Research and Implementation of Iris Recognition Algorithm

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Abstract

Iris recognition usually contains iris location, feature extraction and identification. The proposed algorithm firstly uses the combined method of wavelet analysis and equation of circle to identify iris inner edge. Then, the circular detection operator method is applied to identify iris outer edge. After the iris precise location, the iris recognition method based on wavelet packet decomposition and RBF neural network is proposed. The experiment images are provided by the CASIA iris database. The experimental results show the effectiveness of the proposed algorithm. Also the speed and the accuracy of iris recognition are improved. The proposed algorithm provides a new way for iris recognition.

Keywords: Iris location; Wavelet packet decomposition; RBF neural network; Iris recognition

1. Introduction

Iris with rich texture is highly unique, and is a very promising biometric identification method. The key steps of iris recognition technology are iris location and feature extraction. This paper presents the method of wavelet analysis combined with the equation of a circle for the iris inner edge location. And the outer edge location uses the circle detection operator method. Based on the precise iris location, according to the characteristics of the wavelet packet decomposition with the ability of analyzing the signal high-frequency detail information, the method of the wavelet packet decomposition is applied to extract the iris feature vectors. Then the RBF network with the faster convergence ability is used for iris recognition. The experiments show that the algorithm can achieve good recognition results.

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2. Iris location

Iris location algorithm is to find the centers and radiuses of iris and pupil in the human eye image and split the iris image for the subsequent feature extraction algorithm.

2.1. Iris inner edge location

As the iris has the shape of a special ring, from outside to inside, the sclera, the iris and pupil, the average gray value is basically ladder-like distribution. And observe the captured image, the iris and pupil boundary is more obvious. So take advantage of this feature, firstly locate the inside edge of the iris, named by the pupil boundary. This presents a wavelet-based location with the circle equation method.

The location steps based on the wavelet analysis combined with the circle equation are as follows:

Step1: The Haar wavelet is used to execute the single-scale decomposition of the iris image, as shown in Figure 1 (a). And then the low-frequency part of the decomposed wavelet image is reconstructed. After that, the reconstructed image is carried on quantization coding to improve the image quality. Adjust the image size and use $7 \times 7$ median filter for image filtering, as shown in Figure 1 (b).

Step2: The use of appropriate thresholds to the filtered image gets the binary image. And image morphological opening operation is used to remove the eyelashes image information and other interference, as shown in Figure 1 (c) below.

Step3: Each column of the image gray value sums to find out the column where the maximum value is to determine the abscissa of point, and then each row of the image gray value sums to find out the row where the maximum value is to determine the vertical axis. Gray projection expressions are as follows:

\[
x_j = \sum_{i=1}^{n} f(i, j)
\]

\[
y_i = \sum_{j=1}^{m} f(i, j)
\]

\[
f(i, j)\] is the pixel gray value of the coordinates $(i, j)$ for the image, and its value is 0 or 1. $x_j$ is the column sum and $y_i$ is the row sum. Using $x = \max(x_j), \, y = \max(y_i)$ can determine a point within the pupil. After he point has been determined, the Canny operator is used to extract the original image edges. In the edge of the image, the search from the point to the four directions up, down, left and right is carried on to find the edge points. Then respectively record four points coordinates. The general equation of a circle is given by:

\[
x^2 + y^2 + Ax + By + C = 0
\]

The center coordinate is \((-\frac{A}{2}, -\frac{B}{2}\)) and the radius is \(-\frac{\sqrt{A^2 + B^2 - 4C}}{2}\). The coordinates of any three points in the above four points can be calculated into the center and radius, you can find a total of four groups, and finally these values are averaged to get the center and radius of the iris inner edge.

Specific principles are as follows:

Equation (3) is conducted that:

\[
Ax + By + C = -x^2 - y^2
\]

Remove any three points from the four points, and their coordinates are set $(x_1, y_1), (x_2, y_2), (x_3, y_3)$, then

\[
Ax_1 + By_1 + C = -x_1^2 - y_1^2
\]

\[
Ax_2 + By_2 + C = -x_2^2 - y_2^2
\]
Ax_j + By_j + C = -x_j^2 - y_j^2 \quad (7)

Transform them into the matrix forms are:

\[ UT = V \quad (8) \]

Among

\[
U = \begin{bmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{bmatrix}, \quad T = \begin{bmatrix} A \\ B \\ C \end{bmatrix}, \quad V = \begin{bmatrix} -x_1^2 - y_1^2 \\ -x_2^2 - y_2^2 \\ -x_3^2 - y_3^2 \end{bmatrix}.
\]

Then

\[ T = U^{-1}V \quad (9) \]

It can calculate A, B, and C to determine the center and radius. The computing methods of other three groups are similar. The result of iris inner edge is shown in Figure 1 (d).

This method avoids that the direct use of Hough transform calculates the center and radius of the iris inner edge, greatly reducing the computational complexity, and improving the location accuracy.

![Figure 1: The iris inner edge location: (a) the reconstructed image, (b) image after median filtering, (c) image after opening operation, (d) the inner edge location](image)

### 2.2. The iris outer edge location

Generally the circle centers of the iris inner edge and the iris outer edge are deviated. Using the center and radius of the iris inner edge can determine the center and radius of the outer edge. The radius of the iris inner edge can change from 0.1 to 0.8 according to the radius of the iris outer edge. The iris outer edge can be obtained by a very efficient algorithm as (10) below [1,2].

\[
\max_{(r,x_0,y_0)} \int_{r-x_0,y_0} G_{\sigma}(r) \ast \frac{I(x,y)}{2\pi r} \ ds \quad (10)
\]

In equation (10), \( I(x,y) \) is the iris original image as shown in Figure 1(a). The function by constantly increasing radius \( r \), along the radius \( r \) and the center coordinate \( (x_0,y_0) \), the arc ds is carried on the contour integral. Symbol * denotes convolution, \( G_{\sigma}(r) \) is the Gaussian smoothing function of zero mean, variance \( \sigma \). Select the appropriate \( \sigma \) goes on smoothing filter to eliminate the noise in order to facilitate the gradient detection of the boundary. The process of locating the iris outer edge is that the maximum absolute value of gray-scale changes in the parameter space \( (x_0,y_0,r) \) is searched. Parameter \( (x_0,y_0) \) range is the size of 7 × 7 matrix of the center of the identified inner edge as the center. This algorithm limits the scope of the search and reduces the computational complexity. Finally, the result of the iris location is shown in Figure 2.
3. Iris feature extraction based on wavelet packet decomposition

When the iris image feature is extracted, the processed iris image is carried on two-layer wavelet packet decomposition to generate the coefficients tree, as shown in Figure 3[3,4].

![Wavelet packet decomposition tree](image)

Figure 3: Wavelet packet decomposition tree

The specific algorithm is as follows:

Step 1: Selecting the db4 wavelet of Daubechies wavelet family and Shannon entropy carries on the two-layer wavelet packet decomposition to the $64 \times 256$ size of the processed iris image. The first-level wavelet packet decomposition has four sub-images, the second-level wavelet packet decomposition has 16 sub-images. In the figure, $(i, j)$ denotes the $j$ node on the $i$ layer of the signal. Each node denotes a certain signal characteristic. $(0,0)$ denotes the normalized iris image. $(1,0)$ denotes the low-frequency part of the signal. $(1,1), (1,2), (1,3)$ represents the horizontal, vertical, and diagonal direction of the characteristic information of the signal which are the high-frequency part of the signal. $(2,0)$ denotes the 0 node coefficients of the second layer of the signal, the other channels and so on.

Step 2: Extract the coefficient matrices of $(2,1) \ldots (2,15)$ nodes after wavelet packet decomposition. Node $(2,0)$ is the low-frequency part of the texture image. Because the texture features are mainly concentrated in the high-frequency part, the node is not taken into account.

Step 3: Calculate 2-norm of each coefficient matrix and obtain the 15-dimensional feature vector which represents the iris image.

4. Iris Recognition Based on RBF Neural Network

After using wavelet packet decomposition to extract the iris features, the iris recognition method based on RBF neural network is proposed to model the low-dimensional input data transformation to high-
dimensional space and make that the linear sub-space problem in the low-dimensional is not linear in the high-dimensional space can be divided.

(1) RBF network design

First, get network input samples and target samples. Take $15 \times 26$ iris feature vectors, where each row of the feature vectors as a feature of the sample weight. Each sample has 15 features. Each column of the feature vectors as a sample, it is a total of 26 samples.

Then, determine the network structure. The system uses the RBF network as the state classifier. Among them, the input layer neurons is $15 \times 26$, the output layer neurons is $1 \times 26$. Output results are represented with $0, 1, 2, ..., 25$, which are the classification types of the feature.

Let $P$ represents the network input sample vector and $T$ represents the network target vector.

Then

$$P = \begin{bmatrix} P(1,1) & P(1,2) & \cdots & P(1,26) \\ P(2,1) & P(2,2) & \cdots & P(2,26) \\ \vdots & \vdots & \ddots & \vdots \\ P(15,1) & P(15,2) & \cdots & P(15,26) \end{bmatrix}$$

$$T = [0, 1, \cdots, 25]_{1 \times 26}$$

(2) Network training

The RBF networks, we should note the maximum number of hidden layer neurons settings, and note that as the network input vector dimension is high, the radial basis function network is too large, not practical well, should not be used [5,6]. After finishing designing a network, using the extracted iris feature vectors samples trains the network. The initial network parameters are as follows: the number of neurons is taken as 100, the error indicator is taken as $10^{-3}$, the distribution constant of radial basis function is 1. Use 26 training samples to train the grid. And the network input is $15 \times 26$ matrix, the network output is $1 \times 26$ matrix. Network is created, but can not be directly put into use. It must be trained before you can use. When it meets the requirements, it can be the classification as iris recognition.

The result of network training is shown in Figure 4. After 23 times training, the network error is to get the set minimum.

![Figure 4: Training error curve](image)

5. Simulation results and analysis

The Institute of Automation, Chinese Academy of iris image database (CASIA Iris Image Database (version 1.0)) [7] includes 108 different eye image samples, each eye has seven 8-bit gray scale images.
The images are captured in two phases. Database includes the first phase of three samples and the second stage of four samples. Here firstly take 13 eyes, each eye has the two images, a total of 26 iris images, and then calculate the feature vectors of each of the two images to get the different samples to train the neural network. Using the 26 training samples trains the grid. When training 23 times, the network reaches a good convergence. After training the neural network, the network is applied to test the performance of iris recognition algorithm through 52 test samples. It can make judgments quickly and accurately. For the small sample case, the correct identification rate is 100%. If the first phase of the entire iris database as the training set and the second phase of the iris as the test set, a total of 40 images in the second phase can not be correctly identified (32 images not matched, 8 images refused to identify).

The correct classification rate of the proposed algorithm is as follows:

\[ \frac{(108 \times 4 - 40)}{(108 \times 4)} \times 100\% = 90.74\% \]

6. Conclusion

This paper presents a new iris recognition algorithm. The algorithm implements the iris inner edge location by the wavelet analysis combined with the circle equation. And the use of wavelet packet decomposition to extract the characteristics of high-frequency details extracts the iris feature vectors effectively. Finally, the use of RBF neural network with fast convergence advantages as a classifier achieves the iris recognition. Experiments show that the algorithm can improve the recognition speed and accuracy. However, because of the limited experimental samples, a large number of samples are needed to conduct experiments to verify the robustness of the algorithm.

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