Ear Recognition Based on Centroid and Spindle

Yuncong Xu\textsuperscript{a*}, Weiming Zeng\textsuperscript{a}

\textsuperscript{a}College of Information Engineering, Shanghai Maritime University, Shanghai, 200135, China

Abstract

Ear recognition technology is in a developing period. It includes the methods based on geometric approach, mathematical theory and force field transformations, etc. In this study, we proposed a new geometric method, which took advantage of the theory of gravity and the spindle. To prove the validity of this method, the experiment had been done on the ear database. Its results show this method has better performance.

© 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of Harbin University of Science and Technology Open access under CC BY-NC-ND license.

Keywords: ear biometrics; identification; centroid; spindle; feature extraction

1. Introduction

Ear recognition is a new biometric identification. The ear is unique and stability. Iannarelli, an American scientist, compared 10000 ear images, in 1949\cite{1}. He got a conclusion that different individuals have different external ear and earlobe. And the structure of the ear is unchanged basically with growth of the body after four months of birth.

Compared with other biometrics, ear recognition has its unique advantages as follows Compared with face recognition; the ear is not affected by facial expressions, cosmetics, hairstyle changes, and cosmetic surgery. It does not change with age.

Compared with fingerprint recognition, ear recognition is non-contact. The body will not be harm. Meanwhile, it also reduces the chance of damage to the equipment.

Compared with the iris recognition, it reduced the hardware costs. Because it does not require high-precision instruments, just an ordinary camera.

In summary, ear recognition is not only feasible, but also simple and effective.

\* Corresponding author. Tel.: 13472724578; 13681877268.
E-mail address: xuye811@163.com
In this paper, the new feature extraction method of the ear was introduced based on the shape characteristics of the ear. This method used gravity and principal axis. Obviously, for the same object, its center of gravity does not change with the rotation and scaling, so this method makes human ear recognition robust to the rotation and scaling of ear image.

The paper is organized as follows. Section 2 discusses theory and method about centroid and spindle. Next section presents feature extraction. Ear recognition is analysed in Section 5. Conclusion is given in the last one.

2. Theory and Method

2.1. The center of gravity

In the gravitational field, regardless of the object in any orientation, the resultant of all particles of the gravitational force will pass a point. This point is called the center of gravity. The formula of the centroid can be defined as follows.

\[ X = \frac{x_1m_1 + x_2m_2 + \ldots + x_im_i}{M} \]

(1)

\[ Y = \frac{y_1m_1 + y_2m_2 + \ldots + y_im_i}{M} \]

(2)

where \( M \) represents the total weight of the foreground. \( M = m_1 + m_2 + \ldots + m_i \). \( m_i \) is the gray value corresponding to \((x_i, y_i)\) and \((X, Y)\) is the coordinates of centroid of the object.

2.2. The direction of the principal axis[3]

According to the principle of projection, the direction of spindle can be found by means of Hough transformation method seeking a straight line. The algorithm is as follows:

- Generate 180 lines. They all pass through the origin and the angles made by the X-axis and these lines are respectively 0°, 1°, 2°, ..., 179°.
- Seek the projected coordinates from each point to each line.
- Record two projected points that the distance between them is the farthest on the same line.
- Save the farthest distance to the corresponding line.
- Select the maximum one from 180 farthest distances.
- The angle corresponding maximum distance is the deflection angle of spindle.

The spindle 'L' through the center of gravity point is shown in Fig. 3. (a). The center of gravity is marked as 'O'.

3. Feature Extraction

The process of ear recognition is divided into four main parts--image acquisition, preprocessing, feature extraction and classification.

First, the color image is converted to gray level image. Next the grayscale image is filtered to suppress
noise and the noise suppression image is then adjusted to improve the image contrast. Lastly, edges of the ear are detected by using the canny edge detection algorithm [4]. The image is shown in Fig.1.

After the above preprocessing, we can obtain ear edge images, such as the image shown in Fig. 1. However, those contour images are usually not perfect. As shown in Fig. 2. (a), the outer contour of this map is not continuous, and therefore the connection of the outer edge is needed. The connected image is shown in Fig. 2. (b).

As shown in Fig. 3. (a), the two intersections of the spindle and the outer contour of the ear are respectively 'A' and 'B'. 'C' and 'D' are farthest away from the spindle on both sides. In the second feature vector, the first element is \( A/O/B \) and the second element is \( C'/D' \).

In Fig. 3. (b), The ear image is divided into eight regions by four straight lines --L, L1, L2, L3(The angle made by adjacent lines is 45\(^\circ\)). 'ri' (i=1,2,...,8) indicates the total number of points in each region. The second feature vector FEA is as follows.

\[
FEA = [q_1, q_2, r_1, r_2, ...., r_8] \quad q_1 = AO/BO, \quad q_2 = C'/D' \quad (3)
\]
4. Ear Recognition

First, the color image is converted to gray level image. Then the grayscale image is filtered to suppress noise and adjusted to improve the image contrast. Edges of the ear are detected by using the canny edge detection algorithm [2]. Due to the imperfection, the connection of the outer edge is needed.

Let $\text{FEA}_1 = [q_{11}, q_{12}, r_{11}, \ldots, r_{18}]$, $\text{FEA}_2 = [q_{21}, q_{22}, r_{21}, \ldots, r_{28}]$, be the feature vectors of two images. The similarity of $\text{FEA}_1$ and $\text{FEA}_2$ is calculated as follows

$$\text{simi} = \alpha \cdot \sqrt{(q_1 - q_2)^2} + \beta \cdot \sqrt{(r_1 - r_2)^2}$$

(4)

where $\alpha, \beta$ are the ratio coefficients.

$$S_i = [\text{simi}_1, \text{simi}_2, \ldots, \text{simi}_n]$$

(5)

The matching image is defined as the Minimum in $S_i$.

The proposed approach is experimented on a database. It includes three images of each subject. Two images of each subject are used as the training samples. In the process of testing, the third image is used.

5. Discussion and Conclusion

The method, proposed by Dasari Shailaja and Phalguni Gupta in [5], based on max_line and normal lines. The max_line is divided into $N$ equal parts by the normal lines. Each line has a point of intersection with outer edge. Join each point $P_i$, the upper end point of the max_line $A$ and the center of the max_line $C$. Let $\theta_i$ be the angle made by $P_iC$ and $P_iA$. The first feature vector is formed by $\theta_1, \theta_2, \ldots, \theta_N$. The second feature vector denoted by other points on the normal lines.

This method, mentioned above, is scale and rotation invariant. But it is invalid for the image with rotated ear. The proposed approach is a good solution to this problem. Because of based on the center of
gravity and the spindle, it is scale and rotation invariant. In addition, \( q_1 \) is the ratio of the distance from both sides of the ear to the spindle. It has robustness of the horizontal deflexion of the ear. \( q_2 \) is the ratio of the distance from upper and lower of the ear to the center of gravity, robust to vertical deflexion. The experimental results show the proposed method improves the recognition rate.

Acknowledgements

Experimental results based on the data sets from the University of Science and Technology Beijing ear database--the ear image database of Ear Recognition Laboratory in University of Science & Technology Beijing. The authors are very grateful to Prof. Zhichun Mu in USTB for providing us ear database for no charge.

Research supported by the National Natural Science Foundation of China (Grant No. 31170952), the Innovation Program of Shanghai Municipal Education Commission (Grant No. 11ZZ143) and the Program for Professor of Special Appointment (Eastern Scholar) at Shanghai Institutions of Higher Learning.

References

[1] A. Iannarelli. Ear Identification. Forensic Identification Series. Fremont, California: Paramount Publishing Company, 1989.
[2] J. Canny, A computational approach to edge detection, IEEE Transactions on Pattern Analysis and Machine Intelligence, 8(6), p. 679-98, 1986.
[3] JIANG Yongshui, TANG Jinhui, CHEN Xuequan, Ear biometrics, Extracting Method of Geometrical Principal Axis for Object from Bi-tone Image, Computer Engineering, Vol.31 No.18, p.56-73, 2005.9
[4] J. Canny, A computational approach to edge detection, IEEE Transactions on Pattern Analysis and Machine Intelligence, 8(6), p. 679-98, 1986
[5] Dasari Shailaja, and Dasari Shailaja, A Simple Geometric Approach for Ear Recognition, 9th International Conference on Information Technology, 2006.