according to the expression in equation (4-6). The two-dimensional normalized iris polar image is decomposed into a plurality of one-dimensional signal sequences, which are then convolved in the frequency domain with a 1D Log-Gabor filter.

\[
h_{Re} = 1 \quad \text{si} \quad Re \int_{\rho, \phi} e^{-i\omega(\theta_0-\phi)} e^{-\frac{(\rho_0-\rho)^2}{\alpha^2}} e^{-\frac{\theta_0^2}{\beta^2}} I(\rho, \phi) \rho d\rho d\phi \geq 0
\]

\[
h_{Re} = 0 \quad \text{si} \quad Re \int_{\rho, \phi} e^{-i\omega(\theta_0-\phi)} e^{-\frac{(\rho_0-\rho)^2}{\alpha^2}} e^{-\frac{\theta_0^2}{\beta^2}} I(\rho, \phi) \rho d\rho d\phi < 0
\]

\[
h_{Im} = 1 \quad \text{si} \quad Im \int_{\rho, \phi} e^{-i\omega(\theta_0-\phi)} e^{-\frac{(\rho_0-\rho)^2}{\alpha^2}} e^{-\frac{\theta_0^2}{\beta^2}} I(\rho, \phi) \rho d\rho d\phi \geq 0
\]

\[
h_{Im} = 0 \quad \text{si} \quad Im \int_{\rho, \phi} e^{-i\omega(\theta_0-\phi)} e^{-\frac{(\rho_0-\rho)^2}{\alpha^2}} e^{-\frac{\theta_0^2}{\beta^2}} I(\rho, \phi) \rho d\rho d\phi < 0 \quad (4-6)
\]

The image texture information feature is mainly determined by the phase information, while the amplitude information indicates the strength of the texture change. After the iris is processed by the filter with different directions of the same frequency scale, the texture is changed in different directions at this scale. Feature description. Using the above encoding method, the obtained iris signatures of all scales are combined to form a complete iris signature.

5. Iris feature matching

In this paper, the Hamming distance classifier is used in the matching recognition process. The Hamming distance can determine whether the two templates are produced by the heterogeneous iris or from the same type of iris.
\[ HD = \frac{1}{N} \sum_{j=1}^{N} X_j \oplus Y_j \]  

When comparing the X and Y bits, the Hamming distance HD is defined as the ratio of the number of different bits to the total number of bits in the template. \( \oplus \) Indicates the XOR operation, where N is the feature code length, \( X_j \) with \( Y_j \) The same bit codewords that represent the two template image feature codes, respectively. The resulting Hamming distance should be close to 0; while iris templates generated from different irises are completely independent, the values of the two bit patterns will be completely random, and the Hamming distance between them should be equal to 0.5.

6. Analysis of experimental results based on Matlab

This experiment used the iris image in CASIA-Iris Image Database V1.0 as an experimental sample. The hardware environment for the experiment was Intel Core i5-5200U processor, CPU clocked at 2.20GHz, memory was 4GB, operating system was Window 10, and MATLAB 2016b was used as a programming tool for simulation.

The experiment selected 5 sets of iris images in the standard iris library for analysis. The sample image pixels were 320×280, 8-bit depth, the inner and outer edges of the five sets of iris images were detected, and then the rectangular expansion and feature extraction using 1D Log-Gabor filter were performed, and the Hamming distance between different iris images was compared and determined according to the classification threshold. Match the result.

According to the calculated Hamming distance between different irises, the comparison results of the same type of iris and heterogeneous irises are shown in Table 6-1:

| Hamming distance | 001 | 005 | 009 | 033 | 069 |
|------------------|-----|-----|-----|-----|-----|
| Hamming distance | 001 | 002 | 001 | 002 | 001 | 002 | 001 | 002 |
| 001             | 0.3916 | 0.4850 | 0.4814 | 0.4755 | 0.4894 | 0.4798 | 0.4898 | 0.4473 | 0.4765 |
| 1               | 0.3916 | 0.4781 | 0.4920 | 0.4844 | 0.4885 | 0.4832 | 0.4907 | 0.4738 | 0.4669 |
| 00               | 0.4028 | 0.4801 | 0.4898 | 0.4670 | 0.4924 | 0.4756 | 0.4770 |       |       |
| 5               | 0.4028 | 0.4944 | 0.4885 | 0.4606 | 0.4839 | 0.4807 | 0.4803 |       |       |
| 00               | 0.3667 | 0.4599 | 0.4544 | 0.4731 | 0.4664 |       |       |       |       |
| 9               | 0.3667 | 0.4461 | 0.4490 | 0.4611 | 0.4611 | 0.4702 |       |       |       |
| 03               | 0.2824 | 0.4720 | 0.4553 |       |       |       |       |       |       |
| 3               | 0.2824 | 0.4763 | 0.4774 |       |       |       |       |       |       |
| 06               |       |       |       |       |       |       |       | 0.3525 |       |
| 9               |       |       |       |       |       |       |       |       | 0.3525 |

Bold data is the Hamming distance of the same type of iris

It can be seen from the above table that the Hamming distance of the same type of iris is substantially lower than 0.4, and the Hamming distance of the heterogeneous iris is mostly above 0.45.

Table 6-2 shows the center coordinates and radius parameters of the inner and outer boundary circles of the iris obtained by Canny edge detection and Hough transform during the iris detection
algorithm simulation, and the feature template between the irises in the pattern matching step. Calculate the resulting HD.

Table 6-2. Simulation experiment parameters.

| CASIA DATABASE | Group number | Iris outer circle center coordinates | Iris inner circle center coordinates | Hamming distance |
|----------------|--------------|--------------------------------------|-------------------------------------|-----------------|
|                |              | Iris outer circle radius             | Iris inner circle radius            |                 |
| 001            | _1_1         | [140, 180]                           | [140, 185]                          | 0.3916          |
|                | _1_2         | [145, 170]                           | [140, 175]                          | 0.4028          |
| 005            | _1_1         | [135, 140]                           | [130, 135]                          | 0.3674          |
|                | _1_2         | [150, 165]                           | [155, 165]                          | 0.3675          |
| 009            | _1_1         | [150, 195]                           | [145, 190]                          | 0.3675          |
|                | _1_2         | [155, 185]                           | [150, 180]                          | 0.3675          |
| 033            | _1_1         | [135, 160]                           | [130, 160]                          | 0.2824          |
|                | _1_2         | [130, 180]                           | [125, 180]                          | 0.2824          |
| 069            | _1_1         | [165, 155]                           | [160, 160]                          | 0.2824          |
|                | _1_2         | [170, 135]                           | [165, 140]                          | 0.2824          |

The Hamming distance of the same type of iris is mainly distributed at 0.25~0.45. Between 0.45, the Hamming distance of the heterogeneous iris is mainly distributed between 0.45 and 0.65. From the above analysis, it can be concluded that the classification threshold should be chosen to be around 0.45. In the 40 groups of heterogeneous irises, there are 3 groups of heterogeneous irises with a Hamming distance slightly lower than the classification threshold, which are misidentified as the same type of iris, but the other 37 groups can be correctly identified, so the accuracy of the iris recognition scheme used in this paper is 93.33%.

7. Conclusion

Through experimental simulation, the iris recognition algorithm of Hough transform has high precision. With its superior characteristics, the iris has become one of the important features for identifying personal identity, and iris recognition technology has broad application prospects. However, at the same time, the scheme exposes the disadvantages of poor robustness and slow speed. In addition, the extracted feature template needs to encode the extracted feature template on a large scale, and the traditional coding registration method also makes the pattern matching calculation amount larger. There is still a considerable gap with the current world-class top iris recognition algorithm, which needs to be improved and further research.

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