An Improved Iris Recognition Method Based on Wavelet Packet Transform

Yonghui Wang* and Haoran Zheng

School of Information and Control Engineering, Shenyang Jianzhu University, Liaoning, China

*Corresponding author email: yonghuiwang@sjzu.edu.cn

Abstract. Wavelet packet decomposition transformation is an extension of wavelet transformation, which can achieve more refined decomposition and get more wavelet packet subgraphs. In order to improve the recognition accuracy of iris, an improved iris recognition algorithm based on wavelet packet transform is proposed. First locate and normalize the inner and outer edges of the iris, then obtain the wavelet packet subgraphs through wavelet packet decomposition, calculate the coefficients of each subgraphs to obtain the iris feature vectors, and then calculate the Hamming distances of the corresponding feature vectors of the two iris images, according to different subgraphs. The calculated coefficients are identified by the weighted Hamming distance classifier.

Keywords: Iris Recognition, Wavelet Packet, Weighted Hamming Distance

1. Introduction

The iris is one of the important biological characteristics of the human body, with rich details and texture characteristics. Among various biometric recognition technologies, iris recognition technology has the characteristics of uniqueness, non-invasiveness, stability, etc., which makes iris recognition a recognition technology with research significance in human body feature recognition [1].

Many classic algorithms have been proposed in iris recognition. Daugman has proposed a feature extraction method using Gabor filtering [2]. Boles et al. has proposed a zero-crossing detection algorithm based on wavelet transform [3]. Wildes et al. has Proposes a method to extract iris texture features using Laplacian pyramid [4]. Feng et al. propose to improve Daugman's method with weighted Hamming distance [5]. Lin et al. has proposed a method to eliminate redundant features using odd-numbered symmetric 2D Log-Gabor filters [6]. Yao et al. has proposed a feature extraction method using harr wavelet and log-gabor transform [7]. Wang et al. has proposed an algorithm for extracting energy of iris images as features of iris using wavelet packet decomposition [8]. Zhang et al. has proposed a method of selecting specific sub-bands to extract singular values based on wavelet packet decomposition [9]. Yang et al. has proposed an algorithm that periodic wavelet transform is used first to extract part of information which is in high frequency, and then uses Backpropagation neural network to classify [10].

This paper explores the energy distribution decomposed by the wavelet packet, and weights the
Hamming distance based on this, and improves the algorithm.

2. Iris Recognition Method

An iris recognition system is generally divided into the following steps: iris image preprocessing, which includes iris area positioning and normalization of the image, and then extract text feature of the images and make it into a feature vectors, and finally perform iris matching based on the extracted features.

2.1. Iris Image Preprocessing

2.1.1. Iris positioning. Iris positioning is to find two boundaries of the iris and the first boundary is the boundary between the pupil and the iris, and the second boundary is the that between the sclera and the iris. Usually, the Canny edge detection operator is used for performing edge detection on the original image of the iris, and then the extracted edge points are used to find the boundaries of the iris through Hough transform. Iris positioning result is shown in Figure 1.

![Iris positioning](image)

Figure 1. Iris positioning

2.1.2. Normalization of iris image. normalizing the segmented iris image is usually a necessary step to eliminate the possible influence of iris image rotation, translation and zooming on iris recognition algorithm. Since the two boundaries of the iris area we found are both circular and the iris area we need is in the shape of a ring, the ring-shaped iris image can be convert into a rectangular image using polar coordinates in formula (1).

\[
\begin{align*}
I(r(\rho, \alpha), c(\rho, \alpha)) & \rightarrow I(\rho, \alpha) \\
r(\rho, \alpha) & = (1 - \rho)r_i(\alpha) + \rho r_o(\alpha) \\
c(\rho, \alpha) & = (1 - \rho)c_i(\alpha) + \rho c_o(\alpha)
\end{align*}
\]

(1)

Where \( \rho \in [0, 1] \), \( \alpha \in [0, 2\pi] \), and the pixel coordinates of the two boundaries of the iris area are \( (x_i(\theta), y_i(\theta)) \) and \( (x_0(\theta), y_0(\theta)) \). The iris image is normalized to a uniform pixel image, and the normalized iris image is shown in Figure 2.

![Iris image after normalization](image)

Figure 2. Iris image after normalization

2.2. Iris Text Feature Extraction

2.2.1. Wavelet packet transform. Wavelet packet can be regarded as a discipline extended from wavelet transform, and it decomposes high-frequency sub-band images on the basis of only decomposing low-frequency sub-band images [11]. Each layer of wavelet packet decomposition further decomposes
high-frequency sub-bands and low-frequency sub-bands. Since the approximate value of the image is the low-frequency component, the details are the high-frequency component of the iris image. Therefore, the wavelet packet transform can effectively extract the texture features of the image.

From a given function $f_0$, the generated wavelet packet basis function family $\{f_n\}_{n=0}^{\infty}$ is in formula (2).

$$
\begin{align*}
  f_{2n}(x) &= \sqrt{2} \sum_{k \in \mathbb{Z}} h_{k,n} f_n(2x - k) \\
  f_{2n+1}(x) &= \sqrt{2} \sum_{k \in \mathbb{Z}} g_{k,n} f_n(2x - k)
\end{align*}
$$

Where $f_0(x)$ is given by orthogonal scaling function $\Phi$ and wavelet function $\Psi$. The wavelet packet basis is a set of orthogonal normal basis composed of $2^n$, $x \in \mathbb{Z}$, $k \in \mathbb{Z}$, $n \in \mathbb{N}$ and $l$ is called the scale, $k$ represents frequency factor, and $n$ represents displacement factor.

In images and other two-dimensional signals, the product of two one-dimensional wavelet packet bases along the vertical and horizontal directions can be used to represent the two-dimensional wavelet packet base function, and the corresponding filter can also be represented by the product of a low-pass filter and a high-pass filter in formula (3).

$$
\begin{align*}
  l_L L(r,c) &= l(r)l(c) \\
  l_L H(r,c) &= l(r)h(c) \\
  l_H L(r,c) &= h(r)l(c) \\
  l_H H(r,c) &= h(r)h(c)
\end{align*}
$$

2.2.2. Extraction Features by Wavelet Packet. Wavelet packet transform can decompose the images into multiple layers. If the number of decomposed layers is too low, it will lead to insufficient signal extraction. But it is not that the more sub-band images that are decomposed, the better. As the number of sub-band images increases, the amount of calculation increases, and the information contained in the sub-band images gradually decreases, which has no obvious effect on iris recognition. This paper uses db4 wavelet base and Shannon entropy which are widely used in wavelet packet transform to decompose the normalized iris image into two layers. The result of the first layer decomposition is 4 sub-band images, and the second layer is decomposed to obtain 16 sub-band images.

![Figure 3. Schematic diagram of wavelet packet decomposition](image)

In Figure 3, the sub-band (2, 0) is the low-frequency information obtained by decomposition. Since the texture features of iris image is mainly contained in the medium and high frequency information obtained by decomposition, this article selects the second layer of coefficients except (2,0), that is, the medium-frequency and high-frequency information, and calculates the coefficient of each sub-band in formula (4).

$$
Ent = \sum_{r=1}^{M} \sum_{c=1}^{N} x^2(r,c)
$$
Where \( r, c \) represents the value of each row and value of each column of the decomposed sub-band images, respectively. Construct the iris feature vectors with the obtained coefficients.

2.3. Improved Pattern Matching Algorithm
Matching is performed after constructing the feature vectors. The weighted Hamming distance is used to represent the comparison result of two normalized iris images in this paper. The weighted Hamming distance is calculated in formula (5).

\[
d = w_n \sum_{i=1}^{S} A \oplus B
\]  

(5)

Where \( S \) is 15, which represents the number of selected sub-bands, \( w_i \) is the average of the proportion of each coefficient of the two iris images in the sum of 15 coefficients. In this way, the larger the coefficient of the sub-band image, the greater the weight.

3. Experimental Results and Analysis
The CASIA-Iris-Interval-v4 iris dataset v4 includes 395 categories, 2639 iris pictures, and the picture resolution is 320×240 pixels and it is very suitable to research the detailed texture features of iris images [12]. This paper selects 200 categories and a total of 1600 iris images for experiment. Since the sub-band coefficients decomposed by the wavelet packet are different, the low-frequency signal has more energy and the high-frequency signal has relatively less energy, especially (2,12), (2,13), (2,14), (2,15), contain less information. It is very susceptible to noise if these sub-band images contain noise. The coefficient distribution of the iris image after wavelet packet decomposition is shown in Figure 4.

![Figure 4. Iris image coefficient distribution](image)

This paper compares the unimproved Hamming distance algorithm to verify that the weighted Hamming distance is effective. In the unimproved algorithm to obtain the Hamming distance of the iris, several calculated data are randomly selected.

| Hamming distance of similar irises | Weighted Hamming distance of similar irises | Hamming distance of heterogeneous irises | Weighted Hamming distance of heterogeneous irises |
|-----------------------------------|--------------------------------------------|----------------------------------------|-----------------------------------------------|
| 277.5                             | 226.8                                      | 321.2                                  | 327.2                                         |
| 286.3                             | 253.4                                      | 295.8                                  | 312.1                                         |
| 329.7                             | 257.8                                      | 320.0                                  | 328.1                                         |
| 282.8                             | 227.3                                      | 310.4                                  | 331.5                                         |
| 312.2                             | 269.1                                      | 304.7                                  | 332.9                                         |
| 305.9                             | 277.6                                      | 287.2                                  | 309.7                                         |

As Table 1. shows that the Hamming distances of the same and heterogeneous types are further enlarged using weighted Hamming distance, and some misclassified images can be classified more...
accurately. This is because the sub-band images with smaller coefficients are easy to calculate the Hamming distance. Errors are caused by noise and other influences. When weights are not set, they may have a greater impact on the global Hamming distance. Weighting the Hamming distance calculated with different coefficients can effectively offset this part of the impact. This paper also compares the recognition accuracy with other algorithms.

| Algorithm | Recognition accuracy |
|-----------|----------------------|
| Wavelet packet transform | 94.6% |
| Yao et al.[7] | 95% |
| Zhang et al.[9] | 95.67% |
| Proposed | 96.3% |

Compared with the method of singular value decomposition and feature compression after wavelet packet decomposition, the algorithm we propose in this paper does not need to filter the wavelet packet sub-band images manually, avoiding the loss of some effective information and reducing the impact of noise.

4. Conclusion
This paper analyzes the influence of the ratio of different coefficients to the total energy decomposed by the wavelet packet on the Hamming distance, and then assigns the corresponding weights to the different Hamming distances to improve iris recognition algorithm. Since the iris recognition system needs to compare the wavelet packet coefficients of two iris images, the further work can analyze the influence of the coefficient of each image after the decomposition to the ratio of all energy, and assign different coefficients more targeted the corresponding weight. At the same time, SVM or combined with neural network and other classifiers can also be used to further improve the algorithm of the recognition system.

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